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Suitability for Irrigated Agriculture

R.J. Tucker and P. Sorby

Department of Natural Resources, Queensland
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Summary

The Department of Natural Resources (State Water Projects) commissioned a soil survey and a suitability assessment for irrigated cropping on riparian land between Mundubbera and Gayndah.

During 1991 to 1992, soils were examined up to 5 km north and south from the general course of the Burnett River between Mundubbera and Gayndah. The survey covered 38 890 ha and abuts a previous survey to the west and south-west (Wilson and Sorby, 1991). The land suitability classification and soil types were adopted from the previous survey. A soils map was prepared and accompanies this report. Details of soil types and soil chemical properties are discussed in the report. Suitability for irrigated cropping has been determined for each Unique Map Area (UMA).

The study area contains a major citrus growing region, particularly of mandarins. Other important industries are dairying and other horticultural crops. Irrigation is an essential component of most of these industries. This study will provide information useful in planning development and managing the land and water resources.

Geology and soils

Geological formations include recent alluvia near streams, relict alluvia, sedimentary rocks, basalt and granite. A total of 48 soils were identified, but can be categorised as one of seven major soil groups. These are:

- Uniform sands
- Cracking clays
- Structured loamy to clayey soils
- Massive gradational soils
- Duplex soils - non sodic
- Duplex soils - sodic
- Duplex soils - strongly sodic or sodic magnesic

Principal soil types and their suitability for irrigation agriculture

The principal uniform sandy soil is the *Burnett* soil, which occurs on levees of the Burnett River. This soil is well drained, has a good waterholding capacity and is suited to most crops under sprinkler irrigation. The *Burnett shallow phase* is a moderately deep fine sand overlying clay and is also an important soil for horticulture.

Cracking clays occur on relict alluvia, basalt and sedimentary rocks. Most of these soils are suited to a wide range of field crops with some areas suited to vegetable crops.

The structured loamy to clayey soils have clay loam to clay field textures and have structure at least in the subsoil. Most have good water holding capacity and are well drained. The *Flagstone* soil occurs on alluvial terraces adjacent to the Burnett River. The *Mulgildie* and *Neugildie* soils are highly weathered deep well-drained basaltic red soils. The *Boynewood* soil is a clayey soil formed on rock. All these soils are suited to a wide range of field crops and horticultural crops. However, the *Mulgildie, Neugildie* and *Boynewood* soils can act as recharge areas. With widespread irrigation development, seepage areas may occur on lower slopes below these soils.

The massive gradational soils, principally *Glenrock* and *Chessborough,* are well drained with low to moderate waterholding capacity. They are suited mainly to horticultural crops under sprinklers. They are recharge areas and may be associated with seepage on lower slopes.
The duplex soils have sandy or loamy topsoils and a sharp to abrupt change to a clay subsoil. Three groups of duplex soils are recognised: non-sodic; sodic; strongly sodic and sodic-magnesic.

The non-sodic duplex group, comprised only of the *Boyne* soil, is suited to a wide range of horticultural and field crops, depending on the size of the area. There are also gradational occurrences of this soil type.

The sodic duplex soils have slow infiltration rates and low to moderate water holding capacity. The main soils are: *Riverleigh* on alluvial terraces; some occurrences of *Fison* soils on levees and backslopes; and the *Derrick* soil on the Gayndah Formation. These soils are suited to field crops, vegetable crops, and irrigated pastures. The *Fison* soils are growing citrus in some areas using mounding.

The strongly sodic and sodic-magnesic duplex soils have very slow water infiltration and low to moderate water holding capacity. The principal soils of this group are: *Coonambula* associated with creeks; some of the *Fison* soils on river levees and backslopes; *Kinburn* on levee backslopes; *Auburn* on relict alluvial plains; *Derrick* and *Taughboyne* on the Gayndah Formation; and the *Wigton Association* on granite. Most of these soils are marginally suited to cropping. Some mounding may be carried out on *Fison* for citrus, but care must be taken to ensure sufficient depth of well drained soil. Some vines have been planted on the *Wigton Association.* The upper slopes of the *Wigton Association* can act as recharge areas.

Key development and management issues

The lands are assessed in terms of land suitability for growing asparagus, avocados, chickpea, citrus, cruciferae, cucurbits, grapes, lucerne, mango, mungbean, navybean, improved pastures, peanut, pecan, potato, safflower, soybean, stone fruits, summer grains, sunflower, vegetables and winter grains. Each of the 600 UMAs was individually assessed for its suitability for growing the crops under irrigation.

Table 6 summarises the areas suitable (Class 1, 2 and 3 land) for various crops in the study area. A total of 7990 ha is suitable for asparagus, 950 ha for avocado, 2035 ha for chickpea, 3553 ha for citrus, 7990 ha for cruciferae and cucurbits, 7338 ha for grapes, 3433 ha for lucerne, 950 ha for mango, 2112 ha for mungbean, 4192 ha for navybean, 14 861 ha for pastures, 2262 ha for peanut, 3689 ha for pecan, 2269 ha for potato, 5539 ha for safflower, 4976 ha for soybean, 3689 ha for stone fruits, 8237 ha for summer grains, 5523 ha for sunflower, 8037 ha for vegetables and 8075 ha for winter grains.

A high proportion of land close to the river is suitable for irrigated cropping. Extensive areas suitable for irrigation occur distant from the river, while some are also elevated, being on plateaux.

The UMA data file in combination with other data on the Geographic Information System (GIS) can be used to generate suitability maps for particular crops or combinations of crops. It can also be used to present information on particular soil attributes and land limiting factors, such as soil adhesiveness for root crops or areas likely to develop seeps. Such information will assist planning development of the area, and the provision of capital facilities and infrastructure. Details are available from the Resource Sciences Centre, Department of Natural Resources.

This study area has the potential to develop salinity and waterlogging problems under irrigation as shown by the *Panda saline phase*. Even clearing has altered the hydrologic balance and resulted in the development of seeps or salinity in small areas.

The information from this study can be used to recognise potential hazard areas and help develop land management strategies.

1. Introduction

The locality of the study area is given in Figure 1. This study adjoins the Auburn River Suitability Study conducted to the west (Wilson and Sorby, 1991). Other less detailed soil maps which cover the area are Kent (in preparation), and de Mooy *et al.* (1977); some caution should be used when comparing soils with the current study.

The Department of Natural Resources (State Water Projects) commissioned a study to:

1. Map soils up five kilometres from the Burnett River.
2. Assess irrigated crop suitability.

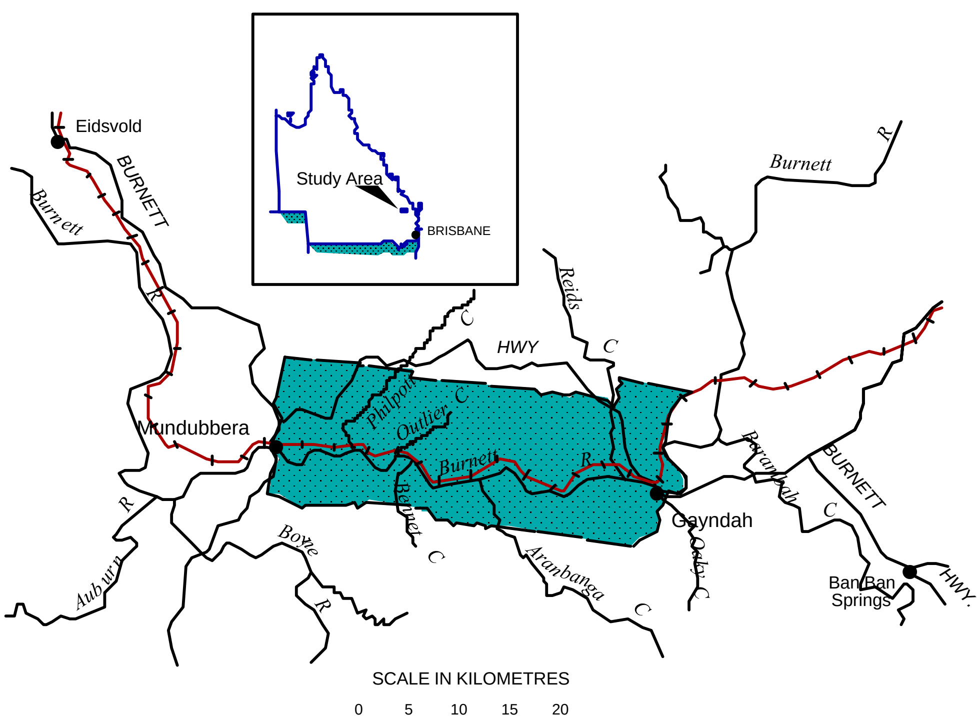

Figure 1. Location of survey area, Mundubbera – Gayndah Area, Queensland

2. Soil survey procedure

A reconnaissance established the main soils of the area. New soils were added to the soil reference developed for the Auburn River study (Wilson and Sorby, 1991).

The survey was conducted on a free survey system. At each site, soils were described from core samples taken to 1.5 m depth or shallower depending on soil depth or penetrability. Records were kept either on soil description forms or in a notebook. Boundaries were drawn (on aerial photos) around the areas of similar soils and later transferred to the soil map by Resource Sciences Centre drafting staff.

The density of ground observations varied from approximately one site per 25 ha on land expected to be suitable for irrigated cropping or land with complex soil distribution, to one site per 100 ha or greater for undulating grazing lands.

The following site data were collected for 417 sites according to McDonald *et al.* (1990): location data, general site information, vegetation; and colour, field texture, coarse fragments, structure, consistency, pH, and roots in each soil horizon.

Soil types were created from these data, in association with earlier data from Wilson and Sorby (1991). Soil phases and variants were also described. Phases are subdivisions of a soil type with particular characteristics which will influence the use of the soil; for example, slope, depth, eroded phases. Variants differ from the soil type in at least one characteristic relating to the soil morphology.

The mapping units were based on the soil types in the reference and usually contain other soil types. General soil groups are given in Table 3, and soil types are described in Table 4.

Each area delineated on the map is called a "Unique Map Area" (UMA). Each UMA has been given a number and can be individually referenced for the principal soil, geology, landform and specific soil attributes and limitations. [All UMA data are on a computer file and can be accessed through the Resource Sciences Centre of the Department of Natural Resources.] These data were used to generate crop suitability information for each UMA, and can be used to provide suitability maps for particular crops.

Nine soil profiles at eight sites were sampled for laboratory analysis. Samples were analysed according to Bruce and Rayment (1982). Analytical data for each profile are given in Appendix 2. Fertility ratings are presented in Appendix 3. Salinity and sodicity ratings are given in Appendix 4. The data in Appendix 3 and 4 include data from the Auburn River Study (Wilson and Sorby, 1991) and selected data collected for an earlier study by CSIRO (de Mooy *et al.,* 1977).

3. Climate

Climatic data for Gayndah are given in Tables 1a, 1b, 1c and 1d. Rainfall data for Mundubbera are given in Tables 2a and 2b. The area experiences warm summers and mild winters. Frosts are common in winter and vary in severity depending on landscape position. Low lying areas near the river are generally more susceptible. The area around the junction of Aranbanga Creek and the Burnett River is known locally for frost problems.

Note that for one year in seven, mean minimum temperatures in July will fall below 1.1°C at Gayndah.

Table 1a. Rainfall statistical summary - Gayndah Post Office (Met. Stn 39039)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean (mm)	117	106	77	39	40	41	39	29	35	64	77	106	772
Median (mm)	107	81	56	30	29	29	29	22	26	61	66	103	798
Coeff. Var (%)	68	92	83	95	100	102	105	110	91	73	66	59	27
Lowest rain (mm)	0	0	0	0	0	0	0	0	0	0	0	2	339
Highest rain (mm)	361	522	288	170	209	203	304	244	141	230	256	321	1468

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

Table 1b. Monthly rainfall probabilities - Gayndah Post Office (Met. Stn 39039)

	Amounts of rain (mm) received or exceeded in 100%, 90%...0% of years.												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
100% of years	0	0	0	0	0	0	0	0	0	0	0	2	339
90% of years	23	13	19	33	2	1	2	2	2	11	17	26	501
80% of years	45	36	28	5	8	5	8	6	6	21	31	49	581
70% of years	66	47	36	10	13	13	12	11	12	31	45	71	647
60% of years	93	55	42	21	19	22	19	14	19	41	54	86	710
50% of years	107	81	56	31	29	29	29	22	26	61	66	103	798
40% of years	119	97	68	42	40	41	40	30	32	72	80	112	824
30% of years	142	120	102	53	49	49	52	36	49	83	98	131	857
20% of years	173	157	117	69	65	66	70	44	68	96	118	157	910
10% of years	227	235	174	94	99	91	86	68	81	121	147	178	1047
0% of years	361	522	288	170	209	203	304	244	141	230	256	321	1468

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

Table 1c. Mean monthly humidity and pan evaporation - Gayndah Post Office (Met. Stn 39039)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rel.Hum. 9am	67	68	69	68	72	75	71	66	61	59	60	63	63
Rel.Hum. 3pm	47	48	48	44	45	46	41	37	34	36	38	42	42
Pan Evap. (mm/day)	7.3	6.4	5.4	4.8	3.7	3.2	3.6	4.3	5.5	6.7	7.8	28.2	n.a.

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

Table 1d. Monthly temperatures - Gayndah Post Office (Met. Stn 39039)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Maximum all years (°C)	32.2	31.7	30.7	28.9	25.3	22.6	21.9	23.7	26.5	29.2	31.3	32.3	28.0
1 yr in 7 above:	35.3	34.5	33.3	31.4	27.9	25.0	24.4	26.5	29.7	32.3	34.6	35.6	n.a.
1 yr in 7 below:	29.1	28.9	28.2	26.7	22.3	20.1	19.0	21.0	23.4	26.1	28.2	29.2	n.a.
Mean Minimum all years (°C)	20.3	20.1	18.5	14.8	10.7	7.9	5.9	7.4	10.4	14.4	17.4	19.3	13.9
1 yr in 7 above:	22.9	22.5	21.5	17.8	15.5	12.2	11.0	12.7	14.8	18.3	20.6	21.9	n.a.
1 yr in 7 below:	17.6	17.4	15.6	11.8	6.0	3.7	1.1	2.7	6.1	10.8	13.9	16.5	n.a.

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

Table 2a. Rainfall statistical summary - Mundubbera Post Office (Met. Stn 39073)

	Jan	Fen	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean (mm)	108	93	66	41	36	36	37	25	31	63	69	102	709
Median (mm)	99	77	46	33	25	26	29	21	21	58	61	89	708
Coeff. Var (%)	60	83	89	88	102	94	100	92	103	76	62	67	28
Lowest Rain (mm)	1	0	0	0	0	0	0	0	0	0	0	0	299
Highest Rain (mm)	311	364	242	195	191	154	211	108	171	203	181	322	1229

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

Table 2b. Monthly rainfall probabilities - Mundubbera Post Office (Met. Stn 39073)

Amounts of rain (mm) received or exceeded in 100%, 90%…0% of years.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
100% of years	1	0	0	0	0	0	0	0	0	0	0	0	299
90% of years	32	15	11	5	2	1	2	2	1	10	17	26	441
80% of years	48	34	21	8	7	6	6	7	4	16	26	45	555
70% of years	65	53	26	16	14	12	13	11	7	27	43	65	600
60% of years	84	67	32	24	22	21	20	15	17	45	55	79	655
50% of years	99	77	46	33	25	26	29	21	21	58	61	89	708
40% of years	111	89	61	41	35	34	39	23	31	71	73	98	750
30% of years	135	99	79	52	45	52	48	30	42	81	84	108	810
20% of years	175	139	108	70	55	62	62	39	56	95	107	153	909
10% of years	195	203	157	90	87	83	83	57	72	133	133	209	976
0% of years	311	364	242	195	191	154	211	108	171	203	181	322	1229

Source: Aust. Bureau of Meteorology *via* DPI Climate Data Base, Toowoomba.

4. Geology, landform and soil occurrence

The geology of the Mundubbera-Gayndah study area is presented in the explanatory notes for the Mundubbera 1:250 000 sheet area (Whitaker *et al.*, 1974) and Maryborough 1:250 000 sheet area (Cranfield, 1994). The main geological formations are summarised below. The geological map reference codes are used; codes for the same geological formation may change between map sheet areas.

Devonian-Carboniferous sedimentary rocks and minor volcanic flows

In the western portion of the study area is a series of steeply dipping geological formations: the Pumpkin Hut Mudstone (Dh); undifferentiated early to middle Devonian-age rocks (D); and the Caswell Creek group (Clc). The lithology consists of sedimentary rocks, pyroclastic rocks[1] and andesite. The andesite has weathered to form undulating plains and undulating rises while the sedimentary rocks usually form undulating rises.

Soil occurrence is complex due to these contrasting rock strata and fluvial smoothing of the land surface. The main soils are structured uniform soils *(Boynewood)*, cracking clays *(Lacon)* and sodic duplex soils *(Beeron)*. Rock outcrops occur. Minor rock formations in this area include the Philpott limestone (Dp), the First Branch Creek sandstone (Df), and the Doonside formation (DCd). Some areas of red soils have been mapped above the Philpott limestone as *Neugildie*, although usually associated with the Tertiary basalt of the Binjour Plateau.

In the centre of the northern section of the survey area lie steeply dipping beds of the Wandilla formation (DCw, Ccw). These beds consist of mudstone, arenite and chert. The landforms are steep to very steep. Limited observations show that soils vary considerably. Sodic duplex soils *(Dillan, Yondilla)* have been differentiated on the footslopes of the hills.

Wigton Granite

The Wigton Granite Formation (Puw, or Pw) occupies the southern central portion of the study area. The landform is mainly undulating rises. Soils vary considerably consisting mainly of sodic duplex soils (*Whiteside, Solwig*), and uniform sands and massive gradational textured soils (*Red Flank, Brownside*). Sandy field textures and fine angular gravels are typical of many soils on this geological formation.

Triassic sedimentary and volcanic rocks

The Triassic Gayndah Formation (Rtg), the Aranbanga Volcanic Group (Ra), and unnamed intrusive rhyolite (Rir) and dacite (Ria) occur in the east of the study area.

The Aranbanga Volcanic Group (Ra) includes andesitic to rhyolitic flows, pyroclastic rocks, minor sediments, and basalt. The Abernethy basalt (Raa) is a major component of the Aranbanga group in the study area. Landform varies from gently undulating plains to hills. The main soils are cracking clays (*Bray, Dunbas, Balark, Bovekel, Jedda*).

The Gayndah Formation (Rtg) consists of sandstones, conglomerate, siltstone, shale and andesite. Lithic sandstone appears to be the major surface component in the study area and forms gently

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[1] Pyroclastic rocks are sedimentary rocks formed by aerial precipitation of particles expelled by volcanoes

undulating to undulating plains, rises and hills. The Gayndah Formation has weathered to form cracking clay soils (*Dargy, Brogue*) and duplex soils (*Taughboyne, Derrick, Ella, Greyfrill*).

The complex soil distribution around Gayndah has been caused in part from basalt flows in pre-existing valleys in the Gayndah Formation. A cracking clay (*Drape*) blankets the junction between the Abernethy basalt (Raa) and the Gayndah Formation (Rtg).

Tertiary basalt

Tertiary (Tb) basalt flows occurred over much of the eastern section of the study area. The same cracking clays occur on the Triassic basalts. Tertiary basalt also occurs as the Binjour Plateau.

Iron-rich structured uniform and gradational textured soils (*Mulgildie, Neugildie*) are found on both deeply weathered basalts and colluvial fans of the Binjour Plateau.

Tertiary, relict and recent alluvia

Minor very old alluvial deposits derived from Tertiary sediments and reworked deposits (Cza, Td) occur on the tops of rises, hills, mountains or plateaux. Red massive gradational textured soils occur (*Glenrock, Chessborough*). These can be moderately shallow over other formations.

Relict alluvia, probably early Quaternary (Qa, Qpa) form level to undulating plains. The main soils are cracking clay soils (*Bonnie Crofts, Overrun, Durong, Derra*) and sodic duplex soils (*Auburn*).

Recent alluvia (Qa, Qha_1) are found as deposits close to major streams. The landforms are mainly levees, terraces, and small plains. Soils vary: deep fine uniform sands (*Burnett*); shallower versions over clay (*Burnett shallow phase, Fison*); structured uniform and gradational soils (*Flagstone*); and sodic duplex soils (*Kinburn, Riverleigh*). Minor areas of cracking clays are found.

5. Soils

A synopsis of the geological formations and soil types is given in Table 3. Major soil types (>300 ha) are shown in bold type. Phases and variants have not been included in the table, apart from the *Riverleigh clayey variant*. Each soil type, phase, and variant has been set out in Table 4. [Note that the new Australian Soil Classification (Isbell, in press) has not been used in Table 4. This system was being developed during the time of the survey.]

Seven broad groupings of soil types are discussed below and have been used in Table 3. Within these groups, soils are broadly similar in appearance and nature across geologic divisions. For details of each soil type, refer to Table 4.

Uniform sands

This group includes mainly soils with sandy field textures throughout the profile.

The deep fine sandy *Burnett* soil occurs on levees and is the most extensive of the group. *Burnett shallow phase* has clay layers usually between 0.6 m and 1.1 m. These clay layers restrict drainage, and may also cause aeration problems in sensitive deep-rooted tree crops. *Burnett* and *Burnett shallow phase* underpin production from most of the orchards along the river. The *Madoora* soil is a little coarser than *Burnett*, while the *Burnett* coarse sandy phase has a much coarser particle size. Some loamy versions of the layered *Stratfield* soil are included in this group for convenience. This soil is less porous than the sandy soils in the group. The *Brownside* and *Red Flank* soils occur on the Wigton Granite and have a considerable content of fine angular gravels derived from the granite. These coarser sands have very low water holding capacities. The *Red Flank* soil is a red earthy sand, and has similarities to the massive gradational soils. However, it possesses a sporadically bleached lower B horizon, suggesting that considerable through-flow of water may occur in this zone.

Cracking clay soils

Cracking clay soils shrink and swell in proportion to moisture content. In the survey area, these soils occur in most geological and landscape groups apart from granites. Some mapping units of dominant alluvial cracking clay soils also contain associated non-cracking clays.

The mapping unit *Alluvial Complex - lower, cracking clays,* contains a wide variety of cracking clay soils found in creek drainage lines. They reflect the characteristics of the alluvium, usually clayey, from which they have been derived, and thus vary in colour and grade of structure. *Panda* is a cracking clay with thin bleached subsurface layers above a heavier clay subsoil. *Platter* occurs on level interfluves between stream channels. It cracks less than most cracking clays and associated non-cracking clay soils are included in the mapping unit.

On the older alluvial plains, *Bonnie Crofts* soil is a very slightly gilgaied cracking clay with poplar box tree vegetation in its natural state. Minor areas of the related *Durong* soil occur which carry brigalow scrub. The *Overrun* soil and *Overrun linear-gilgaied phase* support silver leaved ironbark trees. These cracking clay soils are expected to behave similarly to other alluvial clays. The *Derra* soil has gilgais with depressions up to 1 m deep. The *Derra rocky phase* has cobbly non-cracking clays forming the mounds of the gilgai. The cobbles of quartz may have been part of the bedload of a former stream.

Table 3. Soil types and relationship to geological formation, Mundubbera-Gayndah Riparian Lands, Queensland

Geological Formation	**Uniform Sands**	**Cracking Clays**	**Structured Loamy to Clayey Soils**	**Massive Gradational Soils**	**Duplex Soils**		
					Non-Sodic	**Sodic**	**Strongly Sodic or Sodic-Magnesic**
Alluvium - mainly associated with smaller creeks	Madoora (some Stratfield-loamy)	**Alluvial complex - lower, clays** Panda Platter	some **Flagstone**			some **Riverleigh** some Stratfield	**Coonambula**
Alluvium - mainly associated with the river and major creeks	**Burnett**	Riverleigh, clayey variant	**Flagstone** Boyne (gradational versions)		Boyne (duplex versions)	**Riverleigh** some **Fison**	**Fison** **Kinburn**
Relict Alluvia (early Quaternary)		**Bonnie Crofts** Derra Durong Overrun					**Auburn**
Very old alluvia (Cainozoic)			Wivenhoe	**Glenrock** **Chessborough**			
Basalt and basaltic colluvia		**Bray** **Dunbas** **Balark** **Bovekel** Jedda	**Mulgildie** **Neugildie**				
Basalt - lithic sandstones		**Drape**					
Lithic sandstones and other sedimentary rocks (Gayndah Formation)		**Brogue** **Dargy**	Belrose			**Derrick**	Some **Derrick** **Taughboyne** Ella Greyfrill
Granite (Wigton Formation)	**Brownside** (almost all in *Wigton Association)* Red Flank			Some Red Flank		Aranear	**Whiteside** (mapped in *Wigton Association*) Solwig
Steeply-dipping sedimentary rocks and volcanic rocks (Carboniferous to Devonian)		**Lacon**	**Boynewood**			Yondilla	Dillan **Beeron**

Notes: Major soil types (> 300 ha) shown in bold.
Soils in the following mapping units are not included above: Alluvial Complex - higher, and the miscellaneous mapping units.
Phases or variants of soil types are not shown except *Riverleigh, clayey variant*.

Cracking clays over basalt vary in depth; *Bray, Dunbas* and *Balark* are red, brown and dark respectively. *Bray deep phase* and *Dunbas deep phase* occur on lower slopes and on colluvial fans which form gently sloping plains north west of Reid Creek. *Bovekel* is a deep dark basaltic cracking clay soil which occurs in similar situations. *Jedda* occurs in drainage lines.

The *Drape* soil is usually a deep, dark to dark grey cracking clay associated with both the Triassic basalt and the Gayndah Formation. The basalt overlies the sedimentary rocks of the Gayndah Formation and the *Drape* soil blankets the boundary.

Two cracking clay soils have formed above the more labile and sublabile sedimentary rocks in the Gayndah Formation: *Brogue* which is a shallow to deep, brown to red-brown cracking clay; and *Dargy* which is a shallow to moderately deep, dark cracking clay. Both usually exhibit a coarser structure than their basalt-derived equivalents.

The *Lacon* soil is associated with the steeply dipping sedimentary and volcanic rocks of the Carboniferous and Devonian Formations. *Lacon* is finely structured and friable, influenced principally by the andesitic and other volcanic components of the Arabanga Volcanic Group. Some *Lacon* soils are less finely structured and crack less, most likely because they merge into alluvial cracking clays.

Structured loamy to clayey soils

This group consists of soils which increase gradually in clay content down the profile, and uniform soils which are clay loam or clay throughout but do not crack. The soils are structured, at least in the major part of the B horizon.

The *Flagstone* soil of recent alluvium is a deep dark to brown clay loam to clay soil. The darker occurrences predominate. This soil is noted for its good structure, but is prone to compaction. Some gradational forms of the *Boyne* soil also fit in this group.

The *Wivenhoe* soil is associated with the very old alluvia and has yellow-brown loamy topsoil over structured yellow clay. The soils may have formed by colluvial deposition of loamy material over clay.

The *Mulgildie* and *Neugildie* soils are basalt-derived. They are well drained deep dark red soils with polyhedral structure. *Mulgildie* soils have acid pH while *Neugildie* is neutral pH (see Table 4). *Mulgildie snuffy variant* has a fine loose "snuffy" surface when dry, which is probably caused by cultivation. Both *Mulgildie* and *Neugildie* soils, particularly the lighter clay loam versions, are prone to structure decline through cultivation. *Neugildie colluvial clayey variant* is found in lower slope areas and on fans. This variant consists of the *Neugildie* soil material overlying structured clays of a different origin.

Belrose is a red non-cracking clay soil occupying small areas on crests or saddles above rocks of the Gayndah Formation.

Boynewood soils are shallow to moderately deep brown well structured non-cracking clays above the steeply dipping sedimentary rocks and volcanic rocks of Carboniferous to Devonian age.

Massive gradational soils

These soils are massive with field textures gradually becoming heavier (higher clay content) with depth. *Glenrock* soils and *Chessborough* soils are formed in deeply weathered very old alluvia. *Glenrock* soils are usually very deep. A shallower grey variant occurs in lower slope areas. *Chessborough* soils are found on slopes and are shallower, overlying older unrelated clays or rock. *Chessborough rocky phase* has outcrops of ironstone.

Some *Red Flank* soils on slopes of Wigton Granite Formation have sandier topsoils than other soils in this group. Other occurrences of *Red Flank* are sandy throughout, as discussed earlier.

Duplex soils - non sodic

These soils have loamy topsoils which abruptly overlie clayey subsoils. *Boyne* is the only representative of this group. It has dark brown loamy topsoil overlying reddish subsoil. Some occurrences have a gradual change to the clay subsoil as mentioned earlier.

Duplex soils - sodic

These duplex soils have mainly loamy topsoils abruptly overlying sodic clay subsoils. Deeper in the profile the subsoils become strongly sodic at levels corresponding to pH values ≥8.5.

In the alluvial areas *Riverleigh* is the main soil of this group. It has a hard-setting sandy clay loam to clay loam topsoil with a high fine sand or silt content lying over a dark or dark-brown clay subsoil.

The *Stratfield* soils within this group are stratified loamy soils which overlie dark grey clay, or gravel. These soils are found beside small creeks draining hilly and mountainous areas.

The *Fison* soil occupies levees, channel benches and terraces along the Burnett River. It has a shallow fine sandy soil material overlying buried clay subsoils. However, it will behave like a duplex soil. The lower part of the sandy surface may be bleached. The *Fison* soil occurs in association with *Burnett shallow phase*. Soils with fine sandy material to 0.5 m deep were placed in the *Fison* soil type while soils with sand >0.5 m deep were placed in the *Burnett shallow phase.*

On the Gayndah Formation the *Derrick* soil has shallow clay loam topsoils and red or red-brown clay subsoils.

The *Aranear* soil has shallow loamy topsoil and yellow-brown clay subsoils. It occupies the lower areas of a long alluvial fan which lies below the Wigton Granite. The material is of mixed origin. Associated pockets of red structured gradational soils and dark cracking clay soils suggest contributions from old alluvia or other more weatherable rocks.

The *Yondilla* soil occupies a small fan below hills of the Wandilla Formation. It has a columnar structure sandy clay loam subsoil. The topsoil is moderately deep, sandy, and is bleached above the sandy clay loam subsoil.

Duplex soils - strongly sodic or sodic-magnesic

These soils have very shallow to shallow loamy topsoils abruptly overlying clay subsoils which are strongly sodic or sodic-magnesic in the upper subsoil. Most subsoils are strongly alkaline (pH >8.5). However, a soil on the Wigton Granite has acid subsoils, as do some occurrences on the Gayndah Formation. The topsoils are usually bleached in the lower part.

The *Coonambula* soil is found on creek flats, in drainage depressions and in valley flats draining from hills in the western section of the survey area. Topsoils are usually very shallow dark to grey-brown loam, bleached in the lower part, above very strongly alkaline grey, grey-brown or yellow clays.

The *Kinburn* and *Fison* soils are associated with the levees of the Burnett River. The *Fison* soils are also included in the previous group where shallow fine sandy soil material has been deposited over a strongly sodic clay. *Kinburn* soils have developed strongly sodic subsoils. Seasonal waterlogging has resulted in the development of grey colours.

Taughboyne, Ella, and *Greyfrill* are strongly sodic duplex soils on the Gayndah Formation. These soils have been separated principally on colour differences. *Taughboyne* soils have very shallow clay loam topsoils, dark to brown clay upper subsoils, over grey to brown clay lower subsoils; the upper part of the clay subsoil is usually darker than the lower part. *Ella* soils have shallow clay loam topsoils and yellowish clay subsoils; some of the subsoils are acidic. The *Greyfrill* soils occur at the base of slopes and have very shallow fine sandy loam to light sandy clay loam (fine sandy) topsoils which are usually bleached throughout and overlie alkaline grey clay subsoils. The upper part of the topsoil has usually been lost through sheet erosion. The *Greyfrill* soils have very dispersible subsoils and are prone to very severe erosion.

The *Whiteside* soil is the major component of the *Wigton Association* mapping unit. These soils have shallow to moderately deep coarse sandy surface soils with a conspicuous bleach within 0.1 to 0.2 m of the ground surface over an acid, grey, light grey or brown, sandy clay loam to sandy clay, and gradual transition to decomposing granite. The well developed conspicuous bleach in the *Whiteside* soil points to considerable seasonal soil wetness above the more clayey subsoils. The *Whiteside* soil merges with associated soils including browner better-drained soils which are transitional to the deeper soil types.

The *Solwig* soil also occurs on the Wigton Granite, on footslopes and mid-slope flats. It usually has a shallow to moderately deep hard loamy sand topsoil, over a hard, acid, grey sandy clay loam (coarse sandy) to sandy clay subsoils. A bleach occurs from just below the surface. Some deep, bleached sandy soils are associated.

The *Dillan* soil is found at the base of hills of steeply dipping sandstone and siltstones of the Wandilla Formation. It has shallow sandy to loamy surfaces conspicuously bleached in the lower part, over neutral to strongly alkaline grey, yellow-brown or yellow clay subsoils.

In the western part of the study area, the *Beeron* soil is found on steeply dipping sedimentary and volcanic rocks of Carboniferous to Devonian age. Topsoils are usually very shallow to shallow sandy clay loams or clay loams, bleached in the lower part, over grey-brown, brown, red-brown or yellow clay subsoils. The wide variety of colours in the subsoils is due to changes in the parent material caused by the steep dip of the rock strata. *Beeron deep surface phase* has topsoils more than 0.4 m deep.

Common phases of soil types

Several common phases of soil types are shown on the soil map:

- *Channelly phases* have smooth-sided channels, usually more than 1 m deep and occur beside the river and major creeks
- *Eroded phases* show areas of soils which have been eroded, and usually have severe sheet and/or gully erosion
- *Rocky phases* have high contents (> 20%) of gravel, cobble, stone, rock or bedrock associated with the soils
- *Steep phases*[1] of soils occur on lands with a slope usually over 6% to 8%
- *Steep and broken phases* have slopes over 6% to 8% and changes in slope direction over short distances
- *Saline phases* of soils have been affected by salt accumulation at the surface, usually evident as bare soil or the presence of halophytic vegetation.

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[1] 'Steep' here refers to a relatively steeper slope compared to normal - as opposed to strict definitions in McDonald *et al*. (1990). '*Steep and broken phases*' are often rugged, at least in part.

Miscellaneous mapping units

- *Hills and Mountains* - soils have not been differentiated
- *Pedimentary soils* consist of loamy soils with high contents of gravel or larger rock fragments; found at the foot (pediment) of hills and mountains
- *Rock* mapping units usually consist almost entirely of rock; some rocky phases of soils may be associated
- *Dam* and *Tank* mapping units represent the larger farm dams and tanks
- *Stream Channels* consist of stream beds and their steep banks; this mapping unit is dominated by the Burnett River's bed and associated major creeks and gullies leading into the river
- *Urban areas* cover Mundubbera and Gayndah where soils have not been mapped
- Other miscellaneous units shown on the soil map include quarries and a sewage treatment works.

Table 4. Soils - major distinguishing features of riparian soils between Mundubbera and Gayndah, Queensland

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
Alluvial complex - higher	A complex of soils on terraces and interfluves; cracking clay soils, red gradational soils, duplex soils, and sands deposited on clay soils. Individual soils can not readily be mapped separately. Layering is common.	Brown clay, prairie soils, solodic soils or no suitable group. Ug5.34, Gn3.13, Db1.13, Db1.33, Dr4.41, Uc1.11.	Recent alluvia - creeks and drainage lines.
Alluvial complex - lower	A complex of soils in drainage depressions or streambeds, channel benches, and low terraces and interfluves: gradational soils or duplex soils, sands, non-cracking clay soils, and cracking clay soils from map unit AClc. Individual soils can not readily be mapped. Layering is common.	Alluvial soils, solodic soils, prairie soils, siliceous sands, or no suitable group. Dy3.43, Dy2.11, Dd1.33, Uc1.23, Gn3.13, Uf6.32.	Recent alluvia - creeks and drainage lines.
Alluvial complex - lower, cracking clays.	Contiguous areas of undifferentiated cracking clay soils in drainage depressions or streambeds, channel benches and low terraces and interfluves.	Alluvial soils, black earths, grey clays, brown clays or no suitable group. Ug5.16, Ug5.2, Ug5.25, Ug5.3, Ug5.34.	Recent alluvia - creeks and drainage lines.
Aranear	Deep sodic duplex soils having shallow topsoil with bleached or non-bleached subsurface layers and yellow-brown subsoil; on extremely low ridges developed from fans. 0.2 to 0.3 m dark brown light sandy clay loam to sandy clay loam; over grey to brown, often bleached, light sandy clay loam to sandy clay loam to 0.3 m; over strongly alkaline yellow-brown, often mottled, clay.	Solodic soils, solodized solonetz. Dy2.23, Dy2.33, Dy3.13, Dy3.43.	Relict fans below Wigton Granite. Minor areas of undifferentiated red structured gradational soils and dark cracking clay soils associated.
Auburn	Deep grey to brown sodic duplex soil with very shallow topsoil, bleached subsurface layer, and grey, yellow-brown or brown clay subsoil; on relict alluvial plains; and some terraces. 0.05 - 0.2 m, grey to brown sandy clay loam to clay loam, with a thin layer of bleach at the base, or a bleached subsurface layer to 0.15 - 0.35 m, over strongly alkaline grey, yellow-brown or brown clay, sometimes mottled.	Solodic soil. Dy2.33, Dy3.43, Db1.43, Dy2.43.	Alluvia. Usually poplar box vegetation. Soils under brigalow vegetation may be more arable. Occasionally yellow clay B2t horizons.
Auburn, channelly phase	Auburn soil, but with smooth-sided channels > 1 m deep, near streams.	---	Channels formed by erosion and stabilisation.
Auburn, eroded phase	Auburn soil, but with severe sheet and gully erosion.	---	
Auburn, red subsoil variant	Auburn soil, but with red-brown to red clay subsoil below 0.6 - 1.3 m; on relict alluvial plains.	---	
Balark	Moderately shallow dark self-mulching cracking clay soils; on gently undulating plains to undulating rises. 0.05 - 0.2 m dark medium clay to heavy clay, over neutral to strongly alkaline dark medium clay to heavy clay to 0.35 - 0.9 m, over strongly alkaline brown to dark medium to heavy clay with fragments of weathered basalt, or weathered basalt.	Black earth. Ug5.12, Ug5.13.	Basalt. In deeper profiles, B2 horizon may be brown at depth.
Balark, steep phase	Balark soil, with slopes > 6% to 8%.	---	
Beeron	Shallow to deep sodic duplex soil with very shallow topsoils, bleached subsurface layers, and clay subsoil; formed on rock on undulating plains to rises. 0.05 - 0.25 m, dark, grey-brown or brown sandy clay loam to clay loam; over grey to brown	Solodic soil, solodized solonetz. Db1.33, Dy3.43, Db1.43, Db2.33, Db2.43, Dy2.43,	Steeply dipping sedimentary and volcanic rocks.

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	clay loam to clay loam; over grey to brown, bleached sandy clay loam to clay loam to 0.1 - 0.4 m; over neutral to strongly alkaline grey-brown, brown, red-brown or yellow light medium to medium clay to 0.5 - 1.2 m, often mottled; over either neutral to strongly alkaline brown, yellow-brown or yellow, often mottled, light clay to light medium clay with fragments of weathered rock, or weathered rock.	Dr2.33, Dr2.43.	
Beeron, deep surface phase	Beeron soil, but with surface soil □ 0.4 m deep.	---	
Beeron, eroded phase	As for Beeron, but with sheet or gully erosion.	---	
Beeron, rocky phase	As for Beeron, but with gravel, cobble, stone, or rock outcrop.	---	
Belrose	Shallow to moderately deep, red, friable non-cracking clay soils; on undulating rises. 0.15 - 0.25 m red to red-brown light to medium clay, over strongly alkaline red light medium clay to medium clay to 0.55 - 0.95 m, over strongly alkaline brown to red brown clay loam to light medium clay or weathered rock; carbonate occurs below 0.4 - 0.5 m.	No suitable group (non-cracking clay). Uf6.31.	Sedimentary rocks - Gayndah Formation. May be influenced by nearby basalt, or basalt which previously overlay the Gayndah Formation.
Bonnie Crofts	Very deep dark to dark grey cracking clay soil with nil to slight normal gilgai (□ 0.1 m deep); poplar box forests; on relict alluvial plains. 0.05 - 0.1 m dark to grey-brown clay, often weakly self-mulching, over dark to grey clay, alkaline by 0.3 - 0.6 m; may become yellower, browner or red- brown below 0.8 - 1.3 m, carbonate usually below 0.3 - 1.0 m.	Black earth, grey clay. Ug5.16, Ug5.24, Ug5.25. Some brown clays associated; Ug5.34.	Alluvia. Poplar box vegetation predominates. Usually dark or dark grey to at least 0.8 m. Intergrades to Auburn in some areas.
Bovekel	Deep, dark to dark brown self-mulching cracking clay soils; with brown to red-brown clay subsoil, on lower slopes in undulating plains. 0.1 m dark to dark brown medium clay to heavy clay over neutral to strongly alkaline dark medium clay to heavy clay, usually to 0.5 - 1.1 m, over strongly alkaline very dark brown, brown, or red-brown medium clay to heavy clay, usually with carbonate nodules.	Black earth. Ug5.15, Ug5.1, Ug5.17.	Basalt and basaltic colluvia. Depth to brownish subsoil is very variable; sometimes only 0.15 m. Merges into alluvial plains in some areas.
Bovekel, eroded phase	Bovekel soil, but with gullies to 0.6 m deep.	---	
Boyne	Very deep duplex or gradational soils with well structured red subsoils; on terraces and some channel benches. 0.1 - 0.25 m dark brown sandy loam to clay loam, weakly structured topsoils, with grey to red-brown coarse sandy loam to clay loam weakly structured subsurface soils to 0.2 - 0.5 m over well-structured red-brown to red sandy clay to medium clay; neutral to strongly alkaline at depth.	Red-brown earths, or no suitable group. Gn3.13, Gn3.15, Dr2.23, Dr2.12, Gn3.12.	Recent alluvia - river and major creeks.
Boynewood	Shallow to moderately deep, friable brown clayey soils over rock; on undulating plains and rises. 0.10 - 0.20 m, brown, red-brown or dark, clay loam to light medium clay; over neutral to strongly alkaline brown to red-brown light clay to medium clay to 0.3 - 1.05 m; over similar material with fragments of weathered rock; or weathered rock.	(Reddish) prairie soils; or chernozems. Uf6.31, Gn3.12, Gn3.13.	Steeply dipping sedimentary and volcanic rocks. Weak to massive surface structure in some cultivated areas.
Boynewood, eroded phase	Boynewood soil, eroded.	---	
Boynewood, rocky phase	As for Boynewood, but with gravel or cobble on the surface; or rock outcrops.	---	
Boynewood, steep phase	As for Boynewood, but with slopes over 6% to 8%.	---	
Bray	Moderately shallow red-brown to red self-mulching cracking clay soils; on gently undulating plains to undulating rises.	Red clay. Ug5.37.	Basalt. Pockets of paler non-crack-

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	0.15 m very dark brown self-mulching medium heavy clay over mildly acid to strongly alkaline red-brown to red medium clay to heavy clay to 0.5 - 0.7 m over similar clay soil with many fragments of weathered basalt, and/or strongly alkaline red-brown clay loam to light medium clay weathered rock materials.		ing clay soils in some lower slope areas.
Bray, deep phase	Bray soil, >1.5 m deep; on lower slopes of fans and plains below hills and plateaux.	Red clay; Ug5.38.	Basalt and basaltic col-luvia.
Brogue	Shallow to deep brown self-mulching cracking clay soils; on undulating plains to rises. 0.05 - 0.25 m dark brown light clay to light medium clay, over neutral to strongly alkaline dark brown, brown or red-brown light clay to medium clay to 0.25 - 0.7 m; either overlying strongly alkaline brown, red-brown or grey clay with carbonate to 0.8 - 1.5 m, and/or slightly alkaline to strongly alkaline brown yellow-brown, or red clay with weathered rock or rock fragments to 0.5 - 1.5 m; or weathered rock.	Brown clay, red clay. Ug5.32, Ug5.37, Ug5.35, Ug5.15.	Sedimentary rocks - Gayndah Formation. Coarser structured than Dunbas and Bray (basaltic equivalents).
Brogue, rocky phase	Brogue soil with cobbles.	---	
Brogue, steep phase	Brogue soil, with slopes > 6 to 8% on undulating rises.	---	
Brownside	Moderately deep, brown, coarse sandy soils with quartz gravel and rock debris; on undulating rises. 0.15 to 0.25 m dark to brown loamy coarse sand or coarse sand with fine angular quartz gravel over neutral to mildly alkaline brown to red-brown clayey coarse sand with many fine angular gravels of quartz, felspar or rock debris to 0.8 - 1.5+ m over brown coarse sand, or clay-bound rock debris.	Siliceous sand (brown), earthy sands. Uc5.11, Uc5.22.	Wigton Granite.
Burnett	Very deep, sandy, fine sandy and loamy very well drained soils; on levees, channel benches and ter-races. 0.15 to 0.4 m, dark to brown loam fine sandy to sandy clay loam topsoil, over neutral to mildly alka-line brown clayey fine sand to clay loam fine sandy subsoil. Layering frequently evident.	Alluvial soils, earthy sands. Uc5.21, Uc1.43, Uc1.23, Um1.43.	Recent alluvia - river and major creeks. Fine sandy textures most common. Coarse sandy layers occur in some pro-files. B horizon may also include sandy clay subsoils with earthy fabric.
Burnett, coarse sandy variant	As above, but has coarse sand to □ 1 m; may be red-coloured; may have clay-bound coarse sand or sandy clay at depth.	Siliceous sand. Uc5.21.	Separated because of very low waterholding capacity.
Burnett, shallow phase	Burnett soil, but is moderately shallow, with clay layers in the subsoil usually by 0.6 - 1.1 m depth. Polygenesis usually obvious. Intergrades to Fison (Fn). See Fison for clay layers □0.5 m.	Alluvial soils. Uc5.21, Uc5.23, Dr2.22.	Usually fine sand in upper solum.
Chessborough	Shallow to deep red sandy to loamy porous soil over paler subsoils, former clay soils, or rock; on slopes of undulating rises.	No suitable group, affinities with red earths. Um5.52, Gn2.11.	Deeply weathered, very old alluvia (Tertiary).
Chessborough Cont.	0.1 to 0.3 m red-brown or dark, sandy clay loam to clay loam; over mildly acid red to red-brown, coarse sandy clay loam to clay loam, to 0.6 to 1.45 m; deposited over strongly acid to strongly alkaline, brown or yellow-brown, often mottled, clay. Weathered buried rock may also occur below 1.1 - 1.5+ m. Ironstone may occur >1.5 m or on some scarps. Coarse sand and fine quartz gravel maybe present in the profile.		Sometimes moderate structure in B2 horizon (Um6.33).
Chessborough, rocky phase	Chessborough soil with stones and boulders on the surface (some boulders of ironstone carted in).	---	
Chessborough, rub-bly, shallow and	Chessborough soil with many coarse ironstone nodules, rock outcrops, and shallow sections; on	---	

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
rocky phase	upper slopes of undulating rises.		
Coonambula	Deep sodic duplex soils with shallow to very shallow topsoils, bleached subsurface soils, grey-brown or yellow clay subsoils; on valley flats, drainage depressions and small plains. 0.1 to 0.15 m dark to grey-brown sandy clay loam to clay loam topsoil, usually with bleached subsurface layer to 0.2 - 0.4 m over strongly alkaline grey, brown or yellow, occasionally mottled, clay subsoil.	Solodic soils and solodized solonetz. Dy2.43, Dy3.33, Db1.43, Db1.33, Dy3.43.	Recent alluvia - creeks and drainage lines. Also found adjacent to some large creeks.
Coonambula, eroded phase	As above, but with sheet and gully erosion, which is usually active.	---	
Dargy	Shallow to moderately shallow dark cracking clay soils; on gently undulating plains or rises. 0.05 - 0.1 m dark, light medium to medium heavy clay over neutral to very strongly alkaline dark medium clay to medium heavy clay to 0.3 - 0.95 m, over strongly alkaline yellow-brown light clay to light medium clay; or dark clay with rock fragments; or weathered rock.	Black earth. Ug5.12.	Sedimentary rocks - Gayndah Formation.
Derra	Very deep grey and brown cracking clay soils with normal gilgai 0.4 to 1.0 m deep; brigalow forest; on relict alluvial plains. 0.03 - 0.05 m brown, grey-brown or dark clay over neutral to very strongly alkaline grey to brown clay, occasionally mottled, frequently becoming paler with depth. Non-cracking clay soils may be associated.	Grey clay, brown clay. Ug5.24, Ug5.35, Ug5.34, Ug5.25.	Alluvia. Some non-cracking clay soils associated.
Derra, rocky phase	Derra soil with many pockets of abundant rounded cobbles or stones on the surface. (Possibly relict stream-bed deposit.)	---	Some large melonholes, >1 m deep, occur.
Derrick	Moderately shallow red-brown duplex soil with very shallow clay loam topsoil; on gently undulating plains or rises. 0.1 to 0.2 m dark brown to red-brown clay loam, often bleached in the lower part, over moderately acid to strongly alkaline red to red-brown clay to 0.45 to 0.65 m, over strongly alkaline brown to yellow-brown clay which may contain rock fragments, to □ 0.9 m; over weathered rock.	No suitable group; affinities with red-brown earths and non-calcic brown soils. Dr2.13, Dr2.33, Gn3.23.	Sedimentary rocks - Gayndah Formation. Occasionally fine sandy clay upper B horizons with clay loam (fine sandy) loam lower B horizons. Surface structure may degrade readily under cultivation. Carbonate may be present in lower part of the profile.
Derrick, steep and broken phase	Derrick soil, with slopes > 6 to 8%, and with gullies and channels; on pediments.	---	
Dillan Dillan Cont.	Moderately deep sodic duplex soil having shallow topsoil, bleached subsurface layer, and mottled grey to yellow clay subsoil; on pediments. 0.05 - 0.20 m grey-brown loamy sand to sandy clay loam; over grey, light grey, or yellow-brown, bleached when dry clayed sand to sandy clay loam to 0.20 - 0.45 m; over grey, yellow-brown or yellow, mottled, neutral to very strongly alkaline sandy clay to heavy clay.	Solodic soils, solodized solonetz. Dy3.43, Dy3.42.	Steeply dipping sedimentary rocks (Wondilla Formation).
Drape	Moderately deep to deep, dark to dark grey self-mulching cracking clay soils; on level to gently undulating plains. 0.05 - 0.1 m dark to dark grey medium clay to heavy clay over mildly acid to strongly alkaline dark to grey medium clay to heavy clay to 0.75 - 1.5+ m, over strongly alkaline, grey, light clay to medium heavy clay often with fragments of weathered rock or weathered rock.	Black earth, black earth-grey clay intergrade. Ug5.12, Ug5.14, Ug5.1, Ug5.24.	Basalt and labile sandstones. Basalt on upper slopes and crests; overlies labile sandstones. These soils are a blend derived from both types of parent material.
Dunbas	Moderately shallow very dark brown to red-brown self-mulching cracking clay soils; on gently undulating to undulating plains. 0.05 - 0.15 m very dark brown self mulching medium heavy clay over mildly acid to strongly alkaline very dark brown to red-brown medium heavy clay to 0.35 - 0.55 m over either strongly alkaline brown to red-brown medium heavy clay with many fragments of weathered basalt, or weathered	Brown clay. Ug5.13, Ug5.15, Ug5.37.	Basalt. Some deep profiles occur (Ug5.34).

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	basalt.		
Dunbas, deep phase	Dunbas soil, > 1.5 m deep on lower slopes of fans and plains below hills and plateaux.	Brown clay. Ug5.34.	Basalt and basaltic colluvia.
Dunbas, steep phase	Dunbas soil, with slopes > 6% to 8%.	---	
Durong	Very deep grey cracking clay soils with normal gilgai < 0.3 m deep; brigalow forest; on relict alluvial plains. 0.02 - 0.05 m grey-brown or dark clay over strongly alkaline grey to brown, or yellow-brown clay; frequently becoming mottled and paler with depth; few carbonate nodules.	Grey clays; some brown clays and black earths. Ug5.24, Ug5.25, Ug5.35, Ug5.16.	Alluvia.
Ella	Moderately deep acid to alkaline duplex soil with shallow clay loam topsoil to and yellowish clay subsoil; on mid to lower slopes of gently undulating plains to undulating rises. 0.25 - 0.4 m dark to brown clay loam, often with fine gravel at the base, often over light grey to brown clay loam to 0.35 - 0.45 which is bleached when dry, over moderately acid to strongly alkaline yellow to yellow-brown and often mottled, clay to 0.5 - 1.0 m, over strongly alkaline yellow, yellow-brown or red, usually mottled, clay which may contain carbonate, to 0.7 - 1.5+ m; over weathered rock.	Soloth and solodic soils or no suitable group (alkaline yellow duplex soil). Dy3.43, Dy2.13, Dy3.41.	Sedimentary rocks - Gayndah Formation. Most profiles alkaline. Brown colours in some lower slope positions, Db2.13. Sandier textures and acid soil pH near granitic zones.
Fison	Very shallow to shallow fine sand to fine sandy loam soils deposited over clay layers; on levees, channel benches, and terraces. 0.1 - 0.3 m dark to brown fine sandy loam surface soil with brown, or bleached fine sandy loam subsurface soil over brown, red-brown, or yellow, often mottled, clay layers from 0.3 to 0.5 m; paler or bleached subsurface layers may occur.	Alluvial soils (affinities with red-brown earths, non calcic brown soils, solodic soils, and solodized solonetz) Uc2, Uc5.21, Uc5.2, Uc3, Uc4. (Classified on sur-ficial deposits only)	Recent alluvia - river and major creeks. This soil looks like a duplex and will behave as such.
Fison, rocky phase	Fison soil, but with few to many angular andesite gravels on the surface or in the profile; on a high terrace.	Alluvial soils, affinities with solodic soils. Uc2.	
Flagstone	Very deep, dark to brown friable clay loam or clay soil; on terraces.	Prairie soils; or affiliates.	Recent alluvia - river and creeks.
Flagstone Cont.	0.05 - 0.35 m dark to brown sandy clay loam to light clay (usually fine sandy or silty); over neutral to strongly alkaline dark to brown clay loam to clay (often fine sandy or silty).	Gn3.22, Gn3.23, Gn3.42, Gn3.43, Uf6.32.	Surface structure often becomes massive to weak under cultivation. Also found associated with smaller creeks, and some fans.
Flagstone, channelly phase	Flagstone soil, with smooth-sided channels 1-3 m deep.	---	
Flagstone, channel-bench phase	Flagstone soil; found on low-lying channel benches of creeks.	---	
Glenrock	Deep to very deep red, massive, porous loamy soil; mainly on elevated plains, sometimes on crests or fans. 0.05 - 0.3 m, red, light sandy clay loam to clay loam, over strongly acid to mildly alkaline red sandy clay loam to light clay.	Red earth. Gn2.11, Gn2.12, Um5.51.	Deeply weathered, very old alluvia. Deposits overlie earlier geological formations. Some structured versions included.
Glenrock, grey variant	Shallow grey to brown sandy to loamy porous soil; on lower slopes of undulating rises. 0.1 - 0.15 m dark to grey-brown sandy loam to light sandy clay loam, over slightly acid grey to brown sandy clay loam to 0.4 - 0.6 m; underlain by ironstone, manganiferous pans, or rock. Coarse sand and fine quartz gravels often present.	No suitable group. Gn2.81, Gn3.21.	
Greyfrill	Shallow to moderately deep sodic duplex soil with very shallow bleached topsoil and grey clay subsoil;	Solodized solonetz, solodic soil.	Sedimentary rocks - Gayndah Formation.

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	on pediments and fans below hills. 0.2 m grey-bleached, fine sandy loam to light sandy clay loam (sometimes with unbleached surface to 0.02 m) over strongly to very strongly alkaline grey clay to 0.3 - 1.0+ m over weathered rock.	Dy2.33, Dy2.43.	Prone to severe erosion.
Greyfrill, eroded phase	Greyfrill soil with severe sheet and gully erosion.	---	
Jedda	Deep dark self-mulching cracking clay soils; on valley flats and broad drainage depressions. 0.05 m dark heavy clay over strongly alkaline dark heavy clay to 0.6 - 1.0 m over strongly alkaline dark to grey medium clay to heavy clay.	Black earth. Ug5.1, Ug5.16.	Basalt-derived alluvia.
Kinburn	Deep greyish sodic duplex soil with very shallow topsoil and bleached subsurface soil; on small backplains or drainage depressions associated with levees. 0.1 - 0.15 m dark to grey-brown fine sandy loam to clay loam (fine sandy) topsoil and bleached subsurface soil to 0.2 - 0.25 m, or a thin layer of bleach; over grey or grey-brown, mottled, strongly alkaline clay subsoil. Layering common.	Solodic soils, solodized solonetz. Db2.33, Dy2.33, Dy3.43, Dy5.33.	Recent alluvia - river and major creeks. Generally greyer appearance than Fison. Sometimes sporadic bleach throughout shallower A1 horizons.
Kinburn, eroded phase	Kinburn soil, but with severe erosion.	---	
Lacon .	Shallow to deep dark to brown cracking clay soils over rock; on undulating plains to rises. 0.1 to 0.2 m dark to brown light clay to medium clay; over alkaline dark to red-brown, light medium clay to medium clay to 0.5 - 1.5+ m; over similar material or red-coloured clay, with fragments of rock; or weathered rock.	Black earth, brown clay. Ug5.12, Ug5.15, Ug5.16, Ug5.32.	Steeply dipping sedimentary and volcanic rocks.
Lacon, eroded phase	As for Lacon, but eroded; varies from moderate to severe gullying.	---	
Lacon, rocky phase	As for Lacon, with with gravel or cobble on the surface, or rock outcrop.	---	
Madoora	Deep sandy soils on valley flats adjacent to creeks. 0.3 to 0.7 m dark sand, over medium acid, red or red brown sandy subsoils.	Siliceous sand. Uc5.21.	Recent alluvia - creeks and drainage lines.
Mulgildie	Moderately deep to very deep red clay loam soils with structured acid red subsoils below 0.2 m to 0.5 m; on summit surfaces and plains of plateaux, and footslopes below plateaux. 0.2 - 0.5 m dark reddish brown to red clay loam, massive to weakly structured; over acid red-brown to red clay loam to light clay, moderately structured, usually granular or polyhedral, to 0.9 - 1.5+ m; over similar material with decomposing basalt.	Krasnozems or no suitable group. Gn3.11, Gn3.10, Uf6.31, Um6.33, Um5.21.	Deeply weathered basalt. Surface structure may be degraded by cultivation. Some variants are massive.
Mulgildie, eroded phase	Mulgildie soil, eroded.	---	
Mulgildie, rocky phase	Mulgildie soil, but with high gravel content.	---	
Mulgildie, snuffy variant	Mulgildie soil, but with fine loose "snuffy" surface when dry.	---	
Neugildie	Moderately deep to very deep red structured clay loam to light clay soils with neutral reaction trend; on lower lying areas and valley infills of plateaux, and footslopes; and in some outlying remnant areas. 0.3 - 0.5 m red brown to red clay loam to light clay over neutral, red-brown to red light clay to light medium clay, to 0.7 - 1.5+ m over similar material which is mottled or contains fragments of basalt.	Euchrozem. Gn3.12, Uf6.31, Uf6.4.	Deeply weathered basalt. Neutral version of Mulgildie soil.
Neugildie, colluvial clayey variant	Neugildie soil, but with prismatic, angular blocky or lenticular structure in subsoil; neutral to strongly alkaline. Found in lower-lying areas of plateaux; and in fans and plains below plateaux, and in some outlying remnant areas.	---	Colluvia from deeply weathered basalt.

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
Neugildie, eroded phase	Neugildie soil, with erosion gullies.	---	
Neugildie, saline phase	Neugildie soil, salinised.	---	Colluvia from deeply weathered basalt. Mostly bare of vegetation.
Overrun	Very deep, dark grey cracking clay soils; ironbark woodland with other tree species; on alluvial plains. 0.05 - 0.1 m, dark clay over neutral to strongly alkaline dark grey to grey clay; may be brown below 1.05 - 1.1 m; carbonate below 0.6 - 0.75 m.	Grey clay. Ug5.24.	Alluvia. Lower-lying areas may be occasionally inundated.
Overrun, linear gilgaied phase	Overrun soil; linear gilgai 0.05 m deep.	Grey clay. Ug5.24.	Linear gilgai probably resulted from occasional overtopping by flood water.
Panda	Very deep cracking clay soil with sporadically-bleached subsurface layer; on low terraces. 0.15 to 0.35 m dark to brown clay topsoil over sporadically-bleached silty clay loam to clay subsurface layer to 0.2 - 0.45 m, over strongly alkaline dark clay subsoil; may become brown below 0.7 m.	No suitable group; affinities with solodic soils. Ug3.1.	Recent alluvia - creeks and drainage lines. Distinguished by bleach and dark colours at least in upper B horizon. A_1 horizon may be layered.
Panda, saline phase	Panda soil, salinised.	No suitable group; affinities with (salinised) solodic soils. Ug2.	Bare areas on surface, or salt-bush vegetation present.
Platter	Very deep dark to grey-brown non-cracking and cracking clay soils; on level terraces and interfluves below hills and mountains. 0.1 to 0.25 m dark clay topsoils with strongly alkaline dark to grey-brown and brown clay subsoils; carbonate below 0.45 to 0.55 m.	No suitable group; and black earths. Uf6.33, Ug5.16, Uf6.32.	Recent alluvia - creeks and drainage lines. Layering may be evident.
Red Flank	Moderately deep to deep red coarse sandy soils with bleached or pale layers below 0.9 m; on undulating rises. 0.1 to 0.25 m dark to red-brown coarse sand to coarse sandy loam with fine angular quartz gravels; over moderately acid to mildly alkaline red to red-brown coarse sand to light sandy clay loam (coarse sandy), with many fine angular gravels of quartz, felspar or rock debris; to 0.85 - 1.05 m over moderately acid to neutral red-brown coarse sand to coarse sandy loam - with patches of bleach, bleached throughout or paler colours associated and many fine angular gravels of quartz, felspar or rock debris. May be hard, porous slakable earthy pan formed at the base of the profile (>1.35-1.6 m).	No suitable group, affinities with earthy sands and red earths. Uc5.21, Gn2.12, Gn2.15.	Colluvia? on Wigton Granite. Probably originated as infill from reworked red earths. Often limited in extent. A2 horizon often present; red brown; clayey coarse sand to coarse sandy loam.
Riverleigh	Very deep dark or brown sodic duplex soil with very shallow to shallow topsoil, bleached subsurface soils and dark to brown clay subsoils; on terraces. 0.1 - 0.35 m dark to dark brown sandy clay loam (fine sandy) to silty clay loam, usually with bleached subsurface soil to 0.2 - 0.45 m; over neutral to strongly alkaline dark to dark brown clay subsoil, occasionally mottled; may become grey or red-brown below 0.5 - 0.95 m.	Solodic soils. Dd1.43, Dd1.33, Db1.33.	Recent alluvia - river and creeks. Also found in drainage depressions and valley flats of some creeks, (includes Dd1.12, Dd1.42). Occasionally brown clay subsoils occur. Occasionally clay subsoils may be mottled, Db2.32.
Riverleigh, channelly phase	Riverleigh soil with smooth sided channels 1 to 3 m deep.	---	
Riverleigh, clayey variant	Riverleigh soil, but with clay topsoil.	No suitable group, or black earth. Uf2, Ug5.16.	
Riverleigh, eroded phase	Riverleigh soil, with sheet and gully erosion.	---	
Solwig	Moderately deep to deep sodic duplex soil with hard-setting surface, bleached subsurface layers and grey subsoil; on pediments and some small	Soloths. Dy3.41, Dy2.41.	Wigton Granite. Harder, greyer surface than Whiteside soil; and

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	mid-slope flats of undulating rises. 0.05 to 0.1 m grey to grey-brown loamy sand or loamy coarse sand, over grey to grey-brown bleached when dry, coarse sand to light sandy clay loam (coarse sandy) to 0.25 to 0.75 m, over moderately acid, grey - often mottled, sandy clay loam (coarse sandy) to sandy clay. Some deep bleached coarse sandy soils associated.		than Whiteside soil; and apparent poor growth of vegetation. Some deep, bleached coarse sands associated. May also be solodic soils or solodized solonetz soils present depending on pH in deep subsoil.
Solwig, eroded phase	Solwig soil, with erosion gullies.	---	
Stratfield	Moderately shallow to deep loamy-surfaced layered alluvial soils on small interfluves and terraces; below mountains and hills. 0.1 to 0.25 m dark, grey or brown, light sandy clay loam (coarse sandy) to clay loam topsoils; with neutral to strongly alkaline dark, grey, yellow-brown or brown, coarse sandy clay loam to light clay subsoils, and dark to grey clay soils, or gravel, below 0.4 to 0.95 m.	Alluvial soils. Um6, Um6.31, Dy2.13.	Recent alluvia - creeks and drainage lines. Sand sized white mineral grains give some clay subsoils a grainy appearance. In most areas, soils set hard upon cultivation.
Taughboyne	Shallow to moderately shallow dark to grey-brown sodic duplex soil with very shallow clay loam topsoil usually bleached at the base; on gently undulating plains to undulating rises. 0.05 - 0.1 m grey-brown clay loam, usually over dark to grey brown clay loam, with bleached spots when dry to 0.1 - 0.15 m; over neutral dark to brown clay to 0.25 - 0.35 m over strongly to very strongly alkaline, grey to brown clay to 0.55 - 0.75 m, underlain by weathered rock.	Solodic soil. Dd1.33, Db1.33, Dy2.33, Dy3.33, Db1.13.	Sedimentary rocks - Gayndah Formation. Upper clay subsoil usually darker-looking than lower.
Taughboyne, eroded phase	Taughboyne soil, with erosion gullies.	---	
Whiteside	Shallow to moderately deep sodic-magnesic duplex soil with shallow topsoil and well-bleached subsurface layer and yellow-brown to grey subsoils; on undulating rises. (Not mapped separately; major component of Wigton Association.) 0.1 - 0.2 m dark to brown loamy coarse sand with fine subangular quartz gravel over grey, bleached when dry, clayey coarse sand to coarse sandy loam to 0.3 - 0.85 m with many fine subangular quartz gravels; over moderately acid to neutral, yellow-brown, grey or light grey, often mottled, sometimes bleached in parts, coarse sandy clay loam to light clay with many fine angular quartz gravels, or rock debris. The subsoils are sometimes bleached in parts. There may also be a yellow-brown to light yellow-brown transition layer between the subsurface soil and the subsoil.	Soloths (mainly); or no suitable group; includes bleached sands. Dy3.41, Dy5.41, Dg2.41.	Wigton Granite. Imperfectly drained areas or sites where drainage water lies above subsoil for some time. Some bleached brown soils occur, Uc2.13, Dr2.4. Maximum depths reached were 0.9 m.
Wigton Association	A complex of soils on undulating rises. Constituent soils are mainly Whiteside and Brownside, and intergrades; as well as Red Flank, Solwig, and Glenrock. Usually the constituent soils can not be mapped separately. See individual soil descriptions.	---	Wigton Granite. Soils can vary considerably over short intervals. Small scarps may occur at the margins of the units or near drainage lines.
Wigton Association, eroded phase	Wigton Association, with eroded or natural gullies; on plains or undulating rises.	---	
Wigton Association, steep phase	Wigton Association, with slopes > 8% to 12%; on undulating to rolling rises.	---	
Wigton Association, steep and broken phase	Wigton Association; with slopes > 8% to 12%, and short spaced steep incised gullies; on undulating to rolling rises, some scarps, and low hills.	---	
Wivenhoe	Deep gradational soil with loamy surface soils and yellow, structured, clay subsoils; on lower slopes of undulating rises. 0.1 to 0.15 m dark or grey-brown loam-fine sandy to clay loam; over brown or red-brown loam-fine sandy to clay loam to 0.2 to 0.35 m; over slightly acid to mildly alkaline yellow-brown clay loam to light clay to 0.3 to 0.55 m; over neutral to mildly alkaline	No suitable group; affinities with solodic soil. Gn3.75, Gn3.82, Gn3.72.	Deeply weathered, very old alluvia.

Soil Type	Concept, and Major Attributes of Soil Type[1]	Great soil group[2] and Main Principal Profile Forms[3]	Geology[4] and General Notes
	yellow clay with subangular blocky structure.		
Yondilla .	Deep duplex soil with shallow topsoil, bleached subsurface layers and columnar-structured sandy clay loam subsoil; on fans. 0.1 - 0.2 m grey to brown loamy sand to loamy coarse sand; over yellow-brown to brown, bleached, coarse sand to 0.45 - 0.65 m; over light yellow-brown neutral sandy clay loam with columnar structure.	No suitable group; like solodized solon-etz, but lacks clay subsoil. Dy2.42.	Fan below steeply dipping rocks of Wondilla For-mation. Unnamed associated soil is a deep coarse sand, with coarse sandy loam subsoil, and pan at or below 1.25 m.

Notes:

1. Depth criteria, for soil layers and whole soil, are based on Soil Survey Staff (1951). In the *Burnett shallow phase, Bray deep phase, Dunbas deep phase*; the depth terms indicate relative variation from the basic soil type.
2. Stace *et al.* (1968).
3. Northcote (1979).
4. Names of relevant geological formations are based on Geological Map of Mundubbera 1:250 000 Sheet Area and Maryborough 1:250 000 Sheet Area. Wigton Granite was previously called Wigton Adamellite.

6. Chemical attributes of the soils

Nine profiles were sampled and analysed, as per Baker and Eldershaw (1993). Soil fertility status, salinity and sodicity are discussed in this section. The soil descriptions and laboratory data of the analysed profiles are presented in Appendix 2. The data have been interpreted using general ratings shown in Appendix 1, as given in Bruce and Rayment (1982); calcium and magnesium ratings from Baker and Eldershaw (1993). Soil fertility ratings for each soil type, phase and variant are given in Appendix 3. Salinity and sodicity for each soil type, phase and variant are presented in Appendix 4. The ratings given in Appendices 3 and 4 are based on data from this study, the adjacent study (Wilson and Sorby, 1991), and augmented by data kindly provided by the CSIRO Division of Soils. The latter data were determined in 1959 and 1960, and utilised in de Mooy *et al.* (1977).

Soil fertility

Soil pH

The data refer to pH measured in the laboratory using 1:5 soil:water suspensions. Over the study area, soil pH in the top 0.1 m varies from 5.9 to 8.5, with the majority soils becoming more alkaline at depth. At 0.6 m, the pH range is 5.9 to 9.4 with the majority occurring in the range 7.5 to 9.4.

Soil pH is unlikely to cause major problems with nutrient availabilty or toxicity, particularly in the top 0.1 m. Soils which are strongly alkaline (pH $\geq$ 8.5) by 0.3 m include the cracking clay soils, and the strongly sodic duplex soils except those which are formed on granite.

Problems associated with low pH (acid) soils are unlikely. The lowest pH recorded was 5.1 in the *Glenrock* soil at 0.8 m in the adjacent study area (Wilson and Sorby, 1991). All other laboratory data show that soils have a pH $>$5.5. However, acid soils may develop in the surface from the heavy, prolonged use of nitrogenous fertilisers (Baker and Eldershaw, 1993).

The alluvial prairie soil, *Flagstone,* displayed a range of pH at depth varying from neutral to mildly alkaline (Wilson and Sorby, 1991), to very strongly alkaline for site S4 in Appendix 2.

Cation exchange capacity

Cation Exchange Capacity (CEC) measures the quantity of cations which the soil can retain. Cations are positively charged ions such as calcium - Ca^{2+}; Magnesium - Mg^{2+}; Sodium - Na^{+}; Potassium - K^{+}; Aluminium - Al^{3+}, and Hydrogen - H^{+}. Through ionic bonding, cations become attached to the negatively charged clay colloids and colloidal organic matter.

Baker and Eldershaw (1993) suggest that absolute values of CEC should be used with associated properties such as soil texture. Soils low in clay and organic matter will have low CEC. Certain types of clay minerals have higher CEC than others. For example, the smectite clays responsible for shrinking and swelling in soils contribute high CEC to a soil.

The following CEC ratings have been assigned to the soil types based on available data.

High CEC ($>$40 meq./100 g)	Basaltic cracking clays - *Balark, Dunbas, Bray, Bovekel, Jedda.* Also some *Boynewood* soils.
Medium CEC (10-40 meq./100 g)	Other cracking clays, most structured uniform and gradational soils and duplex soils.
Low CEC (4-10 meq./100 g)	Alluvial sandy soils - *Burnett*; surface soils of *Burnett shallow phase* and *Fison*; the surface of other sandy soils and massive gradational soils - *Glenrock, Chessborough, Brownside;* duplex soils - *Greyfrill* and *Whiteside.*

Very low CEC (≤ 4 meq./100 g)	*Red Flank* and sub-surface horizons of the sandy soils and massive gradational soils above.

More precise details can be gained from analytical data in Appendix 2, and from Wilson and Sorby (1991) (Appendix 4). Baker and Eldershaw (1993) discuss CEC further.

Organic carbon

Organic carbon (Walkley and Black, 1934) levels in the soils are a measure of the organic matter content. Organic matter in surface soils influences waterholding capacity, cation exchange capacity, and also relates to soil aggregation through the influence of some organic substances. It also acts as a store of soil carbon, nitrogen, phosphorus and sulfur (Baker and Eldershaw, 1993).

Organic carbon data are available for surface soils, though data for lower depths have been recorded by de Mooy *et al*. (1977). Organic carbon content in the surface 0.1 m ranges from 0.8% to 5.9% with most soils between 1.0% and 2.0%.

The alluvial *Flagstone* soil sampled by Wilson and Sorby (1991) had a content of 3.8% while the *Flagstone* soil at site S4 (Appendix 2) under cultivation had a content of 1.7%. The contents in *Boynewood* soils varied between 1.9% (Wilson and Sorby, 1991) and 4.8% (de Mooy *et al*., 1977). The *Mulgildie* soil has a very high content of organic carbon (5.9%) although the sample came from an undisturbed forest.

All soils under cultivation suffer some decline in organic matter content. Part of the structural degradation induced by cultivation may relate to reduced organic matter. The rate of organic carbon loss under cultivation can be reduced through protection of the soil surface from soil erosion, avoiding excessive tillage, and maintaining good crop growth through supply of adequate nutrients and water. Levels of organic matter can be increased through addition of plant materials or manure, and no-till management systems.

Total nitrogen

Total nitrogen levels are high in some uncultivated soils: *Flagstone,* 0.27% (Wilson and Sorby, 1991); *Mulgildie,* 0.3%, *Boynewood,* 0.3% to 0.5% (de Mooy *et al*., 1977). Medium levels (0.17% to 0.25%) were found in most samples from cracking clays - *Derra, Durong* (Wilson and Sorby, 1991); *Balark, Bray* (de Mooy *et al*., 1977); *Boynewood* (Wilson and Sorby, 1991); and in a *Derrick*-like soil (de Mooy *et al*., 1977). Almost all other soils had low values of 0.06% to 0.15%, with the majority between 0.1% and 0.14%. This majority group included cultivated clay soils *Bovekel* (0.1%), uncultivated clay soil *Bonnie Crofts* (0.11% to 0.15%), and the cultivated alluvial structured soil *Flagstone* (0.14%). The *Red Flank* soil had very low total nitrogen (0.04%).

Under irrigation, nitrogen fertilisers will be required for most crops to ensure that good crop yields are achieved. Leaching may occur on soils which have moderate to high infiltration rates, and are moderately well drained to rapidly drained; for example, *Burnett, Madoora, Red Flank* and *Glenrock* soils.

Phosphorus

Most Australian soils have low phosphorus levels, apart from recent alluvial soils and soils on specific high phosphorus parent material. Total phosphorus is measured on profile samples; available phosphorus only in the top 0.1 m of soil.

Total phosphorus levels are relatively high only in two soils: the *Bovekel* soil (about 0.1%) on basalt and the sandy *Burnett* soil (about 0.05%) on recent alluvium. All other soils have low to medium total phosphorus (0.005%-0.02%, and 0.02%-0.05% respectively) with some being high (0.05%-0.1%) in the surface soil only.

The recent alluvial soils *Burnett, Fison* and *Flagstone* have high levels of available phosphorus (40-70 µg/g). The *Boyne* soil analysed for the adjacent Auburn River study (Wilson and Sorby, 1991) had very low values (9 µg/g). A *Boyne*-like soil near Gayndah (de Mooy *et al*., 1977) had very high levels of available phosphorus (≥100 µg/g) and total phosphorus (≥ 0.2%). The basaltic clay *Bovekel* and the granitic sand *Brownside* have medium levels of available phosphorus (around 30 µg/g). All other analysed soils have low to very low available phosphorus (10-20 µg/g, and <10 µg/g respectively).

High 'free' iron contents in soils can cause phosphorus to be unavailable to plants by sorption onto the iron minerals. This may occur on the red clay loam to clay soils *Mulgildie* and *Neugildie*, and on the red sandy soils *Glenrock, Chessborough* and *Red Flank.*

Most irrigated crops will require phosphorus fertiliser, depending on crop needs. Soils with high available phosphorus should require little phosphorus fertiliser initially, particularly if there are also high total phosphorus levels throughout the soil profile, as in *Burnett* and *Flagstone* soils.

Potassium

All the analysed soils have medium to high levels of extractable potassium (0.2-0.5 and 0.5-1.0 meq./100 g), at least in the surface soils, and most have medium levels of total potassium (0.5-1%), at least in the surface soils. Soils on Wigton Granite (*Whiteside, Brownside, Red Flank, Wigton Association)* have very high total potassium levels, (3-5% total K) due to the presence of potassium feldspar minerals in the soil profile. Soils with low total potassium are a cracking clay *Bovekel,* and the sandy soils on very old alluvium *Chessborough* and *Glenrock*. Potassium fertiliser may be required on the sandier soils (except those on granite) as reserves may be low.

Other plant nutrients

Calcium and magnesium. Levels are sufficient in most soils (>2 meq./100 g at least in the surface 0.1 m). Low values of calcium were found in surface soils of *Fison* (1.5-2 meq./100 g). Low values of calcium were found throughout the *Whiteside* soil (1-1.6 meq./100 g in surface soils, 0.4 meq./100 g in subsoils). Very low values were found in the subsoils of the red *Mulgildie* soils (≤ 0.2 meq./100 g). Calcium fertiliser could be required to ensure that the growth of crop roots is adequate. The need for calcium fertilisers on other soils is uncertain. It is most likely not required for the majority of crops.

Low values of magnesium were found throughout *Brownside* and *Red Flank* (≤1.4 meq./100g). However, the need for magnesium fertilisers is unknown.

Sulfur. Total sulfur levels are low to medium in all the soils (0.008% to 0.05%). Sulfur fertilisers may not be required. Testing for available $S0_4$-S should be undertaken to assess plant/crop sulfur needs.

Micronutrients. All soils have medium or higher levels of manganese (>2 µg/g). Low values of copper (0.2 µg/g) were found in *Red Flank* and *Whiteside* soils in the *Wigton Association*. Low levels of zinc were found or are expected in the cracking clay soils for example, *Bovekel, Jedda, Drape, Derra* and *Durong* (0.5 - 1.9 µg/g; pH >7). Low levels of zinc were also found in *Boyne* and *Glenrock* soils (0.4 - 0.5 µg/g; pH >7).

Salinity and sodicity

Ratings for each soil are shown in Appendix 4, and relate to the naturally occurring levels of salt and exchangeable sodium in the soil.

Salinity

Salinity ratings are derived from measurements of electrical conductivity (EC) in a soil:water suspension. Chloride levels are derived from the same suspension. EC alone shows up all salts in the soil, including contributions from less soluble sources of salts like gypsum. Chloride levels relate to the more common salts such as sodium chloride. Baker and Eldershaw (1993) show how to interpret the salt profile from EC readings. Detailed discussions on salinity are included in Shaw *et al.* (1987). Salinity ratings for the soil types are given in Appendix 4.

Uniformly low values of salinity and chloride were found in all well drained soils (<0.45 dS/m, and <0.03% Cl). This included alluvial sands such as *Burnett,* other sands, and well drained cracking and non-cracking clays above rock or on sloping land.

Most other soils had low salt content in the topsoil with higher content in the subsoil. Variation in soil salt content is shown in the *Flagstone* soil which occurs on alluvial terraces. The site sampled for the Auburn River study (Wilson and Sorby, 1991 - site S8) had very low salt levels (0.1 dS/m at 0.1 m, decreasing to 0.03 dS/m at 1.5 m). Site S4 in this study (Appendix 2) had low salt levels in the surface (0.16 dS/m at 0.1 m) increasing to high salt levels (0.94 dS/m at 0.9 m). These high levels correspond to a strong alkaline and very strongly sodic subsoil.

The only uniformly high levels of salts are as expected in the *Neugildie saline phase* and *Panda saline phase*. The saline phases have resulted from the development of saline seeps at the base of rises and on associated creek flats. These soils exhibit either bare areas or halophytic vegetation.

Exchangeable sodium

Exchangeable sodium (sodicity) is measured as the percentage of sodium ions in relation to the soil's cation exchange capacity. (Exchangeable sodium percentage: [ESP] = [Na/CEC] x 100). Sodicity ratings are given in Appendix 1. High sodicity increases the expansion of swelling clays resulting in dispersion, particularly of unconfined soil material, leading to blocking of pores, or translocation of clay and reduced infiltration of water. Dispersion can also be enhanced by high levels of exchangeable magnesium which acts in some cases similarly to sodium (Baker and Eldershaw, 1993). Sodicity ratings for the analysed profiles are given in Appendix 4.

The soil most prone to dispersion is *Greyfrill*, and this is shown by its readiness to erode severely, as the *Greyfrill eroded phase* shows. ESP and salinity data are unavailable for the *Greyfrill* soil but high ESP is suggested by a pH >8.5 (Baker *et al.*, 1983) in the subsoils. Other sodic duplex soils which are expected to have sodium induced physical problems in the upper part of the clayey subsoils include *Auburn, Beeron, Coonambula, Derrick, Ella, Fison* and *Kinburn.*

The alluvial duplex soil *Riverleigh* varies from non-sodic to sodic at 0.3 m (Appendix 4). The older alluvial cracking clay soils *(Bonnie Crofts, Durong, Derra* and *Overrun)* have sodic or strongly sodic subsoils. However, dispersion probably does not take place. Some versions of the *Lacon* soil also have sodic or strongly sodic subsoils. Most other soils are non-sodic.

7. Irrigated land suitability

Land suitability methodology

Over 600 unique map areas (UMAs) have been delineated. The significant limitations to production were identified for each UMA. The severity of each limitation was assessed on a 1 to 5 scale (Appendix 5). The suitability classes and relevant limitations to production of irrigated crops were recorded on the UMA record file.

The UMAs have been individually assessed for their relative suitability for growing the following crops using the irrigated land suitability classification scheme described in Appendix 6:

- avocado
- citrus
- mango
- pecan/low-chill stone fruits
- grapes
- vegetables
- cruciferae such as broccoli and cauliflower
- cucurbits such as melons, pumpkins and rockmelons
- asparagus
- peanut
- safflower
- sunflower
- navybean
- mungbean
- chickpea
- winter grains such as wheat and barley
- summer grains such as maize and sorghum
- improved pastures
- potato

Each UMA was also assessed for suitability for surface (furrow) irrigation.

The explanation of land attribute codes for the UMA record file are described in Appendix 6. The UMA information is in computer files and can be accessed from The Resource Sciences Centre, Department of Natural Resources, 80 Meiers Road, Indooroopilly Q 4068. However, the UMA record lines contain the information as follows:

> Record type 1 contains the base data including location, soil types, geology, landform; and soil and land attributes. Records 2 and 3 contain the land suitability assessment of the various crops. The suitability of each UMA for each crop is assessed using soil and land attributes in Record 1.

Limitations to irrigated agriculture

Irrigated agriculture within the study area is affected by the following limitations:

Climate
Water availability
Wetness
Soil depth
Rockiness
Microrelief
Soil physical condition
Secondary salinisation
Water erosion
Furrow infiltration
Water quality

Flooding

The limitations affect crop production through influences on crop growth, machinery operations and land degradation.

Climate

The climate does not vary significantly over the study area, except for the incidence of frosts. Local experience on the frequency and severity of frosts, and landscape position were used to determine the limitation subclasses for the various crops. Seasonal adaptation of crops was considered. For example, frosting did not need to be included in the assessment for summer crops.

Plants vary in their tolerance to frosts. Frosts can suppress the growth of sensitive crops, kill plants or reduce yield through damage to flowers or fruits. Generally, the incidence and severity of frosts in the study area is influenced by position in the landscape. Hill tops and plateaux experience fewer and less severe frosts and are suitable for sensitive crops such as avocados and mangoes. The low lying channel benches and depressions in the terraces along the rivers can receive a large number of severe frosts per year (>20). These severely affected areas limit the suitable crops to deciduous plants such as pecans, low-chill stone fruits, grapes, and adaptable small crops and field crops.

Availability of soil water

Water availability refers to the soil's ability to store and supply water for plant growth. A reduced soil water storage capacity will require more frequent irrigation to obtain optimum yields.

Plant available water capacity (PAWC) provides the best estimate of a soil's storage capacity. PAWC is the difference in volumetric water content between the upper storage limit (approximately field capacity), and the lower storage limit (approximately wilting point) summed for each layer within the rooting depth and adjusted by the rooting profile over the rooting depth. Effective rooting depth is the depth to which approximately 90% of plant roots will extract water. Examples are:

- tree crops, 1 to 1.5 m
- grapes and small crops, 0.5 m
- grain crops, 0.9 m

The effective rooting depth is reduced by restrictive layers which are indicated by rock, consistency, pH, salinity peaks (measured by electrical conductivity), sodicity and segregations such as nodules, etc.

Based on methods of Shaw and Yule (1978) and Gardner and Coughlan (1982), all cracking clays have an estimated PAWC >100 mm. Duplex soils which are strongly sodic (ESP ≥15) and have a salt bulge at 0.6 m to 1 m, have an estimated PAWC of 75 mm to 100 mm; but duplex soils which are strongly sodic at 0.5 m to 0.6 m have an estimated PAWC of 50 mm to 75 mm. Predicted PAWC values have been allocated to six soil groups depending on texture, sodicity and structure to effective rooting depth; for example "structured loamy to clayey soils" and "uniform sands" (See Appendix 6).

Limitation subclass is based on the frequency of irrigation required for optimal plant growth. Soils with higher PAWC require irrigating less frequently if the profile is fully recharged. Irrigation frequency is based on measurements by Gardner and Coughlan (1982) for a dry season maize crop during grain filling. They also showed that on sodic texture contrast soils, recharge of the rooting depth is incomplete due to the impermeable subsoils and the long periods of irrigation necessary to recharge the soil. If longer irrigation times were used to increase recharge, waterlogging may be expected in the topsoils. Therefore the use of predicted PAWC should be interpreted with care.

Based on predictions, all deep cracking clays (*Derra, Durong, Bonnie Crofts, Overrun, Bovekel, Lacon,* the deep phases of *Bray, Dunbas and Balark*) and other deep, structured, medium to heavy textured soils (*Flagstone, Riverleigh*) have a PAWC >100 mm. Other cracking clay soils and structured loamy to clayey soils have variable PAWC depending on soil depth.

The deep alluvial sandy soils (*Burnett* and *Madoora*) are expected to have a moderate to high PAWC.

The sodic and strongly sodic duplex soils with a medium textured topsoil and a rooting depth of 0.6 m to 1 m (*Auburn, Riverleigh, Panda, Taughboyne, Derrick, Aranear*), the massive gradational soils (*Glenrock, Chessborough*), and the non-sodic duplex soil (*Boyne*) have an estimated PAWC of 75 mm to 100 mm.

The sodic and strongly sodic duplex soils with a medium textured topsoil over a strongly sodic subsoil or rock at <0.6 m (*Beeron, Coonambula, Dillan, Solwig, Ella, Greyfrill*) have an estimated PAWC of 50 mm to 75 mm.

The acid sodic-magnesic duplex soil with a light textured topsoil (*Whiteside*), and coarse sandy soils (*Burnett coarse sandy phase, Brownside*, and *Red Flank*) have a low estimated PAWC.

Although irrigation frequency has been used to determine limitation subclasses, irrigation method has been taken into account. Tree crops, grapes and some small crops use microsprinklers or drip irrigation where small amounts of water are applied frequently. These systems require little effort and labour and therefore, subclass limits do not apply. Actual measurements of PAWC for a wide range of soils in the study area are needed for more accurate information.

Wetness

Excess water in the rooting zone affects production by reducing crop growth and quality. Excess water also influences structural degradation and trafficability, so that reclamation works may be needed.

Drainage classes (McDonald *et al.*, 1990) are assessed and take into account all aspects of internal and external drainage in the existing state. The attributes used to indicate internal drainage include soil colour, mottles, segregations and impermeable layers. Red or brown whole colours indicate well drained soils while mottled grey soils with segregations such as manganiferous nodules, often indicate imperfect drainage. However, on older soils (most soils outside of the recent alluvia), some of these features may be relict, or reflect infrequent saturation. Care is needed in interpreting these features. Slope, topographic position and soil permeability are used to assess the ease of disposal of excess water. Soil permeability is assessed using field texture, type and grade of structure, segregations, pH and ESP. The soils have been placed into the various drainage and permeability classes in their existing state and recorded on the UMA record file.

Crop sensitivity to wetness is the overriding criterion for determining suitability. The limitation subclasses also take into account the depth requirements for the various crops. For example, avocados require a well-drained soil to 1.5 m for optimum production while small crops require a well-drained soil to 0.5 m.

Soil depth

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. Uprooting of trees is particularly a problem on shallow, wet soils during windy conditions.

The effective rooting depth is determined by the depth of soil to rock, hardpan or other impermeable layers (see wetness limitation). Subclasses have been determined through consultation with crop specialists and local producers.

Rockiness

Rock fragments (including gravel and cobble) and bedrock within plough depth 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 for a UMA. Levels of tolerance also vary between farmers and between different agricultural enterprises.

In general, crops which require several cultivations annually and have low harvest heights (chickpeas, navybeans, soybeans) have a low tolerance to rock. Root crops (potato, peanuts) are very sensitive. Horticultural tree crops can tolerate considerable amounts.

The size and amount of coarse fragments, as defined by McDonald *et al*. (1990), were used to determine the subclasses. Rock fragments are consistently a problem on the upper slopes of *Beeron, Boynewood, Bray, Dunbas, Balark, Brogue* and *Dargy* soils.

Erosion control measures should be implemented on sloping soils to reduce the concentration of rock fragments at the surface which occur as a result of soil loss.

Microrelief

Gilgai microrelief, smooth-sided channels, and erosion gullies are three types of microrelief recognised in the study area. Gilgai microrelief will affect the efficiency of irrigation, and the depressions will pond water, causing uneven crop productivity. The depth (vertical interval) of gilgai determines the amount of levelling required. The large gilgai (melonholes) in this area require excessive levelling, resulting in exposure of the strongly sodic and/or saline subsoils of the mounds. This will again result in uneven crop production, at least in the short-term.

The *Derra* soil has large melonhole gilgai which may be as deep as 1.5 m with 15 to 20 m between mounds. The *Durong* soil has typically small gilgai with a depth of 0.1 to 0.3 m and 5 to 10 m between mounds. The sloping brown clays and black clays (*Lacon* soil) may have linear gilgai with a depth of 0.1 to 0.3 m and up to 5 m between mounds. The *Bonnie Crofts* soil has normal gilgai ≤ 0.15 m deep, and the *Overrun linear gilgaied phase* has linear gilgai ≤ 0.05 m deep.
Channelly phases of soils have smooth-sided channels which are usually too deep to cultivate.

Erosion gullies have steep sides and vary from less than 1 m deep to greater than 3 m deep. The eroded phases of soils are generally unsuitable for cultivated cropping.

Local opinion and consultation on the feasibility of levelling microrelief has been used to determine the subclasses.

Soil physical condition

Soil physical properties influence seedbed preparation, plant establishment and the harvest of root crops. The soil physical condition is related to properties such as surface condition, moisture range for working, and adhesiveness (for root crops).

Surface condition of soils will affect seedling emergence and establishment, and root crop development through hardsetting, crusting or coarse structure. Adverse surface condition affects fruiting of peanuts; favourable surface conditions during fruiting are more important for this crop than during seedling establishment as only minimal treatments may be used under a mature crop. Surface condition may be managed for most crops by maintaining moist surface conditions. Emergence and establishment of broad leaf plants are generally more severely affected than other crops. Small crops are usually pre-germinated and seedlings transplanted into the field.

Hardsetting surface soil is evident to varying degrees in the massive gradational soils and most duplex soils, apart from *Whiteside (Wigton Association)*. Weak crusting is evident in all the alluvial cracking clay soils (*Derra, Durong, Bonnie Crofts, Overrun)* and some occurrences of *Lacon, Dargy* and *Brogue*. Crusting is also evident or develops in the alluvial structured loamy to clayey soil *(Flagstone),* and in some cases *Boynewood.* Coarse aggregates in the surface affect seed germination by reducing soil to seed contact area, particularly for small seeded crops and some legume crops. This problem occurs in the alluvial cracking clays and some *Dargy* and *Brogue* soils.

It is desirable that a soil can be cultivated over as wide as possible a range of moisture levels to give some flexibility to the timing of field operations for machinery. Cultivation of the soil at moisture contents below the ideal range results in a coarse seed bed. The effects are more pronounced for land uses where timing of operations is critical for future access to favourable markets. The cracking clays have a narrow range of water content within which they can be tilled effectively. The hardsetting soils and structured loamy and clayey soils have a narrow to moderate moisture range for cultivation.

Adhesive soils affect the extraction and quality of root crops. Root crops ideally require friable soils, so that harvesting machinery can easily lift and remove the crop from the soil. The majority of the massive surfaced soils and clay soils are adhesive to varying degrees.

Secondary salinisation

Changes through clearing and irrigation change the hydrology of the landscape to some extent. Less water is intercepted by trees, and increased percolation of water can cause seepage outbreaks lower down the slope. This excess water can bring salts from the subsoil to the surface resulting in secondary salinisation. This process is exacerbated where very permeable soils occupy upper slope positions and slowly permeable soils occur on lower slopes and valley floors.

Areas where excess water enters the landscape are called recharge areas. Areas where water rises to the surface or close to the surface against an impermeable barrier or change in slope are called discharge areas.

Secondary salinisation is a potential threat to the viability of large scale irrigation development in the area. If watertables, existing or developed, remain close to the surface, evaporation will concentrate salts at the surface by capillary flow. In clay soils in the Emerald Irrigation Area, this occurred when watertables were within about 1.2 m of the soil surface (McDonald and Baker, 1986). The severity of surface salinisation will depend on the period of time that watertables remain close to the surface, the salinity of the water and the amount of salt removed from the site by drainage or crop harvesting. Root zone salinisation may also result.

Preliminary studies in the Red Farm area south of Mundubbera have indicated that seepage water at discharge areas has a similar salinity to the water applied by irrigation on upper slopes (Wilson and Sorby, 1991). This indicates that the underlying geology and the soils are contributing little to the salt levels in that area. The cause of salinisation of a creek flat (*Panda saline phase*) is unclear, but probably involves flushing of salts from somewhere near the discharge area.

Management should involve careful monitoring of the quantity and quality of irrigation water applied to recharge areas. The soils acting as major recharge areas are well drained permeable red massive gradational soils (*Glenrock, Chessborough*), and the structured loamy to clayey soils (*Mulgildie, Neugildie*). These soils are suitable for horticultural purposes. Discharge areas usually occur at the contact between the permeable soils and sodic duplex soils.

A similar situation may occur where the loamy to clayey soils (*Boynewood*) contact the relatively impermeable cracking clays (*Lacon*); it may also occur when the sodic duplex soils (*Beeron*) are located on the slope below *Boynewood.* Salinisation may occur if widespread irrigation is practised on this landscape. The suitability of much of this landscape has been downgraded due to possible secondary salinisation.

The *Wigton Association* on granite and the shallow basalt-derived cracking clays (*Balark, Dunbas* and *Bray*) may behave as recharge areas.

The effect of widespread irrigation on regional watertables is unknown and requires investigation. Salinisation on the level plains or alluvial plains is unlikely unless the watertable rises close to the surface due to excessive irrigation. Irrigation development of large areas of the soils in the study area requires further investigation for potential salinity hazard. Management requires the integrated approach of vegetation retention, irrigation management and engineering works such as drains.

Soil erosion

Erosion results in soil degradation and decline in long-term productivity through the loss of soil, organic matter and nutrients. Soil erosion also causes crop damage, higher working costs, uneven harvest heights and damage caused by silt deposition.

Soil erosion caused by flows of water is related to climatic factors such as amount, distribution and intensity of rainfall, landform factors such as gradient and slope length, soil erodibility, and management practices such as the amount of surface cover. Particular crops such as sunflower provide less vegetative cover at critical periods and hence those areas are at greater risk.

Erosion potential has been determined from slope, soil erodibility and management practices. The slope limits for the soil types and crops are outlined in Appendix 6. Land uses such as horticultural tree crops and pastures have higher slope limits than cultivated crops because of the former's reduced cultivation and the maintenance of ground cover throughout the year.

The well-drained massive and structured loamy to clayey soils have an upper slope limit of 8% for arable agriculture. Cracking clay soils have an upper slope limit of 6% for field crops while the loamy surface duplex soils have an arable slope limit of 1% for most crops.

Furrow irrigation on too steep a gradient can cause significant soil erosion simply from the flow of water. Gradient of the furrow can be decreased by adjusting the furrow direction at an angle to the slope. Over-topping of furrows, especially those with excessive side slopes, can initiate rill erosion. Soil type and slope have been used to determine the suitability for furrow irrigation.

Furrow infiltration

The irrigation system (flood, spray) and field layout (furrow length, slope) should be tailored to the permeability of each soil. For furrow irrigation, long furrow lengths and application times are inappropriate for soils where a significant deep drainage component is likely to occur. This causes excess infiltration, leaching, seepage, wastage of water, and problems with aeration at the head ditch end of the furrows. Furrow irrigation is suitable only on land with gentle slopes (see section on erosion above) and slowly permeable cracking clays and duplex soils. Spray, microsprinklers or drip irrigation should be used on permeable soils and sloping soils for even applications of water, and to minimise deep percolation and thus avoid off-site seepage and watertable rises.

Water quality

Irrigation water will be derived mainly from the Burnett River. Water Resources Group of the Department of Primary Industries has been sampling water from various locations along the river and on nearby major streams. The data in Table 5 summarise pH, electrical conductivity (EC), sodium absorption ratio (SAR) and residual alkali at Mundubbera and Gayndah gauging stations. The comments on water quality which follow Table 5 are based on Gill (1984).

Table 5a. Water quality data, Burnett River at Mundubbera, Queensland, Stn No. 136004A; 8 February 1974 to 3 November 1988

Statistic	pH	EC (dS/m)	SAR	Res. Alk.(mg/L)
No. of samples	108	108	108	108**
Mean	7.793	0.697	2.103	-
Maximum	8.6	1.260	2.829	0.04
Minimum	6.5	0.105	1.294	-
Std Dev.	0.300	0.256	0.354	-
Coeff. Var. %	3.851	36.744	16.847	-
Normal range	7.2-8.4	0.185-1.209	1.395-2.811	

Source: Data from records of State Water Projects, Department of Natural Resources, Bundaberg.
Abbreviations: EC: electrical conductivity. SAR: sodium adsorption ratio. Res. Alk.: residual alkali.
Notes: Statistics are not based on even sampling periods.
Normal range = Mean ± 2 X Std Dev.
Data statistically valid to 3 decimal places because of low Std Dev. and number of samples.
*One extreme value of 6.1 for SAR at Gayndah is statistically an outlier, and its validity is uncertain.
**Negative values of residual alkali not presented.

Table 5b. Water quality data, Burnett River at Gaydah, Queensland, Stn No. 136003B; 28 April 1971 to 3 November 1988

Statistic	**pH**	**EC (dS/m)**	**SAR**	**Res. Alk.(mg/L)**
No. of samples	168	168	167	168**
Mean	7.824	0.816	2.133	-
Maximum	9.4	1.900	3.189*	-
Minimum	6.6	0.150	0.564	-
Std Dev.	0.3754	0.376	0.493	-
Coeff Var. %	4.797	46.116	23.131	-
Normal range	7.074-8.754	0.064-1.568	1.147-3.119	

Source: Data from records of State Water Projects, Department of Natural Resources, Bundaberg.
Abbreviations: EC: electrical conductivity. SAR: sodium adsorption ratio. Res. Alk.: residual alkali.
Notes: Statistics are not based on even sampling periods.
Normal range = Mean ± 2 X Std Dev.
Data statistically valid to 3 decimal places because of low Std Dev. and number of samples.
*One extreme value of 6.1 for SAR at Gayndah is statistically an outlier, and its validity is uncertain.
**Negative values of residual alkali not presented.

Salinity. This is measured as electrical conductivity (EC) which is used as an estimator because it is proportional to salt content. Water at Gayndah and Mundubbera is usually <1.3 dS/m and suitable for all crops except those with very low salt tolerance. Some higher salinity readings at Gayndah cause the water to be suitable only for medium to high salt tolerant crops.

Plots of electrical conductivity versus discharge (Figures 2 and 4) show a curvilinear decline as discharge increases. At high flows, the electrical conductivity drops to a little over 0.1 dS/m at Mundubbera and about 0.2 dS/m at Gayndah. The higher salinity values at Gayndah probably relate to sources of water from salt bearing rock strata in creek catchments. Sections of Reid Creek are known to become saline. (An orchard outside the survey area, which was watered out of one section of the creek, died after being irrigated). However, water in Reid Creek further upstream is of good quality (Water Resources Group, unpublished data).

Sodicity. This is measured by the sodium absorption ratio which predicts the induction of sodicity in soil by continued use of the water (Gill, 1984). Figures 3 and 5 plot SAR against discharge, showing how SAR changes with river flow. Sodium absorption ratios are usually less than 3. This, coupled with low residual alkali, means that there should be no sodium problems from using the river water. There was a single high reading of sodium absorption ratio of 6.1 at Gayndah. It could point to an occasional rare sodium hazard. At high discharges (over 50 to 100 cumecs) sodium absorption ratios at Mundubbera and Gayndah were both low at about 1.5.

Residual alkali. This is measured as the amount of sodium carbonate and bicarbonate in the water. The carbonates from irrigation water combine with exchangeable calcium and magnesium in the soil with precipitation as calcium and magnesium carbonates. This can release sodium which raises the exchangeable sodium levels in the soil. The data calculated for the river water shows that there will be no problems.

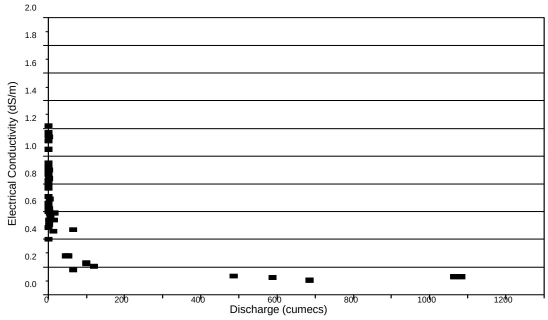

Fig. 2. Electrical conductivity vs discharge, Burnett River Mundubbera, Stn No. 136004A, 8 February 1974 to 3 November 1988.

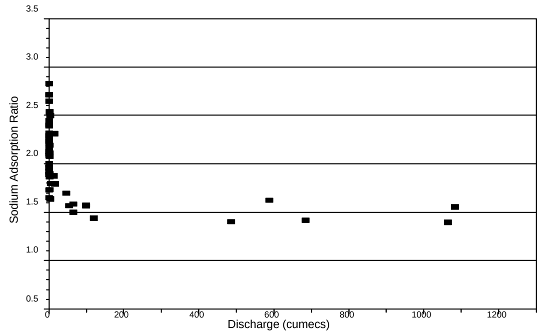

Fig. 3. Sodium absorption ratio vs discharge, Burnett River Mundubbera, Stn No. 136004A, 8 February 1974 to 3 November 1988.

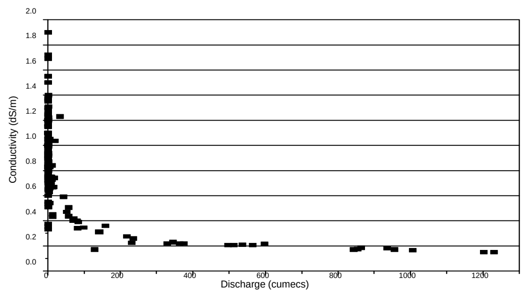

***Fig 4.** Electrical conductivity vs discharge, Burnett River Gayndah, Stn No. 136003B, 28 April 1971 to 3 November 1988.*

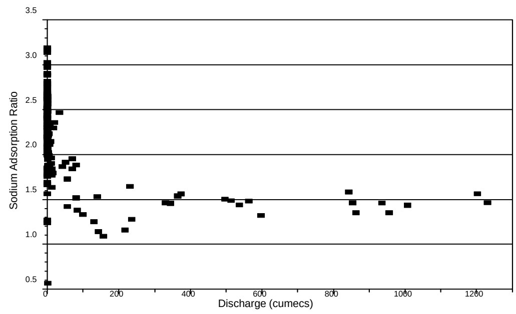

Fig. 5. Sodium absorption ratio vs discharge, Burnett River Gayndah, Stn No. 136003B, 28 April 1971 to 3 November 1988.

Flooding

Flooding is not a major problem in the area and has not been included in the land use limitations. The soils in low lying areas: *Alluvial Complex - lower*; *Alluvial Complex - lower, clays*; and *Flagstone channel bench phase* are subject to flooding.

Preferred land use

Table 6 summarises the total area of each suitability class for each soil mapping unit and each crop.

Burnett, *Flagstone*, *Boyne* and *Glenrock* are the soils suitable for the widest range of crops. The majority of the district's tree crops, small crops and field and grain crops are grown on these soils. The cracking clays and *Boynewood* are soils which are suitable for a wide range of field and grain crops.

Suitability for furrow irrigation was determined on soil and slope attributes only. Crop suitability and furrow irrigation suitability are combined to determine if a crop is suitable for furrow irrigation in a particular area.

Management and development issues

The soils close to the river are being heavily utilised. Extensive areas of other but undeveloped suitable soils are found outside the alluvial areas; these are mainly cracking clay soils, and structured loamy to clayey soils.

Higher pumping costs will be incurred in most new developments because of distance from the river and because of elevation. It may not be feasible to irrigate some plateaux from the river. Bringing new land into production will require careful planning of layouts and development. This survey has defined the areas of potential development. The soils are geographically very complex, so any development will require closer examination of the land to ensure that sufficient area of suitable soil exists at the particular site.

The potential for salinisation may affect development in the survey area. Widespread irrigation development may cause seepage downslope with localised or general rises in watertables where more permeable soils contact with less permeable soils or other barriers. There is evidence of minor seepage occurring even under rainfed cropping.

Table 6 has been based on individual mapping units (UMAs), so that maps of areas with particular problems, such as intake areas, can be computer generated. Management details for individual crops are not discussed in this report, however it is emphasised that internal drainage and soil depth are critical to many crops.

Table 6. Areas of land suitability classes for crops in each mapping unit of the Burnett River Riparian Lands, Mundubbera to Gayndah, Qld

Mapping Unit	Land Suit Class	Aspar agus	Avo- cado	Chick pea	Citrus	Crucif- erae	Cucur bit	Grape	Lucerne	Mango	Mung -bean	Navy- bean	Pasture	Peanut	Pecan	Potato	Saf- flower	Soya- bean	Stone- fruit	Summer grain	Sun- flower	Vege- tables	Winter grain
Alluvial complex-higher	1							25					25										
	2	25				25	25	31				25				25			14			25	
	3			14	14				14		14		70	56	14		56	56		56	56		56
	4	70		81	86	70	70	39	81		81	70		39	86	70	39	39	86	39	39	70	39
	5	122	217	122	117	122	122	122	122	217	122	122	122	122	117	122	122	122	117	122	122	122	122
Alluvial complex-lower	1												158										
	2												114										
	3																						
	4												38										
	5	392	392	392	392	392	392	392	392	392	392	392	82	392	392	392	392	392	392	392	392	392	392
Alluvial complex-lower, cracking clays	1												101										
	2												101										
	3												8										
	4																						
	5	529	529	529	529	529	529	529	529	529	529	529	319	529	529	529	529	529	529	529	529	529	529
Aranear	1																						
	2																						
	3												94										
	4							94															
	5	94	94	94	94	94	94		94	94	94	94		94	94	94	94	94	94	94	94	94	94
Auburn	1																						
	2												67										
	3	213				213	213					27	911									213	
	4	394				394	394	1156				253	178	280		280						394	
	5	549	1156	1156	1156	549	549		1156	1156	1156	876		876	1156	876	1156	1156	1156	1156	1156	549	1156
Auburn, channelly phase	1																						
	2																						
	3																						
	4																						
	5	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Auburn, eroded phase	1																						
	2																						
	3																						
	4							22					22										
	5	44	44	44	44	44	44	22	44	44	44	44	22	44	44	44	44	44	44	44	44	44	44
Auburn, red subsoil variant	1																						
	2																						
	3												52										
	4							68					16										
	5	68	68	68	68	68	68		68	68	68	68		68	68	68	68	68	68	68	68	68	68
Balark	1												276										
	2												296										
	3	533				533	533						188				572	533		572	572	533	533
	4	227		533	760	227	227	760	760		572	533		533	760	533		39	760	188		227	227
	5		760	227						760	188	227		227		227	188	188			188		
Balark, steep phase	1																						
	2																						
	3																						
	4																						
	5	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Beeron	1																						
	2																						
	3												297										
	4	45				45	45	1527					1230									45	
	5	1514	1559	1559	1559	1514	1514	32	1559	1559	1559	1559	32	1559	1559	1559	1559	1559	1559	1559	1559	1514	1559

Table 6, continued

Mapping Unit	Land Suit Class	Aspar agus	Avo-cado	Chick pea	Citrus	Crucif-erae	Cucur bit	Grape	Lucerne	Mango	Mung -bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Saf-flower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Beeron, deep surface phase	1																						
	2																						
	3							32					32										
	4																						
	5	32	32	32	32	32	32		32	32	32	32		32	32	32	32	32	32	32	32	32	32
Beeron, eroded phase	1																						
	2																						
	3												3										
	4							73					70										
	5	159	159	159	159	159	159	86	159	159	159	159	86	159	159	159	159	159	159	159	159	159	159
Beeron, rocky phase	1																						
	2																						
	3																						
	4							109					32										
	5	117	117	117	117	117	117	8	117	117	117	117	85	117	117	117	117	117	117	117	117	117	117
Belrose	1																						
	2																						
	3							6					6										
	4	6			6	6	6		6						6				6	6		6	6
	5		6	6						6	6	6		6		6	6	6			6		
Bonnie Crofts	1												24										
	2												334										
	3	333				333	333					319	24				319	319		333	319	333	333
	4	49		382	382	49	49	382	382		382	63		382	382	382	63	63	382	49	63	49	49
	5		382							382													
Bovekel	1												136										
	2												276										
	3	412				412	412					191	64			10	327	327		412	327	412	412
	4	64		433	476	64	64	476	476		433	242		433	476	423	106	106	476	64	106	64	64
	5		476	43						476	43	43		43		43	43	43			43		
Bovekel, eroded phase	1																						
	2																						
	3																						
	4	12				12	12	12					12									12	
	5		12	12	12				12	12	12	12		12	12	12	12	12	12	12	12		12
Boyne	1							97															
	2			89				115	97		89		212	89			89	89	123	97	89		89
	3	97		8	150	97	97	27			8	97	27	8	150	97	8	8	27		8	97	
	4	115			89	115	115		115						89				89	115		115	115
	5	27	239	142		27	27		27	239	142	142		142		142	142	142		27	142	27	27
Boynewood	1							415					172										
	2	350				350	350	1428	350	63			1671						969	415		350	350
	3	1434	292	350	1247	1434	1434		953	229	415	350		350	1247	350	415	415	278	1428	415	1434	1434
	4	59		1434	596	59	59		540	596	1428	1434		1434	596	1434	1428	1428	596		1428	59	59
	5		1551	59						955		59		59		59							
Boynewood, eroded phase	1																						
	2							60											60				
	3				60								60		60								
	4	60				60	60				60	60				60	60			60	60	60	60
	5		60	60					60	60				60				60					
Boynewood, rocky phase	1							62					62										
	2							43					43						62				
	3	13			112	13	13	7	13				7		112		62		50	75	62	13	13
	4	62		13	108	62	62	108	62		75	13		13	108	13	32	75	108	30	43	62	62
	5	163	238	225	18	163	163	18	163	238	163	225	126	225	18	225	133	163	18	133	133	163	163

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chickpea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung-bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Safflower	Soyabean	Stonefruit	Summer grain	Sunflower	Vegetables	Winter grain
Boynewood, steep phase	1																						
	2							67					67						60				
	3	67			127	67	67	60	60				60		127				67	67		67	67
	4	60		67		60	60		67		67	67		67		67	67	67		60	67	60	60
	5		127	60						127	60	60		60		60	60	60			60		
Bray	1																						
	2												278										
	3	278				278	278										24	24		278	24	278	278
	4			278	278			278	278		278	278		278	278	278	254	254	278		254		
	5		278							278													
Bray, deep phase	1																						
	2												28										
	3																						
	4	28		28	28	28	28	28	28		28	28		28	28	28	28	28	28	28	28	28	28
	5		28							28													
Brogue	1																						
	2												107										
	3	107				107	107					88	50			88	88			107	88	107	107
	4	50		107	157	50	50	157	157		107	19		107	157	19	19	107	157	50	19	50	50
	5		157	50						157	50	50		50		50	50	50			50		
Brogue, rocky phase	1																						
	2												25										
	3																						
	4							25															
	5	25	25	25	25	25	25		25	25	25	25		25	25	25	25	25	25	25	25	25	25
Brogue, steep phase	1																						
	2																						
	3												49										
	4	49			49	49	49	49	49						49				49	49		49	49
	5		49	49						49	49	49		49		49	49	49			49		
Brownside	1																						
	2																						
	3		5		5			5		5					5				5				
	4	5				5	5		5				5							5		5	5
	5			5							5	5		5		5	5	5			5		
Burnett	1							614							611			19	611				
	2			19					560		19		560	19			19	541	3	560	19		560
	3	560		541	537	560	560				541	560		541	3	560	541	43			541	560	
	4	54		54	77	54	54		54		54	54	54	54		54	54			54	54	54	54
	5		614							614													
Burnett, coarse sandy phase	1							12							12				12				
	2																						
	3							31	31				31		31				31			31	
	4	43		43	43	43	43		12		43	43	12	43		43	43	43		43	43	12	43
	5		43							43													
Burnett, shallow phase	1							221															
	2			12					52		12		163	12			12	12	129	163	12		163
	3	221		151	129	221	221		111		151	221	58	209	129	221	209	209		58	209	221	58
	4			58	22				58		58				22				22				
	5		221		70					221					70				70				
Chessborough	1				12			95							12				12				
	2		12					17	95	112			112						100	95			95
	3	112	123	95	123	112	112	23	17	23	95	95	23	95	123	95	95	95	23	17	95	112	17
	4	23		17		23	23		23		17	17		17		17	17	17		23	17	23	23
	5			23							23	23		23		23	23	23			23		

Table 6, continued

Mapping Unit	Land Suit Class	Aspar agus	Avo-cado	Chick pea	Citrus	Crucif-erae	Cucur bit	Grape	Lucerne	Mango	Mung -bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Saf-flower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Chessborough, rocky phase	1							9															
	2																						
	3																						
	4	9	5		14	9	9	5	9	5	9		9		14		9	9	14	9	9	9	9
	5	5	9	14		5	5		5	9	5	14	5	14		14	5	5		5	5	5	5
Chessborough, rubbly, rocky & stony phase	1																						
	2																						
	3																						
	4				41			41		41			41		41				41				
	5	41	41	41		41	41		41		41	41		41		41	41	41		41	41	41	41
Coonambula	1																						
	2																						
	3												224										
	4	228				238	238	314				19	90	19		19						238	
	5	235	473	473	473	235	235	159	473	473	473	454	159	454	473	454	473	473	473	473	473	235	473
Coonambula-Beeron complex	1																						
	2																						
	3																						
	4							23					23										
	5	23	23	23	23	23	23		23	23	23	23		23	23	23	23	23	23	23	23	23	23
Coonambula, eroded phase	1																						
	2																						
	3																						
	4																						
	5	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Dam	1																						
	2																						
	3																						
	4																						
	5	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Dargy	1																						
	2												220										
	3	220				220	220					156					156			220		220	220
	4			220	220			220	220		220	64		220	220	220	64	220	220		156		
	5		220							220											64		
Derra	1																						
	2																						
	3																						
	4																						
	5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Derra, rocky phase	1																						
	2																						
	3																						
	4																						
	5	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Derrick	1							5															
	2							85					81						5				
	3	140		5	5	140	140		5		5	56	72	5	5	56	5	5		39	5	140	39
	4	13		34	34	13	13	63	34	34	34	84		135	34	84	34	34	34		34	13	
	5		153	114	114				114	119	114	13		13	114	13	114	114	114	114	114		114
Derrick, steep and broken phase	1																						
	2																						
	3																						
	4																						
	5	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chick pea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung-bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Safflower	Soyabean	Stonefruit	Summer grain	Sunflower	Vegetables	Winter grain
Dillan	1																						
	2																						
	3												123										
	4	205				205	205	205					82									205	
	5	11	216	216	216	11	11	11	216	216	216	216	11	216	216	216	216	216	216	216	216	11	216
Drape	1																						
	2												849										
	3	849				849	849					849					849	734		849	849	849	849
	4			849	849			849	849		849			849	849	849		115	849				
	5		849							849													
Dunbas	1																						
	2												136										
	3					136	136						51				12	12		136	12	136	136
	4	136		136	187	51	51	187	187		136	136		136	187	136	124	124	187	51	124	51	51
	5	51	187	51						187	51	51		51		51	51	51			51		
Dunbas, deep phase	1																						
	2												49										
	3	6				6	6	6					165							6		6	6
	4	208		214	214	208	208	208	214		214	214		214	214	214	214	214	214	208	214	208	208
	5		214							214													
Dunbas, steep phase	1																						
	2																						
	3																						
	4																						
	5	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Durong	1																						
	2																						
	3	10				10	10						21				10	10		10	10	10	10
	4	11		21	21	11	11	21	21		21	21		21	21	21	11	11	21	11	11	11	11
	5		21							21													
Ella	1																						
	2																						
	3							17					17										
	4	17				17	17	49					49									17	
	5	61	78	78	78	61	61	12	78	78	78	78	12	78	78	78	78	78	78	78	78	61	78
Fison	1							25															
	2			25				177	25		25		75	25			25	25		25	25		25
	3	75				75	75	286				25	413	127		25	413	413		463	413	75	463
	4	413		463	413	413	413		463	488	463	463		336	413	463	50	50	413		50	413	
	5		488		75										75				75				
Fison, rocky phase	1																						
	2																						
	3							3															
	4				3								3		3		3		3	3	3		
	5	3	3	3		3	3		3	3	3	3		3		3		3				3	3
Flagstone	1							239					6							164			
	2	242		178		242	242	173	239		178	164	406	31		164	178	14	257	92	178	242	256
	3	170		78	237	170	170		173		78	92		225	257	92	78	242		156	78	170	156
	4			156	175						156	156		156	155	156	156	156	155		156		
	5		412							412													
Flagstone, channel-bench phase	1																						
	2												16			16	16					16	16
	3																	16					
	4				16			16	16					16	16				16				
	5	16	16	16		16	16			16	16	16								16	16		

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chick pea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung-bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Safflower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Flagstone, channelly phase	1																						
	2																						
	3																						
	4				35										35				35				
	5	59	59	59	24	59	59	59	59	59	59	59	59	59	24	59	59	59	24	59	59	59	59
Glenrock	1				31			35							35				35				
	2		74	31	43			43	31	74	31		74	31	43		31	31	43	31	31		31
	3	74			4	74	74		43			31				31				43		74	43
	4	4		47		4	4		4		47	47	4	47		47	47	47		4	47	4	4
	5		4							4													
Glenrock, grey variant	1																						
	2																						
	3												10										
	4	10		10	10	10	10	10	10	10	10	10		10	10	10	10	10	10	10	10	10	10
	5		10																				
Greyfrill	1																						
	2																						
	3																						
	4	64				64	64	72					72									64	
	5	8	72	72	72	8	8		72	72	72	72		72	72	72	72	72	72	72	72	8	72
Greyfrill, eroded phase	1																						
	2																						
	3																						
	4																						
	5	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Hills	1																						
	2																						
	3																						
	4																						
	5	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763	14763
Jedda	1																						
	2												150										
	3	60				60	60	60				60					60	60		60	60	60	60
	4	90		150	150	90	90	90	150		150	90		150	150	150	90	90	150	90	90	90	90
	5		150							150													
Kinburn	1																						
	2																						
	3																						
	4	12				12	12	106					106									12	
	5	94	106	106	106	94	94		106	106	106	106		106	106	106	106	106	106	106	106	94	106
Kinburn, eroded phase	1																						
	2																						
	3																						
	4																						
	5	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Lacon	1																						
	2												334					201					
	3	304				304	304					245	58				304	161		304	304	304	304
	4	88		362	392	88	88	392	362		392	147		362	392	392	88	30	392	88	88	88	88
	5		392	30					30	392				30									
Lacon, eroded phase	1																						
	2																						
	3																						
	4	12				12	12	12					12									12	
	5	4	16	16	16	4	4	4	16	16	16	16	4	16	16	16	16	16	16	16	16	4	16

Table 6, continued

Mapping Unit	Land Suit Class	Aspar agus	Avo-cado	Chick pea	Citrus	Crucif-erae	Cucur bit	Grape	Lucerne	Mango	Mung -bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Saf-flower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Lacon, rocky phase	1																						
	2																						
	3												36										
	4				36			36							36				36				
	5	36	36	36		36	36		36	36	36	36		36		36	36	36		36	36	36	36
Madoora	1							30							30				30				
	2			30					30		30		30	30			30	30		30	30		30
	3	30			30	30	30					30				30						30	
	4																						
	5		30							30													
Mulgildie	1				137			137							137				137				
	2		191	84	54			54	137	191	84		191	84	54		84	84	54	137	84		137
	3	191		53		191	191		54		53	137		53		137	53	53		54	53	191	54
	4			54							54	54		54		54	54	54			54		
	5																						
Mulgildie, eroded phase	1																						
	2																						
	3																						
	4																						
	5	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Mulgildie, rocky phase	1																						
	2		18		18			18		18			18		18				18				
	3																			18			
	4	18				18	18		18		18						18	18			18	18	18
	5			18								18		18		18							
Mulgildie, snuffy variant	1				111			111							111				111				
	2		121		10			10	111	121			121		10				10	111			111
	3	121		111		121	121		10		111	111		111		111	111	111		10	111	121	10
	4			10							10	10		10		10	10	10			10		
	5																						
Neugildie	1							163					163							80			80
	2	151		80		151	151		151	92	80	80		80		80	80	80	163	83	80	151	71
	3	12	92	71	163	12	12		12		83	71		71	163	71	83	83			83	12	12
	4			12								12		12		12							
	5		71							71													
Neugildie, coluvial, clayey variant	1												66										
	2							27					27										
	3	27				27	27													27		27	27
	4	66		93	93	66	66	66	93		93	93		93	93	93	93	93	93	66	93	66	66
	5		93							93													
Neugildie, eroded phase	1																						
	2																						
	3																						
	4	29		29	29	29	29	29	29		29	29	29	29	29	29	29	29	29	29	29	29	29
	5		29							29													
Neugildie, saline phase	1																						
	2																						
	3																						
	4																						
	5	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Overrun	1																						
	2												9										
	3	9				9	9					9					9	9		9	9	9	9
	4			9	9			9	9		9			9	9	9			9				
	5		9							9													

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chick pea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung-bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Safflower	Soyabean	Stonefruit	Summer grain	Sunflower	Vegetables	Winter grain
Overrun, linear-gilgaied phase	1																						
	2												53										
	3	53				53	53					53					53	53		53	53	53	53
	4			53	53			53	53		53			53	53	53			53				
	5		53							53													
Panda	1																						
	2												13										
	3																						
	4	13		13	13	13	13	13	13		13	13		13	13	13	13	13	13	13	13	13	13
	5		13							13													
Panda, saline phase	1																						
	2																						
	3																						
	4												13										
	5	13	13	13	13	13	13	13	13	13	13	13		13	13	13	13	13	13	13	13	13	13
Pedimentary soils	1																						
	2							22		22			22						22				
	3		22		22										22								
	4																22			22	22		
	5	22		22		22	22		22		22	22		22		22		22				22	22
Platter	1																						
	2												38										
	3	38				38	38					38					38	38		38	38	38	38
	4			38	38			38	38		38			38	38	38			38				
	5		38							38													
Quarry	1																						
	2																						
	3																						
	4																						
	5	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Red Flank	1																						
	2							38											38				
	3				68			30							68				30				
	4	68		38		68	68		68		38	38	68	38		38	38	38		68	38	68	68
	5		68	30						68	30	30		30		30	30	30			30		
Riverleigh	1																						
	2							35														235	
	3	235				235	235						555							174		256	174
	4	256		214	207	256	256	513	322		214	275		275	207	275	214	214	207	148	214	86	148
	5	86	577	363	370	86	86	29	255	577	363	302	22	302	370	302	363	363	370	255	363		255
Riverleigh, clayey variant	1																						
	2												8										
	3	15				15	15					15	7				15	15		15	15	15	15
	4			15	8			15	15		15			15	8	15			8				
	5		15		7					15					7				7				
Riverleigh, eroded phase	1																						
	2																						
	3												29										
	4	29				29	29	29														29	
	5		29	29	29				29	29	29	29		29	29	29	29	29	29	29	29		29
Rock	1																						
	2																						
	3																						
	4																						
	5	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chick pea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung-bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Saf-flower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Solwig	1																						
	2																						
	3																						
	4	113				113	113	126					126									113	
	5	13	126	126	126	13	13		126	126	126	126		126	126	126	126	126	126	126	126	13	126
Solwig, eroded phase	1																						
	2																						
	3																						
	4																						
	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Stratfield	1																						
	2							50					42						8	8			
	3	50		8		50	50		50		8	8	8	8	8	8	8	8		42	8	50	50
	4			42	50						42	42		42	42	42	42	42	42		42		
	5		50							50													
Stream Channel	1																						
	2																						
	3																						
	4																						
	5	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
Tank	1																						
	2																						
	3																						
	4																						
	5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Taughboyne	1																						
	2																						
	3												319										
	4	107				107	107	319														107	
	5	218	325	325	325	218	218	6	325	325	325	325	6	325	325	325	325	325	325	325	325	218	325
Taughboyne, eroded phase	1																						
	2																						
	3												11										
	4							11															
	5	11	11	11	11	11	11		11	11	11	11		11	11	11	11	11	11	11	11	11	11
Treatment Works	1																						
	2																						
	3																						
	4																						
	5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Urban	1																						
	2																						
	3																						
	4																			766			
	5	766	766	766	766	766	766	766	766	766	766	766	766	766	766	766	766	766	766		766	766	766
Wigton Association	1																						
	2							648															
	3							1260					2006										
	4	2023				2023	2023	115				763	17	763		763						2023	
	5		2023	2023	2023				2023	2023	2023	1260		1260	2023	1260	2023	2023	2023	2023	2023		2023
Wigton Association, eroded phase	1																						
	2																						
	3																						
	4																						
	5	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62

Table 6, continued

Mapping Unit	Land Suit Class	Asparagus	Avocado	Chick pea	Citrus	Cruciferae	Cucurbit	Grape	Lucerne	Mango	Mung -bean	Navy-bean	Pasture	Peanut	Pecan	Potato	Saf-flower	Soya-bean	Stone-fruit	Summer grain	Sun-flower	Vege-tables	Winter grain
Wigton Association, steep phase	1																						
	2																						
	3				92			92											92				
	4	92				92	92		92				92		92					92		92	92
	5	219	311	311	219	219	219	219	219	311	311	311	219	311	219	311	311	311	219	219	311	219	219
Wigton Association, steep and broken phase	1																						
	2																						
	3																						
	4																						
	5	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248
	1							2					2							2			2
Wivenhoe	2	2		2		2	2		2		2	2				2	2	2			2	2	
	3													2									
	4				2										2				2				
	5		2							2													
Yondilla	1																						
	2							15					15										
	3	15				15	15													15		15	15
	4			15	15				15		15	15		15	15	15	15	15	15		15		
	5		15							15													
Total	1	0	0	0	291	0	0	2297	0	0	0	0	1191	0	948	0	0	0	948	246	0	0	82
	2	770	416	550	125	770	770	3156	1880	693	550	258	7431	401	125	287	566	386	2145	2847	550	786	1942
	3	7220	534	1485	3137	7220	7220	1885	1553	257	1562	3934	6239	1861	2616	1982	4973	4590	596	6144	4973	7251	6051
	4	5831	102	6922	6934	5831	5831	9678	6547	783	7122	6066	2492	7917	6417	8018	3766	4184	6433	1872	3766	5800	1995
	5	23079	35848	27943	26413	23079	23079	19884	26920	35167	27666	26642	19547	26719	26794	26613	27595	27740	26778	26791	27611	23063	26830

Notes: Suitability data for Furrow Irrigation is not included.

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APPENDIX 1

GENERAL RATINGS USED FOR INTERPRETATION OF SOIL CHEMICAL ANALYSES

Analysis	Units	Very Low	Low	Medium	High	Very High
EC	dS/m	<0.15	0.15-0.45	0.45-0.90	0.90-2.0	>2.0
Cl	%	<0.01	0.01-0.03	0.03-0.06	0.06-0.20	>0.20
P_A	µg/g	<10	10-20	20-40	40-100	>100
P_B	µg/g	<10	10-20	20-40	40-100	>100
Exch. K	meq./100g	<0.1	0.1-0.2	0.2-0.5	0.5-1.0	>1.0
Ext. K	meq./100g	<0.1	01.-0.2	0.2-0.5	0.5-1.0	>1.0
Cu	µg/g	<0.1	0.1-0.3	0.3-5	5-15	>15
Zn						
pH >7:	µg/g	<0.3	0.3-0.8	0.8-5	5-15	>15
pH <7:	µg/g	<0.2	0.2-0.5	0.5-5	5-15	>15
Mn	µg/g	<1	1-2	2-50	50-500	>500
B	µg/g	<0.5	0.5-1	1-2	2-5	>5
Total N	%	<0.05	0.05-0.15	0.15-0.25	0.25-0.50	>0.50
Org. C	%	<0.5	0.5-1.5	1.5-2.5	2.5-5.0	>5.0
SO_4-S	µg/g	<5	5-10	10-20	20-100	>100
Total S	%	<0.005	0.005-0.02	0.02-0.05	0.05-0.10	>0.10
Total P	%	<0.005	0.005-0.02	0.02-0.05	0.05-0.10	>0.10
Total K	%	<0.1	0.1-0.5	0.5-1	1-3	>3
Exch. Ca	meq./100 g		<2			
Exch. Mg	meq./100g		<2			
Sodicity (ESP)	(Na/CEC)%	Non-Sodic < 6	Sodic 6-14	Strongly Sodic ≥ 15		

Sources: R.C. Bruce and G.E. Rayment (1982). *Analytical methods and interpretations used by Agricultural Chemistry Branch for soil and land use surveys*. Queensland Department of Primary Industries, Bulletin QB82004.

Exchangeable Ca and Mg ratings from page 39 of D.E. Baker and V.J. Eldershaw (1993). *Interpreting soil analyses for agricultural land use in Queensland* Department of Primary Industries, Queensland, Project Report QO93014.

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APPENDIX 2

MORPHOLOGICAL AND CHEMICAL DATA FROM SOIL SAMPLE SITES, RIPARIAN SOILS, MUNDUBBERA TO GAYNDAH

Soil Profile Description *Bovekel*

Soil Type: Bovekel
Soil Survey and Site No.: MGR S1
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: 6.7 km from Gayndah along the southern river road toward Mundubbera; 250 m north-west by west of road in farm paddock.
Australian Map Grid Reference: 354 350 m E, 7 164 490 m N; ZONE 56
Sampled and described by: Richard J. Tucker; 25 September, 1991.

Map Unit: Bovekel (Bk)
Australian Soil Classification: Epicalcareous self-mulching Black Vertosol; non-gravelly, very fine/very fine, very deep.
Great Soil Group: black earth.
Principal Profile Form: Ug5.15
Soil Taxonomy Subgroup: Typic Haplotorrert.
Landform Element: plain
Landform Pattern: plain
Geology: basalt.
Slope: 7%
Microrelief: nil.

Vegetation: cleared.
Rainfall: mean 772 mm, range 339 mm - 1468 mm, coeff. var. 27%, summer dominant (Gayndah).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: moderately rapid.
Permeability: slowly permeable.
Drainage: imperfectly drained.
Land Use: rainfed cropping.
Surface Coarse Fragments: very few cobbles, subangular tabular basalt, strong.
Condition of Surface (Dry): recently cultivated (commonly strongly cracking and self-mulching).

HORIZON	DEPTH	DESCRIPTION
Ap	0 to .10 m	Dark (7.5YR3/2); medium heavy clay; moderate 5-10mm granular parting to moderate 2-5mm granular; dry; moderately firm; few <1mm roots. Clear to-
B21	.10 to 1.10 m	Dark (7.5YR3/1); medium heavy clay; very few large pebbles, subangular tabular basalt, moderately strong; strong 20-50mm lenticular parting to moderate 5-10mm lenticular; moderately moist; very firm; very few coarse calcareous nodules; few <1mm roots. Diffuse to-
B22k	1.10 to 1.50 m	Red-brown (5YR3/3); medium heavy clay; moderate 20-50mm prismatic parting to moderate 5-10mm lenticular; moderately moist; moderately firm; few coarse calcareous nodules.

Notes: Samples taken from two cores.

Soil Analytical Data *Bovekel*

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size CF	FS	S	C % @ 105C	Exch. Cations CEC	Ca	Mg	Na	K m.eq/100 g @ 105C	Total Elements P	K	S % @ 80C	Moisture ADM	33*	1500* % @ 105C	Disp. Ratio R1R2 @ 40C	pH CaC12 @ 40C
B 0.10	7.8	.10	.002																	7.0
0.10	8.0	.13	.009	3	14	13	71	73	44	30	.85	.41	.102	.295	.028	11.6		28	.34	7.2
0.20	8.0	.14	.009																	7.2
0.30								75	42	33	1.4	.33	.099	.290	.026	11.2		30		
0.40	8.4	.08	.002																	7.3
0.50	8.5	.08	.002																	7.3
0.60	8.6	.07	.002					75	38	41	2.7	.33	.097	.298	.022	10.8		30		
0.70	8.6	.11	.006																	7.4
0.80	8.7	.15	.008																	7.6
0.90								73	28	45	3.6	.36	.093	.297	.020			32		
1.00	8.7	.20	.013																	7.7
1.10	8.7	.24	.015																	7.7
1.20	8.8	.22	.015	2	15	17	68	73	23	47	4.1	.31	.100	.309	.014	9.10				7.8
1.30	8.8	.26	.015																	7.8
1.40	8.9	.27	.015																	7.9
1.50	8.8	.25	.016																	7.8

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid mg/kg @ 105C	Bicarb	HC1 K meq% @ 105C	CaC12 Extr K mg/kg @ 105C	P	DTPA - extr Fe mg/kg @ 105C	Mn	Cu	Zn	B
B 0.10	1.5	.11		37	.88			29	54	4.0	.55	

Upper Lower depth depth meters	Horizon	pH KC1 SP1 @ 40C	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10					0.35					
0.00-0.10					0.20					
0.10-0.20					1.42					
0.20-0.30					0.03					
0.30-0.40					0.23					
0.40-0.50					0.10					
0.50-0.60					0.04					
0.60-0.70					0.25					
0.70-0.80					1.09					
0.80-0.90					4.70					
0.90-1.00					3.02					
1.00-1.10					6.47					
1.10-1.20					5.04					
1.20-1.30					5.09					
1.30-1.40					5.17					
1.40-1.50					3.43					

Notes: * .33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus om ground sample.
Insufficient sample for some particle size analyses.
Cation method: alcoholic NH_4Cl at pH 8.5
CEC method: alcoholic NH_4Cl at pH 8.5

Soil Profile Description *Bonnie Crofts (mound)*

Soil Type: Bonnie Crofts (mound)
Soil Survey and Site No.: MGR S2A
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: From Mundubbera toward Gayndah on southern river road; 2.1 km past junction with Glenrae road to crossroads; 1.28 km down lane to north; on right side of lane.
Australian Map Grid Reference: 332 880 mE 7 167 050 mN ZONE 56
Sampled and described by: Richard J. Tucker; 9 October 1991.

Map Unit: Bonnie Crofts (Bc)
Australian Soil Classification: Epicalcareous-Endo-hypersodic, self-mulching, Grey Vertosol; non-gravelly, fine/medium-fine, very deep.
Great Soil Group: grey clay
Principal Profile Form: Ug5.29
Soil Taxonomy Subgroup: Sodic Haplotorrert
Landform Element: plain
Landform Pattern: stagnant alluvial plain
Geology: Quaternary alluvium (Pleistocene?)
Slope: 0.25%
Microrelief: Normal gilgai, vertical interval 0.1 m, horizontal interval 15 m.

Vegetation: Mid-high open forest; *Eucalyptus populnea, Dichanthium* ? species, *Aristida* species.
Rainfall: mean 709 mm, range 299 mm - 1229 mm, coeff. var. 28%, summer dominant (Mundubbera).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow
Permeability: slowly permeable
Drainage: imperfectly drained
Land Use: road reserve
Surface Coarse Fragments: few small to medium nodules of calcium carbonate; see notes.
Condition of Surface (Dry): periodic cracking, self-mulching.

HORIZON	DEPTH	DESCRIPTION
A11	0 to .03 m	Grey (2.5Y4/1); medium clay; very few small pebbles, subrounded quartz, very few small pebbles, subrounded platy metamorphic rock (unidentified); weak 5-10mm subangular blocky parting to moderate 2-5mm granular; dry; moderately firm; very few medium calcareous nodules; common <1mm roots. Abrupt to-
A12	.03 to .10 m	Grey (2.5Y4/1); medium clay; weak 20-50mm subangular blocky parting to strong 5-10mm subangular blocky; dry; moderately strong; very few medium calcareous nodules; common <1mm roots. Clear to-
B21	.10 to .80 m	Grey (2.5Y4/1); medium clay; strong 20-50mm lenticular parting to moderate 5-10mm lenticular; common distinct slickensides; moderately strong; few medium calcareous nodules, very few very coarse calcareous soft segregations; few <1mm roots. Gradual to-
B22k	.80 to 1.40 m	Yellow-brown (10YR6/4); medium clay; very few small pebbles, subangular metamorphic rock (unidentified); moderate 20-50mm lenticular parting to moderate 5-10mm lenticular; common faint slickensides; dry; moderately strong; few medium calcareous nodules, very few coarse calcareous soft segregations, very few very coarse calcareous nodules, very few medium ferromanganiferous nodules, very few medium argillaceous tubules; no roots.
B23	1.40 to 1.50 m	Yellow-brown (10YR6/4); medium clay; moderate 20-50mm lenticular parting to moderate 5-10mm lenticular; dry; moderately strong; very few medium calcareous nodules, very few fine ferromanganiferous nodules, very few medium argillaceous tubules.

Notes: Patches of common to many, 6-20 mm nodules of calcium carbonate on surface; patches ≤ 1m x 1m. Some tendency to prismatic structure in B21, B23 horizons. Weak self mulch.
Samples taken from four cores.
Samples taken 0.0-0.03 m; 0.03-0.01 m; then by 0.1 m intervals.

Soil Analytical Data

Bonnie Crofts (mound)

Depth Meters	1:5 Soil/Water pH @ 40C	EC ds/m @ 40C	Cl % 105C	Particle size CF % @ 105C	FS % @ 105C	S % @ 105C	C % @ 105C	Exch. Cations CEC m.eq/100 g @ 105C	Ca	Mg	Na	K	Total Elements P % @ 80C	K	S	Moisture ADM % @ 105C	33*	1500*	Disp. Ratio R1 @ 40C	R2	pH CaC12 @ 40C
B 0.10	8.1	.16	.003																		7.3
0.03	8.1	.13	.004	12	35	12	42	31	20	9.4	.27	1.6	.050	.676	.052	4.10		16	.26		7.2
0.10	8.6	.13	.004	9	32	11	50	34	23	13	1.1	1.0	.037	.561	.038	5.00		18	.36		7.6
0.20	8.9	.27	.013																		7.8
0.30	9.0	.34	.023	8	31	12	54	34	18	16	3.1	.46	.028	.477	.025	6.00		19	.45		
0.40	8.9	.64	.041																		7.9
0.50	8.9	.64	.061																		8.0
0.60	8.9	.74	.073	9	29	10	53	33	13	18	5.0	.34	.025	.479	.037	4.50		18	.55		8.0
0.70	9.1	.79	.079																		8.0
0.80	9.1	.80	.080																		8.1
0.90	9.2	.81	.079	9	29	10	50	30	10	18	5.1	.35	.025	.490	.034	4.70		18	.68		8.1
1.00	9.2	.79	.076																		8.2
1.10	9.2	.78	.074																		8.2
1.20	9.2	.75	.071	9	29	10	51	29	9.4	17	4.8	.30	.026	.498	.037	4.00					8.2
1.30	9.2	.74	.071																		8.2
1.40	9.2	.73	.070																		8.2
1.50	9.2	.72	.068																		8.2

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid mg/kg @ 105C	Bicarb mg/kg @ 105C	HC1 K meq% @ 105C	CaC12 Extr K mg/kg @ 105C	P mg/kg @ 105C	DTPA - extr Fe mg/kg @ 105C	Mn	Cu	Zn	B
B 0.10	1.8	.16		9.5	1.2			15	13	1.3	1.1	

Upper Lower depth depth meters	Horizon	pH KC1 @ 40C	SP1	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10						1.54					
0.00-0.03						2.23					
0.03-0.10						1.13					
0.10-0.20						0.75					
0.20-0.30						1.34					
0.30-0.40						3.47					
0.40-0.50						2.31					
0.50-0.60						0.52					
0.60-0.70						0.83					
0.70-0.80						2.17					
0.80-0.90						2.27					
0.90-1.00						1.29					
1.00-1.10						1.84					
1.10-1.20						2.13					
1.20-1.30						2.35					
1.30-1.40						4.21					
1.40-1.50						1.05					

Notes: * -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Bonnie Crofts (depression)*

Soil Type: Bonnie Crofts (depression)
Soil Survey and Site No.: MGR S2B
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: From Mundubbera toward Gayndah on southern river road; 2.1 km past junction with Glenrae road to crossroads; 1.28 km down lane to north; on right side of lane.
Australian Map Grid Reference: 332 880 mE 7 167 050 mN ZONE 56
Sampled and described by: Richard J. Tucker; 9 October 1991

Map Unit: Bonnie Crofts (Bc)
Australian Soil Classification: Endocalcareous Epipedal, Black Vertosol; non-gravelly, fine/medium-fine, very deep.
Great Soil Group: black earth.
Principal Profile Form: Ug5.16
Soil Taxonomy Subgroup: Typic Haplotorrert
Landform Element: plain
Landform Pattern: stagnant alluvial plain
Geology: Quaternary alluvium (Pleistocene?)
Slope: 0.25%
Microrelief: Crabhole gilgai: vertical interval 0.1 m; horizontal interval 15 m.

Vegetation: Mid-high open forest: *Eucalyptus populnea, Dichanthium* ? species, *Aristida* species.
Rainfall: mean 709 mm, range 299 mm - 1229 mm, coeff. var. 28%, summer dominant (Mundubbera).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: very slow
Permeability: slowly permeable
Drainage: imperfectly drained
Land Use: road reserve
Surface Coarse Fragments: nil
Condition of Surface (Dry): periodic cracking

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Dark (10YR3/1); light clay; weak 20-50mm subangular blocky parting to strong 5-10mm subangular blocky; dry; very firm; common <1mm roots. Clear to-
B21	.05 to .60 m	Dark (10YR3/1); medium clay; moderate 10-20mm lenticular parting to moderate 5-10mm lenticular; few faint slickensides; dry; moderately strong; common <1mm roots. Gradual, wavy to-
B22k	.60 to 1.50 m	Yellow-brown (10YR6/4); medium heavy clay; moderate 20-50mm prismatic parting to moderate 5-10mm lenticular; common distinct slickensides; dry; moderately strong; few medium calcareous nodules, very few medium argillaceous tubules; no roots <1mm roots.

Notes: Samples taken from four cores. Sampled 0-0.05 m; 0.05-0.2 m; then by 0.1 m increments.

Soil Analytical Data

Bonnie Crofts (depression)

Depth Meters	1:5 Soil/Water pH @ 40C	EC ds/m @ 40C	Cl % 105C	Particle size CF % @ 105C	FS	S	C	Exch. Cations CEC m.eq/100 g @ 105C	Ca	Mg	Na	K	Total Elements P % @ 80C	K	S	Moisture ADM % @ 105C	33*	1500*	Disp. Ratio R1 R2 @ 40C	pH CaC12 @ 40C
B 0.10	7.6	.12	.008																	6.4
0.05	7.3	.12	.010	9	48	13	32	23	11	7.6	.56	.97	.049	.659	.041	3.00		12	.44	6.3
0.20	7.9	.17	.017	8	43	15	37	25	13	8.9	1.7	.54	.032	.578	.028	3.30		14	.54	6.7
0.30	7.6	.32	.035	6	36	11	49	29	14	11	2.7	.36	.026	.532	.027	4.00		17	.70	6.6
0.40	7.9	.44	.053																	6.9
0.50	8.2	.55	.065																	7.2
0.60	8.7	.63	.066	5	29	15	54	36	15	18	5.0	.30	.023	.484	.035	4.60		19	.70	7.7
0.70	9.0	.73	.071																	7.9
0.80	9.0	.73	.073																	7.9
0.90	9.1	.67	.066	7	29	13	52	31	13	16	4.5	.26	.025	.515	.038	4.40		19	.65	8.0
1.00	9.2	.65	.062																	8.1
1.10	9.2	.66	.063																	8.1
1.20	9.2	.64	.060	6	30	13	52	29	10	15	4.3	.25	.025	.556	.031	4.00				8.1
1.30	9.2	.63	.058																	8.1
1.40	9.2	.62	.056																	8.1
1.50	9.2	.56	.052																	8.0

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid mg/kg @ 105C	Bicarb	HC1 K meq% @ 105C	CaC12 Extr K mg/kg @ 105C	P	DTPA - extr Fe mg/kg @ 105C	Mn	Cu	Zn	B
B 0.10	1.5	.11		11	.64			24	23	1.4	4.0	

Upper Lower depth depth meters	Horizon	pH KC1 @ 40C	pH SP1	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10						0.40					
0.00-0.05						0.13					
0.05-0.20						0.05					
0.20-0.30						0					
0.30-0.40						0					
0.40-0.50						0					
0.50-0.60						0					
0.60-0.70						0.30					
0.70-0.80						1.12					
0.80-0.90						0.26					
0.90-1.00						0.70					
1.00-1.10						0.51					
1.10-1.20						0.61					
1.20-1.30						0.07					
1.30-1.40						0.37					
1.40-1.50						0.23					

Notes: * -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground samples.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description — *Burnett, shallow phase*

Soil Type: Burnett, shallow phase.
Soil Survey and Site No.: MGR S3
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: Take Mt Debatable Road from southern river road between Mundubbera and Gayndah; cross railway line, and follow it for 900+ m; turn left into farm; 700 m from rail line into orchard area past shed; 380 m north-west by north (150 m in from river).
Australian Map Grid Reference: 349 840 mE 7 165 860 mN ZONE 56
Sampled and described by: Richard J. Tucker; 9 October, 1991.

Map Unit: Burnett, shallow phase (BnSp)
Australian Soil Classification: Basic, Regolithic, Orthic, Tenosol, over buried clayey soil; medium non-gravelly, loamy/loamy, moderate.
Great Soil Group: no suitable group.
Principal Profile Form: Uc5.21 over clay.
Soil Taxonomy Subgroup:
Landform Element: levee
Landform Pattern: terrace
Geology: Quaternary alluvium
Slope: 1%
Microrelief: Nil

Vegetation: cleared.
Rainfall: mean 772 mm, range 339 mm - 1468 mm, coeff. var. 27%, summer dominant (Gayndah).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow.
Permeability: moderate.
Drainage: moderately well drained.
Land Use: irrigated citrus orchard.
Surface Coarse Fragments: nil.
Condition of Surface (Dry): firm.

HORIZON	DEPTH	DESCRIPTION
A1	0 to .30 m	Brown (7.5YR4/3); loamy fine sand; massive; dry; very weak; few <1mm roots. Gradual to-
B21	.30 to .70 m	Red-brown (5YR4/4); loamy fine sand; massive; dry; very weak; few <1mm roots. Clear, wavy to-
2B22t	.70 to 1.00 m	Red-brown (5YR4/4); clay loam, fine sandy; strong 20-50mm prismatic parting to moderate 10-20mm prismatic; many faint clay skins; moderately moist; very firm; few <1mm roots. Diffuse, wavy to-
2B23t	1.00 to 1.40 m	Red (2.5YR4/6); fine sandy, clay; strong 20-50mm prismatic parting to moderate 10-20mm prismatic; many faint clay skins; moderately moist; very firm; few fine manganiferous veins; few <1mm roots. Gradual, wavy to-
2B24	1.40 to 1.50 m	Red-brown (5YR4/4); clay loam, sandy; moderate 20-50mm prismatic; moderately moist; moderately firm.

Notes: Sampled from four cores. Fertilised with 400 kg urea/ha/yr and 400 kg K_2SO4/ha/yr. Also foliar Zn; Cu as fungicide.

Soil Analytical Data

Burnett, shallow phase

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size CF	FS	S	C % @ 105C	Exch. Cations CEC	Ca	Mg	Na	K m.eq/100 g @ 105C	Total Elements P	K	S % @ 80C	Moisture ADM	33*	1500* % @ 105C	Disp. Ratio R1 R2 @ 40C	pH CaC12 @ 40C
B 0.10	7.4	.32	.019																	6.7
0.10	7.6	.19	.013	21	64	7	11	6	4.0	2.1	.16	.58	.054	1.57	.031	.800		4	.42	6.9
0.20	7.6	.09	.006																	6.8
0.30	7.5	.10	.009	21	65	5	10	4	3.0	1.8	.13	.38	.042	1.58	.016	.700		4	.33	6.7
0.40	7.4	.15	.017																	6.7
0.50	7.3	.17	.018																	6.6
0.60	7.3	.20	.019	20	64	7	11	4	3.0	1.7	.22	.14	.040	1.57	.019	.800		4	.64	6.6
0.70	7.6	.16	.013																	6.8
0.80	7.0	.27	.025																	6.2
0.90	6.3	.38	.035	13	35	3	46	18	9.2	5.3	1.2	.24	.094	1.22	.029	2.60		16	.63	5.7
1.00	6.2	.36	.041																	5.6
1.10	6.6	.28	.032																	5.9
1.20	6.8	.25	.030	16	43	3	36	15	8.2	5.4	.70	.22	.053	1.30	.016	2.10				6.2
1.30	7.0	.22	.027																	6.2
1.40	7.2	.19	.023																	6.4
1.50	7.2	.16	.020																	6.4

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid	Bicarb mg/kg @ 105C	HC1 K meq% @ 105C	CaC12 Extr K	P mg/kg @ 105C	DTPA - extr Fe	Mn	Cu	Zn	B mg/kg @ 105C
B 0.10	1.1	.11		51	1.1			11	26	10	3.0	

Upper depth - Lower depth meters	Horizon	pH KC1 SP1 @ 40C	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10					0					
0.00-0.10					0					
0.10-0.20					0					
0.20-0.30					0					
0.30-0.40					0					
0.40-0.50					0					
0.50-0.60					0					
0.60-0.70					0					
0.70-0.80					0					
0.80-0.90					0					
0.90-1.00					0					
1.00-1.10					0					
1.10-1.20					0					
1.20-1.30					0					
1.30-1.40					0					
1.40-1.50					0					

Notes: * -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus/on ground samples.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Flagstone*

Soil Type: Flagstone
Soil Survey and Site No.: MGR S4
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: Take Burnett Highway from Gayndah towards Mundubbera, 4.3 km from Burnett River; 660 m west by south from road (perpendicular to road) in field near Reid Creek.
Australian Map Grid Reference: 357 000 mE 7 168 240 mN ZONE 56
Sampled and described by: Richard J. Tucker; 10 October, 1991.

Map Unit: Flagstone (Fs)
Australian Soil Classification: Melanic, Hypocalcic, Brown, Dermosol; medium, non-gravelly, clay-loamy/clayey, very deep
Great Soil Group: No suitable group, affinities with prairie soil.
Principal Profile Form: Gn3.23
Soil Taxonomy Subgroup:
Landform Element: plain.
Landform Pattern: alluvial plain
Geology: Quaternary alluvium
Slope: 0.1%
Microrelief: nil

Vegetation: cleared.
Rainfall: mean 772 mm, range 339 mm - 1468 mm, coeff. var. 27%, summer dominant (Gayndah).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow
Permeability: moderately permeable
Drainage: moderately well drained
Land Use: rainfed cropping
Surface Coarse Fragments: nil
Condition of Surface (Dry): surface crust

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .03 m	Dark (7.5YR3/2); fine sandy clay loam; weak 5-10mm granular; dry; moderately weak; few <1mm roots. Abrupt to-
Ap2	.03 to .20 m	Dark (7.5YR3/2); fine sandy clay loam; massive; dry; very firm; few <1mm roots. Sharp to-
B1	.20 to .35 m	Brown (7.5YR4/3); clay loam; moderate 20-50mm prismatic parting to moderate 5-10mm subangular blocky; dry; very firm; few <1mm roots. Gradual to-
B21	.35 to .55 m	Brown (10YR4/4); light clay; moderate 20-50mm prismatic parting to moderate 5-10mm angular blocky; dry; very firm; few <1mm roots. Clear, wavy to-
B22	.55 to 1.00 m	Brown (7.5YR4/3); light medium clay; moderate 20-50mm prismatic parting to moderate 5-10mm angular blocky; dry; moderately strong; very few medium calcareous nodules; few <1mm roots. Clear to-
B23kn	1.00 to 1.50 m	Brown (10YR4/3); medium clay; moderate 20-50mm prismatic parting to moderate 5-10mm angular blocky; moderately moist; very firm; few medium calcareous nodules, few fine manganiferous nodules.

Notes: Sampled from four cores. Urea fertilised when cropped. Some fine cracks on surface.

Soil Analytical Data — *Flagstone*

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size % @ 105C CF	FS	S	C	Exch. Cations m.eq/100 g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moisture % @ 105C ADM	33*	1500*	Disp. Ratio @ 40C R1	R2	pH CaC12 @ 40C
B 0.10	6.6	.16	.005																		5.8
0.03	6.5	.16	.006	6	44	25	28	19	9.2	4.7	.15	2.6	.091	1.29	.035	2.10		11		.69	5.8
0.10	6.7	.12	.003	5	46	26	29	19	9.2	4.8	.19	2.1	.088	1.27	.030	2.30		12		.69	5.8
0.20	7.3	.07	.001																		6.4
0.30	8.2	.08	.001	4	36	23	43	23	11	10	1.8	.58	.044	1.15	.021	3.50		15		.64	7.0
0.40	8.8	.14	.005																		7.5
0.50	9.0	.18	.009																		7.7
0.60	9.0	.26	.017	3	30	20	51	27	9.3	16	5.6	.39	.032	1.10	.024	3.60		20		.92	7.8
0.70	9.0	.51	.037																		7.9
0.80	9.0	.69	.057																		7.9
0.90	9.0	.94	.084	3	27	18	55	29	7.3	17	9.2	.39	.030	.924	.043	4.70		20		.95	8.0
1.00	9.1	1.1	.101																		8.1
1.10	9.2	1.2	.116																		8.1
1.20	9.3	1.2	.130	9	28	16	48	25	6.2	16	8.6	.41	.032	.821	.048	4.00					8.2
1.30	9.3	1.3	.139																		8.2
1.40	9.3	1.4	.164																		8.2
1.50	9.3	1.4	.180																		8.2

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P mg/kg @ 105C Acid	Bicarb	HC1 K meq% @ 105C	CaC12 Extr mg/kg @ 105C K	P	DTPA - extr mg/kg @ 105C Fe	Mn	Cu	Zn	B
B 0.10	1.7	.14		118	2.1			46	16	1.4	1.9	

Upper Lower depth depth meters	Horizon	pH @ 40C KC1	SP1	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10						0					
0.00-0.03						0					
0.03-0.10						0					
0.10-0.20						0					
0.20-0.30						0					
0.30-0.40						0					
0.40-0.50						0					
0.50-0.60						0.05					
0.60-0.70						0.28					
0.70-0.80						0.10					
0.80-0.90						0.21					
0.90-1.00						0.19					
1.00-1.10						0.05					
1.10-1.20						0.30					
1.20-1.30						0.38					
1.30-1.40						0.26					
1.40-1.50						1.18					

Notes: * -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Brownside*

Soil Type: Brownside (Bs)
Soil Survey and Site No.: MGR S5
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: From Gayndah along southern river road toward Mundubbera; 1.2 km past Mt Debatable turn off; through fence to right; north along fence, which runs perpendicular to road, for about 320 m; 450 m right from fence. (Site south of power line).
Australian Map Grid Reference: 351 040 mE 7 164 160 mN ZONE 56
Sampled and described by: Richard J. Tucker; 10 October 1991.

Map Unit: Brownside (Bs)
Australian Soil Classification: Basic, Paralithic, Bleached, Tenosol; medium, moderately gravelly, loamy/loamy, very deep.
Great Soil Group: no suitable group, affinities with earthy sand
Principal Profile Form: Uc2.1?
Soil Taxonomy Subgroup:
Landform Element: hillslope
Landform Pattern: undulating rises
Geology: Wigton Granite
Slope: 9.5%
Microrelief: nil

Vegetation: partially cleared; *Eucalyptus tessellaris, Eucalyptus intermedia, Eucalyptus crebra, Heteropogon contortus, Aristida* species.
Rainfall: mean 772 mm, range 339 mm - 1468 mm, coeff. var. 27%, summer dominant (Gayndah).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow
Permeability: moderately permeable
Drainage: moderately well drained
Land Use: Grazing
Surface Coarse Fragments: many small pebbles, angular tabular granite
Condition of Surface (Dry): very weakly coherent

HORIZON	DEPTH	DESCRIPTION
A11	0 to .15 m	Brown (10YR4/3) dry, dark (7.5YR3/2) moist; loamy coarse sand; common small pebbles, subangular quartz; few small pebbles, subangular granite; massive parting to weak 10-20mm subangular blocky; dry; very weak; common <1mm roots. Clear to-
A12?	.15 to .30 m	Light brown (7.5YR7/4) dry, brown (7.5YR5/4) moist; coarse sand; common medium pebbles, subangular granite, common small pebbles, subangular quartz; massive; dry; moderately firm; few <1mm roots. Gradual to-
A2?	.30 to .90 m	Light brown (7.5YR8/4) dry, brown (7.5YR6/4) moist; coarse sand; common medium pebbles; angular quartz, many small pebbles, angular granite; massive; loose; few <1mm roots. Diffuse to-
B?	.90 to 1.50 m	Light brown (7.5YR7/4) dry, brown (7.5YR5/4) moist; coarse sand; common medium pebbles angular quartz; many small pebbles, angular granite; massive; dry; moderately firm.

Notes: Sampled from four cores. Sampled in 0.15 m intervals.

Soil Analytical Data *Brownside*

Depth	1:5 Soil/Water			Particle size				Exch. Cations					Total Elements			Moisture			Disp. Ratio		pH
Meters	pH	EC	Cl	CF	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	33*	1500*	R1	R2	CaC12
		ds/m	%	%				m.eq/100 g					%			%					
	@ 40C		105C	@ 105C				@ 105C					@ 80C			@ 105C			@ 40C		@ 40C
B 0.10	7.3	.04	.002																		6.1
0.15	7.2	.04	.001	55	26	9	11	8	5.1	1.4	.09	.34	.056	3.26	.026	1.00		5	.35		6.0
0.30	7.4	.03	.001	57	26	10	11	4	4.0	.78	.02	.23	.043	3.30	.016	.800		4	.60		6.1
0.45	7.5	.02	.001																		6.4
0.60	7.7	.02	.001	53	28	10	12	3	2.0	.68	.01	.19	.030	3.46	.012	.600		4	.77		6.4
0.75	7.7	.03	.001																		6.4
0.90	7.6	.03	.001	54	27	9	12	3	3.0	.56	.02	.24	.030	3.10	.011	.700		4	.65		6.3
1.05	7.9	.03	.001																		6.6
1.20	7.9	.03	.001	53	28	9	12	4	3.0	.76	.03	.32	.034	3.08	.011	.700		5	.71		6.6
1.35	7.9	.03	.001																		6.6
1.50	7.9	.03	.001																		6.7

Depth	Org. C	Tot. N	Extr. P		HC1	CaC12 Extr		DTPA - extr				
metres	(W&B)		Acid	Bicarb	K	K	P	Fe	Mn	Cu	Zn	B
	%	%	mg/kg		meq%	mg/kg		mg/kg				
	@ 105C	@ 105C	@ 105C		@ 105C	@ 105C		@ 105C				
B 0.10	1.3	.09		31	.44			14	52	.35	2.9	

Upper Lower depth depth meters	Horizon	pH KC1 SP1 @ 40C	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10					10.5					
0.00-0.15					24.1					
0.15-0.30					38.3					
0.30-0.45					36.9					
0.45-0.60					36.4					
0.60-0.75					43.1					
0.75-0.90					43.2					
0.90-1.05					50.3					
1.05-1.20					44.8					
1.20-1.35					42.7					
1.35-1.50					42.1					

Notes:

* -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Fison*

Soil Type: Fison (Fn)
Soil Survey and Site No.: MGR S6
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: On Humphrey Road, 1.5 km from junction with Gayndah-Mundubbera southern river road; 70 m north-east of road, in pasture land near shed.
Australian Map Grid Reference: 348 970 mE 7 165 880 mN ZONE 56
Sampled and described by: Richard J. Tucker; 10 October 1991.

Map Unit: Fison (Fn)
Australian Soil Classification: Eutrophic, Mesonatric, Brown, Sodosol; thick, non-gravelly, loamy/clayey, very deep.
Great Soil Group: no suitable group.
Principal Profile Form: Uc5.21 over clay.
Soil Taxonomy Subgroup:
Landform Element: levee
Landform Pattern: levee
Geology: Quaternary alluvia
Slope: 7%
Microrelief: nil

Vegetation: cleared
Rainfall: mean 772 mm, range 339 mm - 1468 mm, coeff. var. 27%, summer dominant (Gayndah).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: moderately rapid
Permeability: slowly permeable
Drainage: imperfectly drained
Land Use: grazing
Surface Coarse Fragments: nil
Condition of Surface (Dry): hard-setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .05 m	Brown (7.5YR6/3) dry, brown (7.5YR4/3) moist; fine sandy loam; weak 5-10mm platy; dry; very weak; common <1mm roots. Clear to-
A12	.05 to .10 m	Brown (7.5YR6/3) dry, brown (7.5YR4/3) moist; fine sandy loam; massive; dry; very weak; few <1mm roots. Clear to-
B21	.10 to .30 m	Brown (7.5YR6/3) dry, brown (7.5YR4/4) moist; fine sandy loam; massive; dry; moderately weak; few <1mm roots. Clear to-
B22j	.30 to .40 m	Brown (7.5YR6/3) dry, brown (7.5YR5/4) moist; fine sandy loam; massive; dry; moderately weak; very few fine ferromanganiferous nodules; few <1mm roots. Abrupt to-
2B23t	.40 to .60 m	Brown (7.5YR4/4) dry, brown (7.5YR4/4) moist; light clay; strong 20-50mm prismatic parting to strong 10-20mm angular blocky; common distinct clay skins; dry; moderately strong; few <1mm roots. Gradual to-
2B24t	.60 to .80 m	Red-brown (5YR4/4) dry, red-brown (5YR4/4) moist; light clay; strong 20-50mm prismatic parting to moderate 5-10mm angular blocky; dry; moderately strong; few <1mm roots. Gradual to-
2B25	.80 to 1.50 m	Red-brown (5YR4/4) dry, red-brown (5YR4/4) moist; clay loam; strong 20-50mm prismatic parting to strong 5-10mm angular blocky; dry; moderately strong; very few coarse calcareous nodules, very few fine manganiferous soft segregations; few <1mm roots.

Notes: Sampled from four cores.

Soil Analytical Data *Fison*

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size CF	FS % @ 105C	S	C	Exch. Cations CEC	Ca m.eq/100 g @ 105C	Mg	Na	K	Total Elements P	K % @ 80C	S	Moisture ADM 33*	1500* % @ 105C	Disp. Ratio R1 @ 40C	R2	pH CaC12 @ 40C
B 0.10	6.6	.04	.001																	5.1
0.05	7.4	.02	.001	62	22	7	11	2	2.0	.58	.02	.19	.030	3.68	.012	.600	4			6.4
0.10	6.5	.03	.001	7	73	10	13	6	1.5	1.3	.02	.84	.074	1.50	.022	1.00	5	.52		4.9
0.20	6.2	.04	.001																	5.1
0.30	7.1	.06	.001	6	72	10	15	5	1.8	1.6	.06	.61	.043	1.50	.016	1.00	5	.51		5.9
0.40	7.2	.04	.001																	5.8
0.50	7.8	.11	.006																	6.5
0.60	8.2	.19	.015	4	50	7	41	15	3.3	7.8	2.5	1.5	.034	1.33	.021	2.20	14	.71		7.0
0.70	8.4	.24	.026																	7.2
0.80	8.5	.34	.039																	7.4
0.90	8.6	.38	.044	5	52	4	38	14	3.3	8.6	3.7	1.0	.032	1.27	.021	2.70	13	.92		7.6
1.00	8.7	.42	.048																	7.7
1.10	8.9	.46	.050																	7.8
1.20	9.0	.49	.050	4	58	6	32	14	3.3	10	5.3	.51	.034	1.32	.021	2.40				7.8
1.30	9.1	.52	.052																	7.9
1.40	9.2	.48	.049																	7.9
1.50	9.2	.52	.052																	8.0

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid mg/kg @ 105C	Bicarb	HC1 K meq% @ 105C	CaC12 Extr K mg/kg @ 105C	P	DTPA - extr Fe mg/kg @ 105C	Mn	Cu	Zn	B
B 0.10	1.1	.09		70	.86			87	32	1.1	.68	

Upper Lower depth depth meters	Horizon	pH KC1 @ 40C	SP1	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10						0.03					
0.00-0.05						0.07					
0.05-0.10						0.04					
0.10-0.20						0					
0.20-0.30						0					
0.30-0.40						0					
0.40-0.50						0					
0.50-0.60						0					
0.60-0.70						0					
0.70-0.80						0					
0.80-0.90						0					
0.90-1.00						0					
1.00-1.10						0					
1.10-1.20						0.22					
1.20-1.30						0.20					
1.30-1.40						0.31					
1.40-1.50						0.13					

Notes: * -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample.
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Red Flank*

Soil Type: Red Flank (Rf)
Soil Survey and Site No.: MGR S7
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: From Gayndah toward Mundubbera along southern river road; 2 km past Aranbanga Ck, at pit face on southern side of road.
Australian Map Grid Reference: 344 130 mE 7 165 160 mN ZONE 56
Sampled and described by: Richard J. Tucker; 11 October 1991.

Map Unit: Wigton Association (WA)
Australian Soil Classification: no suitable subgroup, affinities with red earth. Eutrophic, Red, Kandosol over sporadically bleached red porous gravelly pan; medium, gravelly, sandy/loamy, deep
Great Soil Group: no suitable group, affinities with red earth.
Principal Profile Form: Gn2.12?
Soil Taxonomy Subgroup:
Landform Element: plain
Landform Pattern: undulating rises
Geology: reworked alluvia on Wigton Granite
Slope: 5.25%
Microrelief: nil

Vegetation: tall woodland: *Eucalyptus crebra, Eucalyptus tessellaris, Eucalyptus intermedia, Acacia* species, *Alphitonia excelsa, Heteropogon contortus, Dichanthium* ? species.
Rainfall: mean 709 mm, range 299 mm - 1229 mm, coeff. var. 28%, summer dominant (Mundubbera).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow
Permeability: moderately permeable
Drainage: imperfectly drained
Land Use: road reserve, soil pit
Surface Coarse Fragments: nil
Condition of Surface (Dry): firm

HORIZON	DEPTH	DESCRIPTION
A11	0 to .08 m	Brown (7.5YR6/3) dry, brown (7.5YR4/3) moist; loamy coarse sand; few small pebbles, subangular quartz, very few medium pebbles, subangular quartz; weak 5-10mm subangular blocky; many very fine macropores, few fine macropores; dry; very weak; common <1mm roots. Abrupt to-
A12	.08 to .18 m	Brown (7.5 YR6/4) dry, red-brown (5YR4/4) moist; loamy coarse sand; very few small pebbles, subangular quartz; weak 5-10mm subangular blocky; many very fine macropores, few fine macropores; dry; very weak; common <1mm roots. Clear to-
B1	.18 to .28 m	Red-brown (5YR6/4) dry, red-brown (5YR4/6) moist; clayey coarse sand; few small pebbles, subangular quartz; massive; many very fine macropores, few fine macropores; dry; very weak; common <1mm roots. Clear to-
B21	.28 to .90 m	Red-brown (5YR6/6) dry, red (2.5YR4/6) moist; coarse sandy clay loam; common small pebbles, subangular quartz; massive; many very fine macropores, common fine macropores; dry; moderately weak; common <1mm roots. Clear to-
B22e	.90 to 1.38 m	Light brown (7.5YR8/3) dry, yellow-brown (7.5YR6/6) moist; clayey coarse sand; common small pebbles, subangular quartz; massive; many very fine macropores, few fine macropores; dry; moderately firm; common <1mm roots. Clear to-
B23xj?	1.38 to 1.50 m	Light brown (5YR6/6, 7.5YR8/3) dry, red-brown (5YR5/6) moist; clayey coarse sand; many small pebbles, subangular quartz; few medium pebbles, angular tabular granite; few small pebbles, angular tabular granite; massive; many very fine macropores, many medium macropores; dry; moderately strong; vesicular discontinuous uncemented hardpan; common <1mm roots.

Notes: Sampled from roadside pit - cut back up to 0.3 m. Sampled by horizons to 0.28 m.

Soil Analytical Data *Red Flank*

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size % @ 105C CF	FS	S	C	Exch. Cations m.eq/100 g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moisture % @ 105C ADM	33*	1500*	Disp. Ratio @ 40C R1	R2	pH CaC12 @ 40C
B 0.10	6.8	.04	.001																		5.7
0.08	7.0	.04	.001	50	34	9	10	3	2.7	1.4	.03	.53	.029	4.75	.020	.600		3	.40		6.0
0.18	6.4	.02	.001																		5.1
0.28	6.1	.01	.001	43	39	8	10	2	1.1	.53	.05	.17	.022	4.65	.015	.600		3	.82		5.0
0.40	5.9	.01	.001																		4.8
0.50	5.9	.01	.001																		4.9
0.60	6.0	.01	.001	38	37	8	18	3	1.7	.65	.05	.15	.024	4.15	.015	.800		5	.56		5.1
0.70	6.5	.02	.001																		5.6
0.80	6.7	.02	.001																		5.8
0.90	6.8	.01	.001	40	39	7	14	3	1.4	.68	.05	.13	.024	4.17	.013	.800		4	.85		5.9
1.00	6.7	.01	.001																		5.8
1.10	6.7	.01	.001																		6.1
1.20	6.8	.01	.001	45	40	7	7	1	.92	.54	.05	.08	.019	4.43	.012	.400					5.9
1.30	6.8	.01	.001																		5.8
1.40	6.9	.02	.001																		5.9
1.50	7.2	.03	.002																		6.0

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P mg/kg @ 105C Acid	Bicarb	HC1 K meq% @ 105C	CaC12 Extr mg/kg @ 105C K	P	DTPA - extr mg/kg @ 105C Fe	Mn	Cu	Zn	B
B 0.10	.60	.04		4.0	.30			13	63	.21	1.7	

Upper Lower depth depth meters	Horizon	pH KC1 SP1 @ 40C	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	SP3 @ 105C	SP4 @ 105C	SP5 @ 105C	SP6 @ 105C	SP7 @ 105C
B 0.10					6.68					
0.00-0.08					17.2					
0.08-0.18					14.3					
0.18-0.28					13.4					
0.30-0.40					13.8					
0.40-0.50					24.4					
0.50-0.60					11.0					
0.60-0.70					26.0					
0.70-0.80					23.8					
0.80-0.90					46.0					
0.90-1.00					33.7					
1.00-1.10					35.3					
1.10-1.20					37.3					
1.20-1.30					37.0					
1.30-1.40					40.1					
1.40-1.50					49.3					

Notes: *-33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.

Soil Profile Description *Whiteside*

Soil Type: Whiteside (Ws)
Soil Survey and Site No.: MGR S8
Agricultural Chemistry Lab. Batch No. and Year: 1121 (1991).
Location: From Gayndah toward Mundubbera on southern river road; 1.5 km past Aranbanga Creek; on road reserve to south.
Australian Map Grid Reference: 344 630 mE 7 165 060 mN ZONE 56
Sampled and described by: Richard J. Tucker; 11 October 1991

Map Unit: Wigton Association (WA)
Australian Soil Classification: Eutrophic, Subnatric, Brown, Sodosol; thick, gravelly, sandy/clay-loamy, moderate.
Great Soil Group: soloth
Principal Profile Form: Dy5.41
Soil Taxonomy Subgroup:
Landform Element: plain
Landform Pattern: undulating rises
Geology: Wigton Granite
Slope: 5.25%
Microrelief: nil

Vegetation: mid-high woodland; *Eucalyptus tereticornis, Eucalyptus intermedia, Eucalyptus crebra, Petalostigma pubescens, Alphitonia excelsa.*
Rainfall: mean 709 mm, range 299 mm - 1229 mm, coeff. var. 28%, summer dominant (Mundubbera).
Air Temperature: mean max. 28°C, mean min. 13.9°C (Gayndah).
Runoff: slow
Permeability: very slowly permeable
Drainage: poorly drained
Land Use: road reserve
Surface Coarse Fragments: nil
Condition of Surface (Dry): soft

HORIZON	DEPTH	DESCRIPTION
A11	0 to .10 m	Dark (10YR3/1) moist; loamy coarse sand; weak 5-10mm subangular blocky; dry; very weak; common <1mm roots. Clear to-
A12	.10 to .25 m	Grey (10YR6/1) dry, dark (10YR3/1) moist; loamy coarse sand; few small pebbles, subangular quartz; massive; dry; very weak; few <1mm roots. Clear to-
A2e	.25 to .50 m	Light grey (10YR8/1) dry, grey (10 YR6/2) moist; coarse sand; common small pebbles, subangular quartz; massive; dry; very weak; few <1mm roots. Clear to-
B2t	.50 to .65 m	Yellow-brown (10YR5/3) moist; coarse sandy clay; common small pebbles, subangular quartz; moderate 5-10mm angular blocky; dry; moderately strong.

Notes: Sampled from four cores. Sampled by horizons because of low volume of fine earth.

Soil Analytical Data *Whiteside*

Depth Meters	1:5 Soil/Water pH	EC ds/m @ 40C	Cl % 105C	Particle size CF	FS	S	C % @ 105C	Exch. Cations CEC	Ca	Mg	Na	K m.eq/100 g @ 105C	Total Elements P	K	S % @ 80C	Moisture ADM	33*	1500* % @ 105C	Disp. Ratio R1	R2 @ 40C	pH CaC12 @ 40C
B 0.10	6.3	.03	.001																		5.1
0.10	6.1	.02	.001	53	34	7	7	6	1.6	1.1	.05	.31	.030	4.52	.022	.700		3			4.8
0.25	6.0	.02	.001	51	37	8	7	4	.96	.83	.05	.21	.022	4.68	.016	.500		2			4.8
0.50	6.3	.01	.001																		5.1
0.65	6.2	.06	.005	37	28	4	31	7	.42	3.3	.29	.15	.023	3.87	.015	2.00		9			5.1

Depth metres	Org. C (W&B) % @ 105C	Tot. N % @ 105C	Extr. P Acid	Bicarb mg/kg @ 105C	HC1 K meq% @ 105C	CaC12 Extr K	P mg/kg @ 105C	DTPA - extr Fe	Mn	Cu	Zn	B mg/kg @ 105C
B 0.10	1.0	.06		6.0	.29			45	27	.22	1.7	

Upper Lower depth depth meters	Horizon	pH KC1 SP1 @ 40C	CaCO3 % @ 105C	Bulk den. mg/m3 @ 105C	Gravel (>2mm) % @ 105C	Alternative cation method Ca	Mg	Na	K	ECEC
B 0.10					3.51					
0.00-0.10					3.92	2.2	1.0	.05	.3	4
0.10-0.25					8.70	1.6	.79	.05	.19	3
0.25-0.50					28.8					
0.50-0.65					34.5	2.0	3.1	.46	.12	6

Notes:

* -33 kPa (-0.33 bar) and -1500 kPa (-15 bar) using pressure plate apparatus on ground sample
Cation method: alcoholic NH_4Cl at pH 8.5.
CEC method: alcoholic NH_4Cl at pH 8.5.
Alternative cation method: aqueous NH_4Cl at pH 7.0; Effective CEC (ECEC) = Sum of Exch. (Ca + Mg + Na + K) + Exch. Acidity.

APPENDIX 3

SOIL FERTILITY RATINGS FOR RIPARIAN SOILS, MUNDUBBERA TO GAYNDAH

Soil Types, Phases and Variants	Depth (m)	OC	Tot N	Avail P	Rep/ Ext K	Ext Mn	Ext Cu	Ext Zn	Tot P	Tot K	Tot S	Exch Ca	Exch Mg
Alluvial complex - higher*	0.1	m	m	m	m	m	m	m	m	m	l	s	s
	0.3 - 0.9				m				m	m	l	s	s
Alluvial complex - lower*	0.1	m	m	m	m	m	m	m	m	m	l	s	s
	0.3 - 0.9				m				m	m	l	s	s
Alluvial complex - lower, cracking clays*	0.1	m	m	m	h	m	m	m	m	m	l	s	s
	0.3 - 0.9				m				m	m	l	s	s
Aranear*	0.1	m	m	m	m	m	m	m	m	h	m	s	s
	0.3 - 0.9				m				m	h	l	s	s
Auburn	0.1	m	m	vl	h	h	m	m	m	l	m	s	s
Auburn, channelly phase*	0.3 - 0.9				m				l	m	l	s	s
Auburn, eroded phase*													
Auburn, red subsoil variant*													
Balark**	0.1	m	m	vl	m	m	m	m	m	m	m	s	s
Balark, steep phase*	0.3 - 0.6				l				m	m	m	s	s
Beeron	0.1	m	l	vl	h	h	m	m	h	m	m	s	s
Beeron, eroded phase*	0.3				m				l	m	l	s	s
Beeron, deep-surface phase*	0.6				l				l	m	l	s	s
Beeron, rocky phase*	0.9				l				l	h	l	s	s
Belrose*	0.1	m	m	vl	m	m	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	l	s	s
Bonnie Crofts	0.1	m	l	vl	h	m	m	m	m	m	m	s	s
	0.3				m				m	m	m	s	s
	0.6 - 0.9				m				m	l	m	s	s
Boyekel	0.1	l	l	m	h	m	m	l	h	l	m	s	s
Boyekel, eroded phase	0.3 - 0.9				m				h	l	m	s	s
Boyne	0.1	l	l	vl	m	m	m	l	m	m	l	s	l
	0.3				m				m	m	l	s	l
	0.6 - 0.9				m				m	m	l	s	s
Boynewood	0.1	m	m	vl	h	h	m	m	m	m	m	s	s
Boynewood, eroded phase*	0.3				m				m	m	l	s	s
Boynewood, rocky phase*	0.6				m				l	l	l	s	s
Boynewood, steep phase*													
Bray**	0.1	m	m	l	h	m	m	m	h	m	m	s	s
Bray, deep phase*	0.3 - 0.9				l				m	m	m	s	s
Brogue *	0.1	m	m	l	m	m	m	m	m	m	m	s	s
Brogue, rocky phase*	0.3 - 0.9				m				m	m	m	s	s
Brogue, steep phase*													
Brownside	0.1	l	l	m	m	h	m	m	h	vh	m	s	l
(Most is in *Wigton Association*.)	0.3				m				m	vh	l	s	l
	0.6				l				m	vh	l	s	l
	0.9				m				m	vh	l	s	l
Burnett	0.1	l	l	h	h	m	m	m	h	h	m	s	l
	0.3				h				h	h	l	s	l
	0.6				m				h	h	l	s	s
	0.9				l				h	h	l	s	s
Burnett, coarse sandy phase*	0.1	l	l	m	m	m	m	m	l	m	l	s	l
	0.3				m				l	m	l	s	l
	0.6 - 0.9				m				l	m	l	s	s

Soil Types, Phases and Variants	Depth (m)	OC	Tot N	Avail P	Rep/ Ext K	Ext Mn	Ext Cu	Ext Zn	Tot P	Tot K	Tot S	Exch Ca	Exch Mg
Burnett, shallow phase	0.1	l	l	h	vh	m	h	h	h	h	m	s	s
	0.3				m				m	h	l	s	l
	0.6				l				m	h	l	s	l
	0.9				m				h	h	l	s	s
Chessborough	0.1	m	l	vl	h	m	m	m	h	l	m	s	l
Chessborough, rocky phase*	0.3				h				m	l	l	s	s
Chessborough, rubbly, shallow	0.6				m				m	l	l	s	s
and rocky phase*	0.9				h				m	l	l	s	s
Coonambula	0.1	m	m	vl	h	h	m	m	m	m	m	s	s
Coonambula, eroded phase*	0.3 - 0.9				m				l	m	l	s	s
Coonambula-Beeron*													
Dargy*	0.1	m	m	l	m	m	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	m	s	s
Derra	0.1	m	m	l	h	m	m	l	h	m	m	s	s
Derra, rocky phase*	0.3				m				m	m	m	s	s
	0.6 - 0.9				m				l	m	m	s	s
Derrick**	0.1	m	l	vl	m	m	m	m	m	m	m	s	s
Derrick, steep and	0.3 - 0.9				m				m	m	m	s	s
broken phase*													
Dillan*	0.1	l	l	vl	m	h	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	l	s	s
Drape*	0.1	l	l	l	h	m	m	l	h	m	m	s	s
	0.3-0.9				m				h	m	m	s	s
Dunbas*	0.1	m	m	l	m	m	m	m	m	m	m	s	s
Dunbas, deep phase*	0.3 - 0.9				l				m	m	m	s	s
Dunbas, steep phase													
Durong	0.1	m	m	vl	vh	m	m	l	m	m	m	s	s
	0.3 - 0.9				m				l	m	l	s	s
Ella*	0.1	l	l	vl	m	m	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	l	s	s
Fison	0.1	l	l	h	h	m	m	m	m	h	l	l	l
Fison, rocky phase*	0.3				h				m	h	l	l	l
	0.6 - 0.9				vh				m	h	l	s	s
Flagstone	0.1	m	m	h	vh	m	m	m	h	vh	m	s	s
Flagstone, channel-bench phase*	0.3				h				m	vh	m	s	s
Flagstone, channelly phase*	0.6 - 0.9				m				m	vh	m	s	s
Glenrock	0.1	l	l	vl	m	m	m	l	m	vl	l	s	l
Glenrock, grey variant*	0.3				vl				l	vl	l	l	l
	0.6 - 0.9				vl				m	l	l	s	l
Greyfrill*	0.1	l	l	vl	m	m	m	m	m	m	m	s	s
Greyfrill, eroded phase*	0.3 - 0.9				m				l	m	l	s	s
Jedda*	0.1	m	l	l	h	m	m	l	h	m	m	s	s
	0.3 - 0.9				m				h	m	m	s	s
Kinburn*	0.1	l	l	l	m	h	m	m	m	m	l	l	l
Kinburn, eroded phase*	0.3 - 0.9				m				m	m	l	s	s
Lacon	0.1	m	m	vl	m	h	m	m	m	m	m	s	s
Lacon, eroded phase*	0.3 - 0.9				m				l	m	l	s	s
Lacon, rocky phase*													
Madoora*	0.1	m	m	h	h	m	m	m	h	h	m	s	l
	0.3 - 0.9				m				h	h	l	s	s

Soil Types, Phases and Variants	Depth (m)	OC	Tot N	Avail P	Rep/ Ext K	Ext Mn	Ext Cu	Ext Zn	Tot P	Tot K	Tot S	Exch Ca	Exch Mg
Mulgildie**	0.1	vh	h	vl	vh	m	m	m	m	m	m	s	s
Mulgildie, rocky phase*	0.3	m	l		l				m	m	m	vl	s
Mulgildie, snuffy phase*	0.6	l			l				m	m	m	vl	s
Mulgildie, eroded phase*	0.9	vl			m				m	m	m	vl	s
Neugildie*	0.1	m	m	vl	m	m	m	m	m	m	m	s	s
Neugildie, eroded phase*	0.3	m	l		l				m	m	m	vl	s
Neugildie, saline phase*	0.6	l			l				m	m	m	vl	s
	0.9	vl			m				m	m	m	vl	s
Neugildie, colluvial,	0.1	m	m	vl	m	m	m	m	m	m	m	s	s
clayey variant*	0.3				l				m	m	m	vl	s
	0.6				m				m	m	m	l	s
	0.9				m				m	m	m	s	s
Overrun*	0.1	m	l	vl	h	m	m	m	m	m	m	s	s
Overrun, linear gilgaied phase*	0.3 - 0.9				m				m	m	m	s	s
Panda*	0.1	m	m	l	h	h	m	m	m	h	m	s	s
Panda, saline phase*	0.3 - 0.9				m				m	h	m	s	s
Pedimentary soils*	0.1	l	vl	vl	m	h	m	m	m	m	m	s	l
	0.3 - 0.9				l				m	l	l	l	l
Platter*	0.1	m	m	l	m	m	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	m	s	s
Red flank	0.1	l	vl	vl	m	h	l	m	m	vh	l	s	l
	0.3 - 0.9				l				m	vh	l	l	l
Riverleigh*	0.1	l	l	h	h	m	m	m	m	h	m	s	s
Riverleigh, clayey variant*	0.3 - 0.9				m				m	h	m	s	s
Riverleigh, eroded phase*													
Solwig*	0.1	l	l	vl	m	m	m	m	m	h	m	s	s
Solwig, eroded phase*	0.3 - 0.9				m				m	h	l	s	s
Stratfield*	0.1	l	l	l	m	m	m	m	m	m	m	s	s
	0.3 - 0.9				m				m	m	l	s	s
Taughboyne**	0.1	l	l	l	h	m	m	m	m	m	m	s	s
Taughboyne, eroded phase*	0.3				h				m	m	m	s	s
	0.6				vl				m	m	m	l	s
	0.9				m				m	m	m	l	s
Whiteside (Major component of	0.1	l	l	vl	m	m	l	m	m	vh	m	l	l
Wigton Association; not	0.3				m				m	vh	l	l	l
mapped.)	0.6 - 0.9				l				m	vh	l	l	s
Wigton association	0.1	l	l	vl	m	m	l	m	m	vh	m	l	l
Wigton association, eroded phase	0.3				m				m	vh	l	l	l
Wigton association, steep and	0.6				l				m	vh	l	l	s
broken phase	0.9				m				m	vh	l	l	s
Wigton association, steep phase													
Wivenhoe	0.1	m	l	vl	m	m	m	m	m	m	l	l	l
	0.3				l				l	m	l	l	l
	0.6 - 0.9				vl				l	h	l	l	s
Yondilla*	0.1	l	l	l	m	m	m	m	m	m	l	l	l
	0.3				l				l	l	l	l	l
	0.6				l				l	l	l	l	l
	0.9				m				m	m	l	s	l

Notes
Ratings: vh = very high; h = high; m = medium; l = low; vl = very low; s = sufficient.
Data from analyses conducted for this survey and for the Auburn River Study (Wilson and Sorby, 1991) except as marked by asterisks, which sources are explained below.
* Estimated. Ratings for phases and variants have been estimated from their main soil types and/or related soil types. Ratings for other soils have been estimated from related soil types.
** Derived from early data provided by CSIRO Division of Soils.
Most of the ratings are derived from analyses of one site only.

APPENDIX 4

SALINITY AND SODICITY RATINGS FOR RIPARIAN SOILS, MUNDUBBERA TO GAYNDAH

Soil Types, Phases and Variants	Depth (m)	Salinity (EC)	Chloride	Sodicity
Alluvial complex - higher*	0.1	vl - l	vl	non sodic
	0.3	vl	vl - l	non sodic - sodic
	0.6 - 1.5	vl - m	vl - m	non sodic - strongly sodic
Alluvial complex - lower*	0.1	vl - l	vl	non sodic
	0.3	vl	vl - l	non sodic - sodic
	0.6	vl - m	vl - m	non sodic - strongly sodic
	0.9 - 1.5	vl - h	vl - h	non sodic - strongly sodic
Alluvial complex - lower, cracking clays*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic - sodic
	0.6 - 1.5	vl - m	vl - m	non sodic - sodic
Aranear*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic - sodic
	0.6	m	m	sodic - strongly sodic
	0.9 - 1.5	m	m	strongly sodic
Auburn	0.1	vl	vl	non sodic
Auburn, channelly phase*	0.3	vl	vl	sodic - strongly sodic
Auburn, eroded phase*	0.6 - 1.5	m	h	strongly sodic
Auburn, red subsoil variant*				
Balark**	0.1	vl	vl	non sodic
Balark, steep phase*	0.3 - 1.2	vl	l	non sodic
Beeron	0.1	vl	vl	non sodic
Beeron, deep surface phase*	0.3	vl	l	non sodic - strongly sodic
Beeron, eroded phase*	0.6 - 1.2	m	h	strongly sodic
Beeron, rocky phase*				
Belrose*	0.1	vl	vl	non sodic
	0.3 - 1.2	vl	vl	non sodic
Bonnie Crofts	0.1	vl	vl	non sodic
	0.3	l	l	sodic
	0.6	m	h	sodic - strongly sodic
	0.9	m	h	sodic - strongly sodic
	1.2 - 1.5	m	m - h	sodic - strongly sodic
Bovekel	0.1	vl	vl	non sodic
Bovekel, eroded phase*	0.3	vl	vl	non sodic
	0.6	vl	vl	non sodic
	0.9	vl	vl	non sodic
	1.2	l	vl	sodic
	1.5	l	l	
Boyne	0.1	vl	vl	non sodic
	0.3 - 1.5	vl	vl	non sodic
Boynewood	0.1	vl	vl	non sodic
Boynewood, steep phase*	0.3 - 1.2	vl	vl	non sodic
Boynewood, rocky phase*				
Boynewood, eroded phase*				
Bray**	0.1	vl	vl	non sodic
Bray, deep phase*	0.3 - 1.5	vl	vl	non sodic
Brogue*	0.1	vl	vl	non sodic
Brogue, steep phase*	0.3	vl	l	non sodic
Brogue, rocky phase*	0.6	l	l	sodic
	0.9 - 1.2	l	l	sodic
Brownside	0.1	vl	vl	non sodic
(most is in *Wigton Association*)	0.3-0.5	vl	vl	non sodic
Burnett	0.1	l	vl	non sodic
	0.3 - 1.51	vl	vl	non sodic
Burnett, coarse sandy phase*	0.1	vl	vl	non sodic
	0.3 - 1.5	vl	vl	non sodic
Burnett, shallow phase	0.1	l	l	non sodic
	0.3	vl	vl	non sodic
	0.6	l	l	non sodic
	0.9	l	m	non sodic - sodic
	1.2 - 1.5	l	l	non sodic - sodic
Chessborough	0.1	vl	vl	non sodic
Chessborough, rocky phase*	0.3	vl	vl	non sodic
Chessborough, rubbly, shallow and rocky phase*	0.6 - 1.5	vl	vl	non sodic - strongly sodic
Coonambula	0.1	vl	vl	non sodic
Coonambula, eroded phase*	0.3	l	l	sodic
Coonambula-Beeron*	0.6 - 1.5	m	m	strongly sodic

Soil Types, Phases and Variants	Depth (m)	Salinity (EC)	Chloride	Sodicity
Dargy*	0.1	vl	vl	non sodic
	0.3	vl	l	non sodic
	0.6	vl	l	non sodic
	0.9	l	l	sodic
Derra	0.1	vl - l	vl	non sodic
Derra, rocky phase*	0.3	vl - l	vl - l	non sodic - sodic
	0.6	l - h	vl - h	sodic - strongly sodic
	0.9	l - h	l - h	strongly sodic
	1.2	l- h	m - h	strongly sodic
	1.5	m - h	m - h	strongly sodic
Derrick**	0.1	vl	l	non sodic
Derrick, steep and broken phase*	0.3	l	h	non sodic - sodic
	0.6	m	h	sodic - strongly sodic
	0.9 - 1.2	m	h	strongly sodic
Dillan*	0.1	vl	vl	non sodic
	0.3	vl	l	non sodic - sodic
	0.6 - 1.2	m	h	strongly sodic
Drape*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic
	0.6	vl	vl	non sodic
	0.9	l	l	non sodic
	1.2 - 1.5	l	l	sodic
Dunbas*	0.1	vl	vl	non sodic
Dunbas, deep phase*	0.3 - 1.5	vl	vl	non sodic
Dunbas, steep phase*				
Durong	0.1	vl	vl	non sodic
	0.3	vl	vl	sodic
	0.6 - 1.5	m	h	sodic
Ella*	0.1	vl	vl	non sodic
	0.3	vl - l	vl	non sodic - strongly
	0.6	l - m	m - h	sodic strongly sodic
	0.9 - 1.2	m	m - h	strongly sodic
Fison	0.1	vl	vl	non sodic
Fison, rocky phase*	0.3	vl	vl	non sodic - sodic
	0.6	vl	l	non sodic - strongly
	0.9	l	l	sodic
	1.2 - 1.5	m	m	sodic - strongly sodic
				sodic - strongly sodic
Flagstone	0.1	vl-l	vl	non sodic
Flagstone, channel-bench phase*	0.3	vl	vl	non sodic - sodic
Flagstone, channelly phase*	0.6	vl - l	vl - l	non sodic - sodic
	0.9 - 1.5	vl - h	vl - m	non sodic - strongly sodic
Glenrock	0.1	vl	vl	non sodic
Glenrock, grey variant*	0.3	vl	vl	non sodic
	0.6	vl	vl	non sodic
	0.9 - 1.5	vl	l	non sodic
Greyfrill*	0.1	vl	l	sodic
Greyfrill, eroded phase*	0.3-0.09	l	m	strongly sodic
Jedda*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic
	0.6	vl	vl	non sodic
	0.9	vl	vl	non sodic
	1.2 - 1.5	l	vl	sodic
Kinburn*	0.1	vl	vl	non sodic
Kinburn, eroded phase*	0.3	vl	vl	sodic - strongly sodic
	0.6 - 1.5	l	l	strongly sodic
Lacon	0.1	vl	vl	non sodic
Lacon, eroded phase*	0.3	vl	vl - l	non sodic - sodic
Lacon, rocky phase*	0.6 - 1.5	l - m	vl - h	non sodic - strongly sodic
Madoora*	0.1	vl	vl	non sodic
	0.3 - 1.5	vl	vl	non sodic
Mulgildie**	0.1	vl	vl	non sodic
Mulgildie, rocky phase*	0.3 - 1.5	vl	vl	non sodic
Mulgildie, snuffy phase*				
Mulgildie,eroded phase*				
Neugildie*	0.1	vl	vl	non sodic
Neugildie, eroded phase*	0.3 - 1.5	vl	vl	non sodic
Neugildie, colluvial, clayey variant*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic
	0.6	vl	vl	non sodic
	0.9	vl	vl	non sodic
	1.2 - 1.5	vl	vl	non sodic

Soil Types, Phases and Variants	Depth (m)	Salinity (EC)	Chloride	Sodicity
Neugildie, saline phase*	0.1	vh	vh	sodic
	0.3 - 1.5	vh	vh	sodic
Overrun*	0.1	l	vl	non sodic
Overrun, linear gilgaied phase*	0.3	l	l	sodic
	0.6 - 1.5	m	h	sodic
Panda*	0.1	vl - l	vl	non sodic
	0.3	vl	vl	non sodic - sodic
	0.6	vl - l	vl - l	sodic
	0.9	vl - h	vl - m	strongly sodic
	1.2 - 1.5	vl - h	vl - h	strongly sodic
Panda, saline phase*	0.1	vh	vh	non sodic
	0.3	vh	vh	sodic
	0.6	vh	vh	sodic
	0.9 - 1.5	vh	vh	strongly sodic
Pedimentary soils*	0.1	vl	vl	non sodic
	0.3 - 1.5	vl	vl	non sodic
Platter*	0.1	vl	vl	non sodic
	0.3	vl	vl	sodic
	0.6	l	l	sodic
	0.9 - 1.5	l	l	strongly sodic
Red flank	0.1	vl	vl	non sodic
	0.3 - 1.5	vl	vl	non sodic
Riverleigh*	0.1	vl - l	vl	non sodic
Riverleigh, clayey variant*	0.3	vl	vl	non sodic-sodic
Riverleigh, eroded phase*	0.6	vl - l	vl - l	non sodic-sodic
	0.9	vl - h	vl - m	sodic - strongly sodic
	1.2 - 1.5	vl - h	vl - h	sodic - strongly sodic
Solwig*	0.1	l	l	non sodic
Solwig, eroded phase*	0.3	l	l	sodic
	0.6 - 1.5	m	h	strongly sodic
Stratfield*	0.1	vl	vl	non sodic
	0.3	vl	l	non sodic
	0.6 - 1.5	l	l	non sodic - sodic
Taughboyne**	0.1	vl	vl	non sodic
Taughboyne, eroded phase*	0.3	vl	m	non sodic - sodic
	0.6	vl	m	strongly sodic
	0.9 - 1.2	m	h	strongly sodic
Whiteside (Not mapped; major component of	0.1	vl	vl	non sodic
Wigton Association).	0.3	vl	vl	non sodic
	0.6 - 0.9	vl	vl	sodic
Wigton Association	0.1	vl	vl	non sodic
Wigton Association, eroded phase	0.3	vl	vl	non sodic
Wigton Association, steep and broken phase	0.6 - 1.2	vl	vl	non sodic - sodic
Wigton Association, steep phase				
Wivenhoe	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic
	0.6	l	m	sodic - strongly sodic
	0.9	l	m	strongly sodic
	1.2 - 1.5	l	h	strongly sodic
Yondilla*	0.1	vl	vl	non sodic
	0.3	vl	vl	non sodic
	0.6	l	l	non sodic
	0.9 - 1.5	l	l	sodic

Notes

Ratings: vh = very high; h = high; m = medium; l = low; vl = very low

The table is based on data from analyses conducted for this survey, and for the Auburn River study (Wilson and Sorby, 1991); except as marked by asterisks, which sources are explained below.

*** Estimated. Ratings for soil phases and variants have been estimated from their main soil types and/or similar soils. The ratings for other soil types have been estimated from related soil types.**

**** Derived from early data provided by CSIRO Division of Soils.**

Most of the ratings are from analyses of one site only.

APPENDIX 5

LAND SUITABILITY CLASSES

Class definitions

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 for each specified land use according to the severity of the limitations encountered. The aim is to achieve optimum land use with minimal degradation.

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[1] 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 considered unsuitable due to severe limitations. The precise effects of these limitations on the proposed land use may or may not be known. The use of this land is dependent upon undertaking additional studies either to determine its suitability for sustained production, or to reduce the effects of the limitations. With present knowledge, large inputs may be required to provide economic returns. Consideration of using this land should wait until all suitable land has been utilised.

Class 5 Unsuitable land with extreme limitations that preclude its use.

Land is considered less suitable as the severity of limitations for each particular land use increases. The limitations reflect either (a) reduced potential for production, and/or (b) the need for increased inputs to achieve an acceptable level of production, and/or (c) increased inputs required to prevent land degradation. The first three land suitability classes should provide viable returns from 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 land is considered presently unsuitable and is used for marginal land where it is doubtful that the inputs required to achieve and maintain production outweigh the benefits in the long-term. 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, having limitations overall that are so severe that the benefits would 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.

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[1] Where more than simple management practices are required, this may involve changes in land preparation, irrigation management, the addition of soil ameliorants and the use of additional measures to prevent land degradation.

APPENDIX 6

LIMITATION SUBCLASSES AND UMA CODES FOR IRRIGATED CROPS, MUNDUBBERA TO GAYNDAH

Climate

Effect
Frosts will suppress growth, kill plants and reduce yield.

Assessment
The incidence and severity of frosts relate to position in the landscape, which has been used to distinguish affected areas.

Subclass determination
Based on crop tolerance and local experience. Note that out of season cropping has not been considered. Summer-growing crops are in Class 1 because it is assumed they will not be grown in winter.

UMA CODES AND LIMITATION SUBCLASSES - CLIMATE

Crop/Land Use	Code C1 Nil to light frosts (hill tops)	Code C2 Regular frosts	Code C3 Severe frosts (channel benches, depressions, etc.)
Avocado	2	5	5
Citrus	1	3	4
Mango	2	5	5
Pecan	1	1	1
Stone fruits	1	1	1
Grapes	1	1	1
Vegetables	1	1	1
Cruciferae	1	1	1
Cucurbits	1	1	1
Asparagus	1	1	1
Potato	1	1	1
Peanut	1	1	1
Safflower	1	1	1
Sunflower	1	1	1
Navybean	1	1	1
Mungbean	1	1	1
Chickpea	1	1	1
Lucerne	1	1	1
Soybean	1	1	1
Summer grains	1	1	1
Winter grains	1	1	1
Pastures	-	-	-

Availability of soil water (m)

Effect
Plant yield will be decreased by periods of water stress particularly during critical growth periods.

Assessment
Plant available water capacity (PAWC) is based on predicted values (Gardner and Coughlan, 1982; Shaw and Yule, 1978). Generally, PAWC depends on soil texture and degree of structure in relation to the effective rooting depth. The effective rooting depth is taken to the depth of optimal water extraction, for example, tree crops 1-1.5 m, grapes and small crops 0.5 m, field crops 0.9 m.

Subclass determination

Subclass limits relate to PAWC and the frequency of irrigation needed, using spray or furrow irrigation only:

Subclass	PAWC	Irrig. Freq.
1	>100 mm	>10 days
2	5 to 100 mm	8 to 10 days
3	50 to 75 mm	5 to 8 days
4	<50 mm	<5 days

Subclass limits do not apply to microsprinkler or drip irrigation systems where small amounts of water are added frequently. This irrigation system has been assumed for all tree crops and grapes.

UMA CODES AND LIMITATION SUBCLASSES - SOIL MOISTURE

Crop/Land Use	M1				M2M3				M4				M5				M6			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Avocado	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Citrus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mango	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pecan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stone fruits	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Grapes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vegetables	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Cruciferae	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Cucurbits	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Asparagus	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Potato	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Peanut	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Safflower	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Sunflower	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Navybean	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Mungbean	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Chickpea	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Lucerne	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Soybean	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Summer grains	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Winter grains	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4
Pastures	1	1	2	3	2	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4

Notes

Codes:

M1 = Well structured clays and loamy soils
M2 = Massive porous earthy soils and fine sands
M3 = Duplex soils with loamy surfaces
M4 = Duplex soils with sandy surfaces
M5 = Uniform sandy soils
M6 = Uniform coarse sandy soils

Effective rooting depth: (a) >1 m, (b) 0.6 to 1 m, (c) 0.4 to 0.6 m, (d) <0.4 m.

Wetness (w)

Effect

Waterlogged soils reduce plant growth and cause problems with trafficability and the timing of cultivation.

Assessment

Subclasses are based on components of soil permeability and drainage as per McDonald *et al.* (1990). The subclasses have been split into three groups based on the rooting depths of crops: w1 - wetness to 1.5 m, w2 - wetness to 1.0 m, and w3 - wetness to 0.5 m. Indicators of internal drainage relate to texture, degree of structure, porosity, colour, mottles, segregations and impermeable layers. Slope and topographic position assess external drainage.

Subclass determination
Consultation, crop tolerance information, and the effects concerning delays in using machinery.

UMA CODES AND SUBCLASSES - WETNESS (permeability/drainage)

Crop/ Land Use	Depth Required	1/1	1/2	1/3	2/2	2/3	2/4	3/1	3/2	3/3	3/4	3/5	4/4	4/5	4/6
Avocado	w1 (0-1.5m)	5	5	5	5	5	4	5	5	5	3	1	3	2	1
Citrus	w2 (0-1m)	5	5	5	5	4	3	5	5	4	3	1	3	1	1
Mango	w2 (0-1m)	5	5	4	4	4	2	5	4	3	2	1	2	1	1
Pecan	w1 (0-1.5m)	5	5	5	5	4	3	5	5	4	3	1	3	1	1
Stone fruits	w1 (0-1.5m)	5	5	5	5	4	2	5	5	4	2	1	2	1	1
Grapes	w3 (0-0.5m)	5	5	4	5	4	2	5	5	3	1	1	1	1	1
Vegetables	w3 (0-0.5m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Cruciferae	w3 (0-0.5m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Cucurbits	w3 (0-0.5m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Asparagus	w3 (0-0.5m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Potato	w3 (0-0.5m)	5	5	5	5	3	2	5	5	4	2	1	2	1	1
Peanut	w3 (0-0.5m)	5	5	5	5	4	2	5	5	4	2	1	2	1	1
Safflower	w2 (0-1m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Sunflower	w2 (0-1m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Navybean	w3 (0-0.5m)	5	5	4	5	3	2	5	5	3	2	1	2	1	1
Mungbean	w2 (0-1m)	5	5	4	5	3	2	5	5	3	2	1	2	1	1
Chickpea	w2 (0-1m)	5	5	4	5	3	2	5	5	3	2	1	2	1	1
Lucerne	w2 (0-1m)	5	5	5	5	4	3	5	5	4	2	2	2	1	1
Soybean	w2 (0-1m)	5	5	4	5	3	2	5	5	3	1	1	1	1	1
Summer	w2 (0-1m)	5	5	4	5	3	1	5	5	3	1	1	1	1	1
grain	w2 (0-1m)	5	5	4	5	3	1	5	5	3	1	1	1	1	1
Winter grain		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pastures															

Permeability Ratings

1 Very slowly permeable .... K_{sat} <5mm/d
2 Slowly permeable .... K_{sat} 5-50mm/d
3 Moderately permeable .... K_{sat} 50-500mm/d
4 Highly permeable .... K_{sat} >500mm/d

Drainage Ratings

1 Very poorly drained .... Watertable near surface most of year
2 Poorly drained .... Seasonal ponding, perched watertable
3 Imperfectly drained .... Some horizons wet for several weeks
4 Moderately well drained .... Some horizons wet for one week
5 Well drained .... Some horizons wet for several days
6 Rapidly drained .... No horizon wet for more than several hours

Soil depth (d)

Effect
Shallow soils limit root proliferation and anchorage. Plants may be uprooted during strong winds.

Assessment
Effective soil depth: depth to decomposing rock, pan or impermeable layer.

Subclass determination
Consultation.

UMA CODES AND LIMITATION SUBCLASSES - SOIL DEPTH

Crop/Land Use	D1	D2	D3	D4
Tree crops	1	2	3	4
All other crops	1	1	1	1

Codes: Effective soil depth D1 >1m D2 = 0.6-1.0m D3 = 0.4-0.6m D4 <0.4m

Coarse fragments and rockiness (r)

Effect

Coarse (rock) fragments[1] and rock in the plough zone interfere with the efficient use of agricultural machinery and can cause damage. Surface rock interferes with the harvesting of some low growing crops such as soybean.

Assessment

Size and amount of coarse fragments or rock in the plough layer have been considered, together with machinery and farmer tolerance.

Subclass determination

Consultation, particularly related to farmer tolerances which are implicitly related to profitability and technological capability.

UMA CODES AND LIMITATION SUBCLASSES - COARSE FRAGMENTS AND ROCKINESS

Crop/Land Use	G1	G2	G3	G4	G5	C1	C2	C3	C4	C5	R1	R2	R3	R4	R5
Avocado	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Citrus	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Mango	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Pecan	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Stone fruits	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Grapes	1	1	1	2	3	1	1	2	3	4	1	2	3	4	4
Vegetables	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Cruciferae	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Cucurbits	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Asparagus	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Potato	3	4	5	5	5	4	5	5	5	5	3	4	5	5	5
Peanut	3	4	5	5	5	4	5	5	5	5	4	5	5	5	5
Safflower	1	2	3	4	5	2	3	4	5	5	3	4	5	5	5
Sunflower	1	2	3	4	5	2	3	4	5	5	3	4	5	5	5
Navybean	3	4	5	5	5	4	5	5	5	5	3	4	5	5	5
Mungbean	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Chickpea	3	4	5	5	5	4	5	5	5	5	4	5	5	5	5
Lucerne	2	3	4	5	5	3	4	5	5	5	4	5	5	5	5
Soybean	2	3	4	5	5	3	4	5	5	5	4	5	5	5	5
Summer grains	1	2	3	4	5	2	3	4	5	5	3	4	5	5	5
Winter grains	2	3	4	5	5	3	4	5	5	5	3	4	5	5	5
Pastures	1	1	1	2	3	1	1	2	3	4	2	3	4	5	5

Codes:
G = gravel 20-60 mm
C = cobble 60-200 mm
R = stone, boulders, etc. >200 mm; and rock

Quantity: 1 = <2% 2 = 2-10% 3 = 10-20% 4 = 20-50% 5 = >50%

[1] By definition (McDonald *et al.*, 1990), coarse fragments are particles greater than 2 mm and not continuous with underlying bedrock. Rock is defined as being continuous with bedrock.

Microrelief (g)

Effect
Microrelief refers to an uneven land surface, caused by gilgai, channels or gullies. Uneven crop productivity can be associated with irregular surface water distribution; for example water ponded in gilgai depressions. Large gilgai depressions, channels and gullies interfere with layout, and working the land.

Assessment
Microrelief vertical interval relates to the amount of levelling required. Levelling is required for efficient irrigation and surface drainage.

Subclass determination
Local opinion and consultation.

UMA CODES AND LIMITATION SUBCLASSES - MICRORELIEF

Crop/Land Use	G0, C0, Y0	G1, C1, Y1	G2, C2, Y2	G3, C3, Y3
Tree crops	1	3	4	5
All other crops	1	3	4	5

Codes:
G = gilgai — **0 = <0.1 m**
C = smooth-sided channels — **1 = 0.1 to 0.3 m**
Y = gullies — **2 = 0.3 to 0.6 m**
3 = >0.6 m

Soil physical condition (p)

Effect
1. *Nature of surface soil*. Germination and seedling development problems are associated with adverse conditions of the soil surface; such as hardsetting, crusting and coarse aggregates.

2. *Moisture range for cultivation*. This results in difficulties in achieving favourable tilth with machinery in soils with a narrow moisture range for working.

3. *Soil adherence*. Soil adheres to root crops and peanuts. This causes harvesting difficulties and reduces quality.

Assessment
Soil morphological properties such as texture, structure and consistency are evaluated and matched to crop requirements. Local experience indicates problems are associated with certain soils.

Subclass determination
1. Plant tolerance limits and requirements in relation to germination and harvesting, and supported by local experience.

2. Local opinion about the problem of narrow moisture range.

UMA CODES AND LIMITATION SUBCLASSES - SOIL PHYSICAL CONDITION

Crop/Land Use	P0	P1	P2	P3	P4	P5	P6	P7	P8
Avocado	1	1	1	1	1	1	1	1	1
Citrus	1	1	1	1	1	1	1	1	1
Mango	1	1	1	1	1	1	1	1	1
Pecan	1	1	1	1	1	1	1	1	1
Stone fruits	1	1	1	1	1	1	1	1	1
Grapes	1	1	1	1	1	1	1	1	1
Vegetables	1	1	1	1	1	2	2	1	3
Cruciferae	1	1	1	1	1	2	2	1	3
Cucurbits	1	1	1	1	1	2	2	1	3
Asparagus	1	1	1	1	1	2	2	1	3
Potato	1	1	2	2	2	3	2	3	3
Peanut	1	2	2	3	2	3	2	4	3
Safflower	1	1	2	1	2	3	2	1	3
Sunflower	1	1	2	1	2	3	2	1	3
Navybean	1	1	2	1	2	3	2	1	3
Mungbean	1	1	2	1	2	3	2	1	3
Chickpea	1	1	2	1	2	3	2	1	3
Lucerne	1	1	2	1	2	3	2	1	3
Soybean	1	1	2	1	3	3	2	1	3
Summer grains	1	1	1	1	1	2	2	1	3
Winter grains	1	1	1	1	2	3	2	1	3
Pastures	1	1	2	1	2	3	1	1	2

Codes:
P0 no soil physical limitations
P1 slightly adhesive soils
P2 massive hardsetting soils, moderately firm consistency
P3 moderately adhesive soils
P4 crusting clayey soils
P5 massive hardsetting soils, very firm consistency
P6 moderate moisture range for cultivation
P7 strongly adhesive soils
P8 narrow moisture range for cultivation

Secondary salinisation (s)

Effect

Secondary salinisation refers to salinity induced from rising watertables. Drainage through permeable soils, usually higher in the landscape, may cause secondary salinisation downslope.

Assessment

Recharge areas are determined by soil permeability and position in the landscape, and the affect that deep drainage losses may have on watertables downslope. High watertables may occur at discharge areas where there are impediments to through-flow of sub-surface water; for examples soils with heavy textured slowly permeable subsoils.

Subclass determination

Soil permeability and position in the landscape. More research is needed on hydraulic conductivity and groundwater measurements for a wide range of soils and landscapes.

UMA CODES AND LIMITATION SUBCLASSES - SECONDARY SALINISATION

Crop/Land Use	Code S0 No restriction	Code S1 High to moderately permeable soils acting as recharge areas and usually higher in the landscape	Code S2 Areas susceptible to development of secondary salinisation due to high watertables (discharge areas)
All crops	**1**	**0***	**4**

* **Recharge areas are not downgraded, because their recharge characteristics alone do not detract from the value of the land. "0" symbol is used to flag the fact that deep drainage may cause salinisation downslope.**

Erosion (e)

Effect

Land degradation and long term decline in productivity will occur on unprotected land because of excessive soil erosion.

Assessment

Soil loss will depend on soil erodibility as well as slope. This will also vary for each 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.

Subclass determination

Slope limits are determined in consultation with soil conservation extension and research personnel, and extension and research agronomists. The implications of the subclasses are:

Subclass 1	surveyed row direction only required
Subclass 2	conventional parallel structures required
Subclass 3	Subclass 2 measures, and some surface management practices. A range of options aimed at minimum soil disturbance, combined with the retention of harvest residue material as a surface cover
Subclass 4 & 5	non-arable land

In the following tables, the slope categories for each of the five soil groups is a key component in determining the limitation subclasses of each crop/land use.

UMA CODES AND LIMITATION SUBCLASSES - EROSION (a)

Uniform sands (S) Uniform coarse sands (K) Massive gradational soils (E)

Crop/Land Use	S1, K2, E1 <1%	S2, K2, E2 1-2%	S3, K3, E3 2-5%	S4, K4, E4 5-8%	S5, K5, E5 8-12%	S6, K6, E6 >12%
Avocado	1	1	1	2	3	5
Citrus	1	1	1	2	3	5
Mango	1	1	1	2	3	5
Pecan	1	1	1	2	3	5
Stone fruits	1	1	1	2	3	5
Grapes	1	1	1	2	3	5
Vegetables	1	1	2	3	4	5
Cruciferae	1	1	2	3	4	5
Cucurbits	1	1	2	3	4	5
Asparagus	1	1	2	3	4	5
Potato	1	2	3	4	5	5
Peanut	1	2	3	4	5	5
Safflower	1	2	3	4	5	5
Sunflower	1	2	3	4	5	5
Navybean	1	2	3	4	5	5
Mungbean	1	2	3	4	5	5
Chickpea	1	2	3	4	5	5
Lucerne	1	1	2	3	4	5
Soybean	1	2	3	4	5	5
Summer grains	1	1	2	3	4	5
Winter grains	1	1	2	3	4	5
Pastures	1	1	1	2	3	5
Furrow irrigation	s	s	4	5	5	5

UMA CODES AND LIMITATION SUBCLASSES - EROSION (b)

Structured loamy to clayey soils (P)

Crop/Land Use	P1 <1%	P2 1-2%	P3 2-4%	P4 4-8%	P5 8-10%	P6 >10%
Avocado	1	1	1	2	3	5
Citrus	1	1	1	2	3	5
Mango	1	1	1	2	3	5
Pecan	1	1	1	2	3	5
Stone fruits	1	1	1	2	3	5
Grapes	1	1	1	2	3	5
Vegetables	1	1	2	3	4	5
Cruciferae	1	1	2	3	4	5
Cucurbits	1	1	2	3	4	5
Asparagus	1	1	2	3	4	5
Potato	1	2	3	4	5	5
Peanut	1	2	3	4	5	5
Safflower	1	2	3	4	5	5
Sunflower	1	2	3	4	5	5
Navybean	1	2	3	4	5	5
Mungbean	1	2	3	4	5	5
Chickpea	1	2	3	4	5	5
Lucerne	1	1	2	3	4	5
Soybean	1	2	3	4	5	5
Summer grains	1	1	2	3	4	5
Winter grains	1	1	2	3	4	5
Pastures	1	1	1	2	3	5
Furrow irrigation	s	s	4	5	5	5

UMA CODES AND LIMITATION SUBCLASSES - EROSION (c)

Cracking clay soils (C)

Crop/Land Use	C1 <1%	C2 1-2%	C3 2-4%	C4 4-6%	C5 6-8%	C6 >8%
Avocado	1	1	1	2	3	5
Citrus	1	1	1	2	3	5
Mango	1	1	1	2	3	5
Pecan	1	1	1	2	3	5
Stone fruits	1	1	1	2	3	5
Grapes	1	1	1	2	3	5
Vegetables	1	1	2	3	4	5
Cruciferae	1	1	2	3	4	5
Cucurbits	1	1	2	3	4	5
Asparagus	1	1	2	3	4	5
Potato	1	2	3	4	5	5
Peanut	1	2	3	4	5	5
Safflower	1	2	3	4	5	5
Sunflower	1	2	3	4	5	5
Navybean	1	2	3	4	5	5
Mungbean	1	2	3	4	5	5
Chickpea	1	2	3	4	5	5
Lucerne	1	1	2	3	4	5
Soybean	1	2	3	4	5	5
Summer grains	1	1	2	3	4	5
Winter grains	1	1	2	3	4	5
Pastures	1	1	1	2	3	5
Furrow irrigation	s	s	4	5	5	5

UMA CODES AND LIMITATION SUBCLASSES - EROSION (d)

Duplex soils with loamy surfaces (T)

Crop/Land Use	T1 0%	T2 0-1%	T3 1-2%	T4 2-4%	T5 4-6%	T6 >6%
Avocado	1	2	2	3	4	5
Citrus	1	2	2	3	4	5
Mango	1	2	2	3	4	5
Pecan	1	2	2	3	4	5
Stone fruits	1	2	2	3	4	5
Grapes	1	2	2	3	4	5
Vegetables	1	3	4	5	5	5
Cruciferae	1	3	4	5	5	5
Cucurbits	1	3	4	5	5	5
Asparagus	1	3	4	5	5	5
Potato	1	4	5	5	5	5
Peanut	1	4	5	5	5	5
Safflower	1	4	5	5	5	5
Sunflower	1	4	5	5	5	5
Navybean	1	4	5	5	5	5
Mungbean	1	4	5	5	5	5
Chickpea	1	4	5	5	5	5
Lucerne	1	3	4	5	5	5
Soybean	1	4	5	5	5	5
Summer grains	1	3	4	5	5	5
Winter grains	1	3	4	5	5	5
Pastures	1	2	2	3	4	5
Furrow irrigation	s	s	4	5	5	5

UMA CODES AND LIMITATION SUBCLASSES - EROSION (e)

Duplex soils with sandy surfaces (D)

Crop/Land Use	D1 0%	D2 0-2%	D3 2-4%	D4 4-6%	D5 6-8%	D6 >8%
Avocado	1	1	2	3	4	5
Citrus	1	1	2	3	4	5
Mango	1	1	2	3	4	5
Pecan	1	1	2	3	4	5
Stone fruits	1	1	2	3	4	5
Grapes	1	1	2	3	4	5
Vegetables	1	2	3	4	5	5
Cruciferae	1	2	3	4	5	5
Cucurbits	1	2	3	4	5	5
Asparagus	1	2	3	4	5	5
Potato	1	3	4	5	5	5
Peanut	1	3	4	5	5	5
Safflower	1	3	4	5	5	5
Sunflower	1	3	4	5	5	5
Navybean	1	3	4	5	5	5
Mungbean	1	3	4	5	5	5
Chickpea	1	3	4	5	5	5
Lucerne	1	2	3	4	5	5
Soybean	1	3	4	5	5	5
Summer grains	1	2	3	4	5	5
Winter grains	1	2	3	4	5	5
Pastures	1	1	2	3	4	5
Furrow irrigation	s	4	5	5	5	5

Furrow infiltration (i)

Effect
The amount of irrigation water applied, particularly in furrow irrigation, must match the infiltration characteristics of the soil to minimise deep drainage and runoff. The infiltration characteristics also determine the most suitable furrow length. Additional management requirements are associated with short furrows, whereas waterlogging occurs in the upper end of furrows if furrow lengths are too long. Furrow gradient affects soil erosion if the gradient is very steep.

Assessment
Based on soil permeability and slope. Permeability is assessed using texture, degree and grade of structure, sodicity, pH and the salt bulge if any.

Subclass determination
Consultation.

Soil permeability is determined in relation to excessive water loss or additional management requirements. Hydraulic conductivity measurements are required for better estimations.

Slope is considered mainly in relation to excessive soil loss from irrigation. Furrow irrigation is not recommended on slopes >1% for duplex soils and >2% for other soils. When irrigating across steeper slopes, slopes in the direction of irrigation should not be >0.5% for duplex soils and not >1% for other soils. Slope limits need further substantiation for each soil, crop and management system.

UMA CODES AND LIMITATION SUBCLASSES - FURROW IRRIGATION

Limitation	Suitability (All crops)
(a) Permeability	
Code I1 Slowly permeable soils which are strongly sodic (ESP ≥15), strongly alkaline (pH >8.5) or with salt bulge at 1 m.	**(suitable)**
Code I2 Soils which are sodic (ESP 6 to 14), moderately alkaline (pH 7.5 to 8.5), and low in salt at 1 m.	**4**
Code I3 Permeable soils which are non-sodic (ESP <6), acid to neutral (pH <7.5), low in salts, or have sandy textures at 1 m.	**5**
(b) Slope	
Duplex soils <1%	**(suitable)**
Duplex soils 1-2%	**4**
Duplex soils >2%	**5**
Other soils <2%	**(suitable)**
Other soils 2-4%	**4**
Other soils >4%	**5**