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SOILS OF THE BILOELA RESEARCH STATION, QUEENSLAND

P. G. Shields
Land Resources Branch

Department of Primary Industries
Queensland Government

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SUMMARY

The Biloela Research Station is situated in the Callide Valley of central Queensland, approximately 100 km south-west of Gladstone. Current research on the 240 ha station includes plant breeding, crop variety testing, crop nutritional work, weed control research and soil management studies.

The boundaries enclose part of an extensive alluvial plain and a small area of gently undulating rises. The rises have developed on Tertiary sedimentary rocks while subsequent Quaternary deposition has resulted in an alluvial plain covering the lower landscape positions.

A very high intensity grid survey (scale 1:5 000) was undertaken to identify and map the soils present. Six soil types, including one gravelly phase, were identified and are described in detail. A grey and brown massive earth, a dark non-cracking clay to duplex soil and a black earth occur on the levees transecting the alluvial plain. Another black earth and two dark non-cracking clays occupy the intervening flats and drainage depressions. A number of very shallow and stony, miscellaneous soils were also delineated on the gently undulating rises. Soil distribution is shown on the accompanying map.

The soils of the alluvial plain are non-saline and non-sodic. They have similar levels of plant nutrients in the surface soil with only organic carbon and total nitrogen reserves being low. Levels of exchangeable cations are adequate throughout all profiles and the soil cation exchange capacities are also considered adequate to retain these nutrients against leaching.

The soil physical characteristics are more variable. Particle size analysis reveals two distinct groups with one having less clay and silt and more fine sand than the other. The condition of the surface soil and subsoil structure also vary. Three groups can be identified on the basis of plant available water capacity but different groups are obtained when considering deep drainage characteristics.

The implications for designing field trials are discussed.

1. INTRODUCTION

1.1 Location and history

The Biloela Research Station is situated in the Callide Valley of central Queensland, approximately 100 km south-west of Gladstone (Figure 1).

The station was established in 1924 as the Callide Cotton Research Station. It was initially developed as a demonstration farm to show new settlers appropriate cotton management practices for the soils of the Callide alluvium. This initial role soon expanded into an investigation of all potential crops for the area (McTaggart 1987).

The station now comprises 240 ha of which 150 ha can be irrigated from shallow aquifers. The current research programme includes:

- Cotton and sorghum plant breeding;
- Summer and winter crop variety testing;
- Crop nutritional work;
- Weed control research;
- Soil management studies;
- Insect research;
- Pig research; and
- Agricultural engineering development.

1.2 Aims of the survey

The aims of this survey were to describe and map the soils of the research station and to comment on their homogeneity for experimentation. Previously published soils data are of insufficient detail for this purpose. A comprehensive soils report also allows more precise comparison of the soils with those of the surrounding district serviced by the station.

2. CLIMATE

Rainfall is the major climatic element determining plant growth. The mean annual rainfall recorded for the 60 year period 1924 to 1984 at Biloela Research Station is 699 mm. Mean monthly values are presented in Table 1.

Table 1. Mean rainfall, mean pan evaporation and 9 am relative humidity for Biloela Research Station

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean rainfall (mm)	106	110	64	38	41	37	30	21	23	51	80	97	699
Mean pan evaporation (mm)	217	175	170	147	112	84	87	115	150	195	210	236	1898
9am relative humidity (%)	64	68	67	65	69	72	70	65	58	57	59	60	

Source: Bureau of Meteorology

Annual totals are highly variable, due to the convective origin of much of the rainfall and the sporadic incidence of rainfall depressions associated with tropical cyclones. This is evident in Figure 2 which shows the rainfall values equalled or exceeded in one in ten years, five in ten years (median) and nine in ten years.

Figure 2 also demonstrates a marked seasonal distribution. Median rainfall for the six warmer months, October to March, represents 69% of the median value for the entire 12 month period beginning in October.

The EI_{30} rainfall erosion index has been calculated for the research station by Rosenthal and White (1980). The index is a function of total storm energy and the maximum 30 minute rainfall intensity of the storm. The average annual EI_{30} and the average monthly figures, expressed as a percentage of the annual index, are given in Table 2. Compared with similar agricultural centres further south the annual value is lower than for Kingaroy (EI_{30} of 283) but higher than both Dalby (174) and Inverell (200).

Table 2. Average annual erosion index (EI_{30}) and average monthly index for Biloela Research Station

Average monthly erosion index as a percentage of average annual EI_{30}												Average annual EI_{30}
J	F	M	A	M	J	J	A	S	O	N	D	
16.1	19.5	8.7	2.3	2.8	3.0	1.2	0.8	2.0	8.6	16.0	19.0	245

Source: Rosenthal and White (1980)

Locality Map

BILOELA RESEARCH STATION

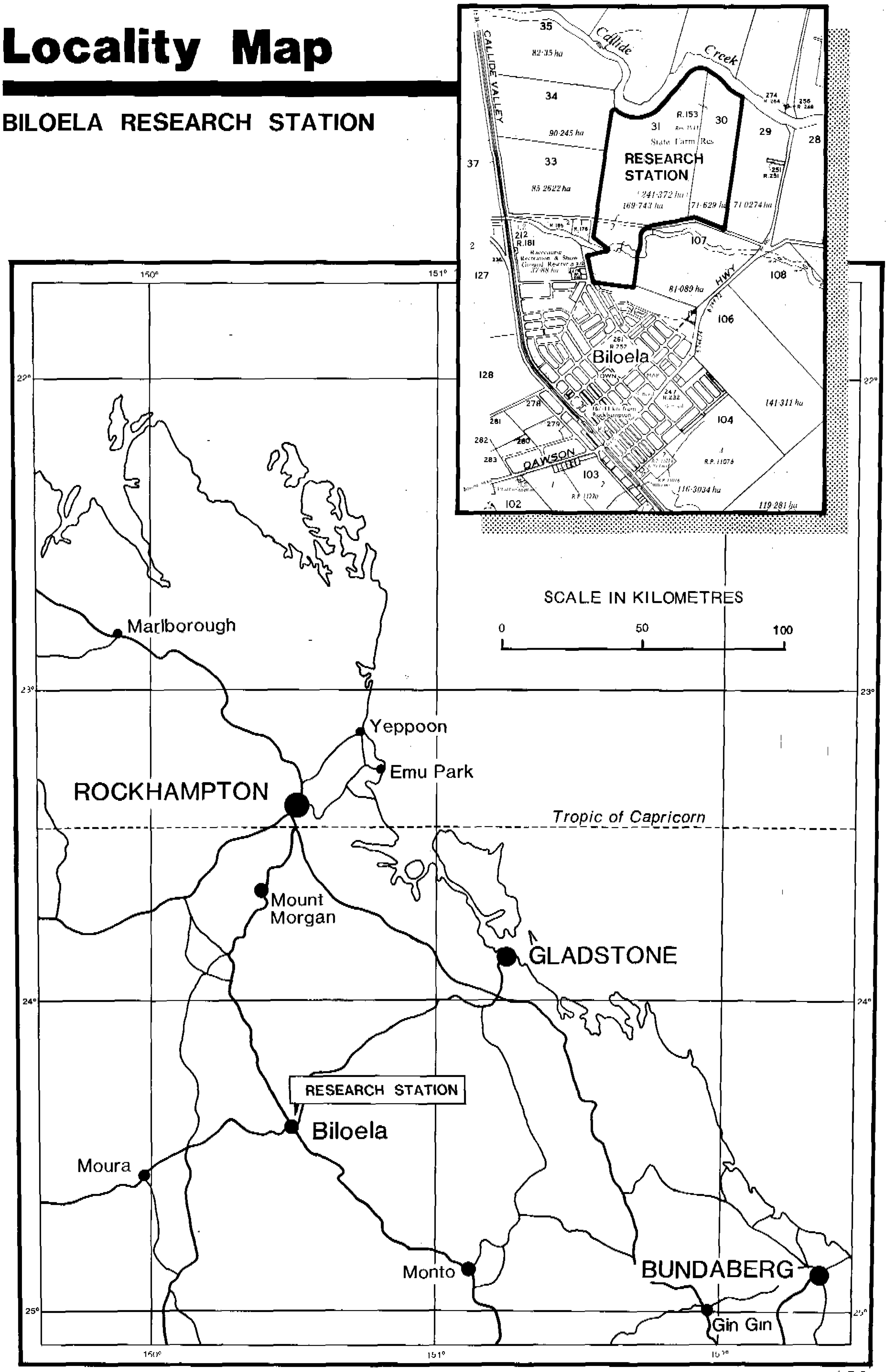


Figure 1

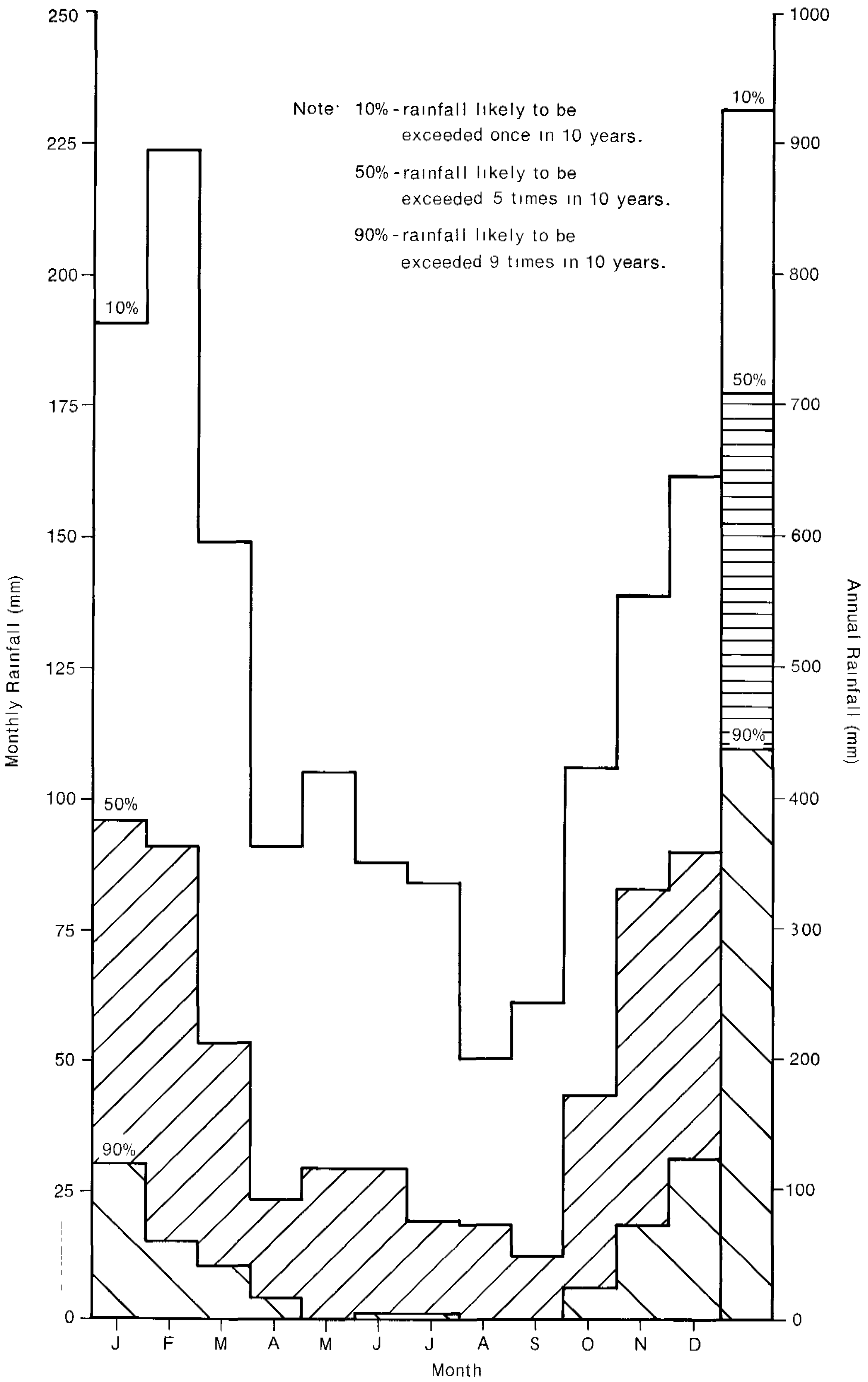
Temperature data are given in Table 3 for the research station. Between October and March an average 26 days experience maximum temperatures of at least 35oC but very few days are likely to reach 38oC. Skerman (1958) showed that heat waves (three consecutive days with temperatures over 37.8oC) adversely affect grain sorghum. The probability of heat waves occurring at Biloela is remote. An average 21 days have minimum temperatures of less than 2oC between May and September. At screen temperatures of 2oC, light frosts can be expected. The eight days with minimum temperatures less than 0oC represent the average number of heavy frosts which occur.

Table 3. Temperature data for Biloela Research Station for the period 1965 to 1986

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Av Max (oC)	33.0	31.9	31.1	28.7	25.2	22.1	21.8	23.8	26.9	29.7	31.7	32.9	28.2
Av Min (oC)	19.7	19.4	17.6	13.3	9.4	6.3	5.0	5.2	8.4	13.1	16.3	18.3	12.7
Average days with –													
Max =>35 (oC)	8	5	2							1	4	7	26
Max =>38 (oC)	1	1									1	1	3
Min <2 (oC)					1	5	9	5	1				21
Min <0 (oC)						1	4	2					8

Source: Bureau of Meteorology

Relative humidity and pan evaporation data are presented in Table 1. The mean monthly pan evaporation exceeds mean rainfall in all months.



Source Bureau of Meteorology

Figure 2 Monthly and annual rainfall variability at Biloela Research Station.

3. GEOLOGY AND LANDFORM

3.1 Geology

The geology of the Callide Valley has been described by Dear *et al.* (1971). The valley may have formed as a result of fault movements during the Tertiary period (65 to 1.8 million years before present).

A thick sequence of flat-lying sediments was deposited during this period. The office and glasshouse complex are situated on this sequence. The sedimentary rocks are soft and consist mostly of grey clay shale and white to buff quartz sandstone. Minor pebble conglomerate and thin coal seams have also been reported.

Subsequent fluvial action resulted in deposits of clay, sand and gravel forming an extensive alluvial plain across the lower parts of the landscape. The research station is mainly sited on these Quaternary sediments (1.8 million years to present). Their maximum thickness is approximately 25 m.

3.2 Landform

The flat-lying Tertiary rocks form gently undulating rises with predominantly 2 to 3% slopes. Elevation varies between approximately 180 and 190 m. The Washpool Gully forms their northern border and also marks the southern limit of the alluvial plain.

The alluvial plain has an elevation of approximately 170 m. Callide Creek dissects the plain and forms the northern boundary of the research station. Between Callide Creek and the Washpool Gully are a series of levees separated occasionally by intervening flats. One flat contains a lower lying, run-on area most appropriately described as a backplain. Several open drainage depressions also transect the area.

Three of the drainage depressions have the position, direction, shape and deep incision similar to stream channels. They appear to be former courses, either main channels or overflow channels, of Callide Creek.

4. HYDROLOGY

The research station is drained by Callide Creek and, to a lesser extent, Washpool Gully. Queensland Water Resources Commission records indicate that Callide Creek has overtopped its banks only twice at Biloela since the station was established. The Washpool Gully has not caused flooding on the station.

Underground water resources are available in the recent (Quaternary) alluvial deposits which overlie the Tertiary sedimentary rocks. Their most important aquifer consists of clean gravel and sand and attains a maximum thickness of 9 m (Dear *et al.* 1971).

The standing water level varies between 8 and 12 m below ground level. Water quality is indicated for four bores in Table 4. Gill (1984) developed a scheme for classifying the quality of water for irrigation in Queensland. According to this scheme, all four bores have water suitable for irrigating all crops except tobacco, and they have no sodium problem.

Table 4. Water quality data (sampled 2/7/85) for four bores on the station

Measurement	Unit	Bore number			
		33557	34284	34286	62940
Conductivity[a] (corrected)	$dS\ m^{-1}$	520	520	500	640
Cations	$meq\ L^{-1}$				
Ca^{++}		2.84	2.69	2.25	2.99
Mg^{++}		2.06	2.06	1.73	2.55
Na^{+}		2.35	2.44	2.52	2.65
Anions	$meq\ L^{-1}$				
HCO_3^-		3.09	2.99	2.79	3.79
CO_3^{--}		0.01	0.01	0.01	0
Cl^-		3.81	4.09	3.67	4.37
Residual alkali[a]	$meq\ L^{-1}$	0	0	0	0
Sodium adsorption ratio[a] (corrected)		2.3	1.7	1.9	2.3

[a] For definition of these terms see Gill (1984)

Source: Queensland Water Resources Commission

5. VEGETATION

Speck (1968) has described the vegetation of the Callide Valley. The research station has been extensively cleared and only remnants of the native vegetation occur.

Scattered trees of brigalow *(Acacia harpophylla)* and narrow leaf bottle tree *(Brachychiton rupestris)* remain on the gently undulating rises as well as isolated clumps of narrow leaved ironbark *(Eucalyptus crebra)*, variable bark bloodwood *(E. erythrophloia)* and Moreton Bay ash *(E. tessellaris)*.

The levees of the alluvial plain contain isolated trees of Queensland blue gum *(E. tereticornis)*, Moreton Bay ash, silver leaved ironbark (*E. melanophloia*) and sally wattle *(A. salicina)*.

The vegetation fringing Callide Creek and the Washpool Gully includes Queensland blue gum, Moreton Bay ash, silver leaved ironbark, sally wattle, long fruited bloodwood *(E. polycarpa)*, snow-in-summer *(Melaleuca linariifolia)*, black teatree *(M. bracteata)*, river sheoak *(Casuarina cunninghamii)*, weeping bottle brush *(Callistemon viminalis)* and bauhinia *(Lysiphyllum hookeri)*. Minor softwood species such as figs *(Ficus spp.)*, white cedar *(Melia azederach)* and boonaree *(Heterodendrum oleifolium)* also occur on Callide Creek.

6. SOIL SURVEY METHOD

The scale of published soil maps should be determined by the purpose of the survey (McDonald 1975). The density of ground observations should then be appropriate for the selected scale. Biloela Research Station is used for small plot experiments such as plant breeding, crop variety testing and weed control research. A very high intensity mapping scale (1:10 000 or larger) was therefore chosen for the alluvial plain where experimentation is carried out.

Ground observations were recorded every 100 m along fixed traverses set 100 m apart. The distance between observations was varied where necessary to avoid highly disturbed sites. Sites were described according to McDonald *et al.*(1984). Soil profiles were described to a depth of 1.5 m or gravel, whichever occurred first.

The site descriptions were sorted into three landscape units and six soil types (see section 7.2). The six soils were then mapped on air photos (scale 1:5 000). Additional ground observations were taken to verify map boundaries. A total of 199 ground observations were recorded on the alluvial plain at a frequency of one per 1.1 ha.

Only two sites were described on the gently undulating rises giving an approximate density of one per 6 ha. Field plot experimentation is not carried out on this area.

7. SOILS - MORPHOLOGY, CLASSIFICATION AND DISTRIBUTION

7.1 Previously published soils data

Isbell (1954) prepared a reconnaissance soil map of the Callide Valley at a scale of approximately 1:250 000. Soil associations were also delineated by landscapes as part of the Atlas of Australian Soils (Isbell *et al.* 1967). Mapping scale was 1:2 000 000. Sweeney (1968) identified soil families of the Dawson-Fitzroy area but did not delineate them on a map.

7.2 Definition and description of soil types

Six soil types, a soil phase and one group of miscellaneous soils were identified.

A soil type is a three-dimensional soil body. Any profile within this body has a similar number and arrangement of major horizons whose attributes, primarily morphological, are within a defined range. All profiles within the soil type have similar parent materials. A soil phase is a subdivision of the soil type based on attributes which have notable significance in the use of the soil (R.C. McDonald, personal communication).

A few soils were not adequately described and named as soil types because of their negligible agricultural value and extent. They are referred to as miscellaneous soils.

A detailed description and classification of the soil types are given in Table 5. The conventions used in Table 5 are explained in Appendix 1.

7.3 Relationship between soils

The soils have been arranged into three landscape units on the basis of landform and parent material.

7.3.1 Soils of the very gently to gently undulating levees

Hodge, **Callide** and **Woodall** soil types occur on the levees transecting the alluvial plain. **Hodge** is situated adjacent to Callide Creek, **Woodall** occurs in close proximity to the Washpool Gully and **Callide** occupies the levees in between. All three have a neutral to alkaline soil reaction trend and overlie similar buried layers (D horizons). Profile development appears to increase with distance from Callide Creek.

Hodge is a dark, grey or brown gradational soil with hard setting sandy clay loam to clay loam, sandy surface soil (A horizons) and massive to moderately pedal sandy clay subsoil (B horizons) and medium sized sand grains (Northcote 1979,p.26) are evident throughout the profile.

Callide is a dark, gradational soil, duplex soil or non-cracking clay. The sandy clay loam to light medium clay surface soil either hardsets or crusts; the light medium clay to heavy clay subsoil is moderately pedal and medium to fine sand occurs throughout the profile.

Table 5. Detailed description and classification of the soils

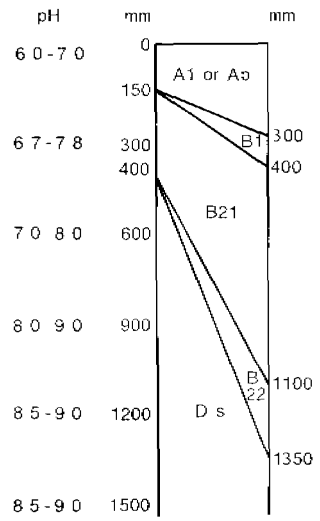
Soil type	PPF		Description	Landscape unit	Vegetation
Hodge	Gn 2.82P Gn 2.83P Gn 2.43P Gn 3.42 Gn 3.43P		<u>Grey and brown massive earth and minimal prairie soil</u> Hardsetting surface, may have very few subrounded coarse gravels A1 or Ap - dark (5 YR to 10 YR 3/1, 3/2), grey-brown to grey (dry); sandy clay loam to clay loam, sandy; massive to weak 2 to 5 mm subangular blocky; dry moderately firm; may have few subrounded fine gravels; gradual to diffuse to - B1 (where present) - dark (7.5 YR 2/1); clay loam, sandy; weak subangular blocky; moderately moist moderately firm; gradual to - B21 - grey-brown to dark or brown (5 YR to 10 YR 4/1, 4/2, 3/1, or 10 YR 3/3); may have few fine distinct brown mottles; clay loam, sandy to sandy clay; massive to moderate structure; dry moderately firm; clear to gradual to - B22 (where present) - mottled grey-brown to dark and brown (7.5 YR, 10 YR 2/1, 3/1 and 3/3) sandy clay; massive to moderate structure, dry moderately firm; may have very few medium soft carbonate; clear to gradual to - D's - grey-brown, brown or dark (5 YR, 7.5 YR 3/1, 3/2, 4/1, 4/3), may have 50% mottles; loamy sand to sandy, medium clay or fine sandy clay; dry very weak to very firm; may have few fine soft carbonate; may have few subrounded fine gravels <u>Comments</u>: The profiles with dark B2 horizons generally have a stronger grade of pedality. <u>Variant</u>: The A1 horizon may have moderate grade of pedality and abruptly overlie D horizons (Um 6.21).	Very gently to gently undulating levees; slopes 0.5 to 3%	Completely cleared

Table 5 continued

Soil type	PPF	Description	Landscape unit	Vegetation
Callide	Uf 6.32 Uf 6.32P Dd 1.13 Dd 2.12P Gn 3.42P Uf 6.42P	<u>Dark, neutral to alkaline, non-cracking clay, duplex soil and gradational soil</u>: Hard setting (coarser textures) or surface crust (finer textures); may have few subrounded medium to coarse gravels Ap or A1 - dark to grey-brown (5 YR, 7.5 YR 2/1, 2/2, 3/1, 3/2, 4/1, 4/2), grey-brown (dry), sandy clay loam to fine sandy, light medium clay; massive to weak 2 to 5 mm subangular blocky; dry moderately firm to moderately strong; abrupt to gradual to - B1 (where present) - dark to grey-brown (5 YR, 7.5 YR 2/1, 3/1, 4/2), may have few fine distinct brown mottles, sandy clay to fine sandy, light medium clay; dry very firm, clear to gradual to - B21 - dark to grey-brown (5 YR, 7.5 YR 2/1, 2/2, 3/1, 3/2, 4/1, 4/2), may have many fine to medium distinct brown mottles; sandy, light medium clay to fine sandy, heavy clay; moderately moist very firm to moderately strong; may have few subrounded fine gravels; clear to diffuse to - B22? (where present) - mottled dark to grey-brown and yellow-brown to red-brown (5 YR, 7.5 YR 2/1, 3/1, 3/2, 4/1, 4/2 and 3/3, 4/3, 4/4, 5/4, 5/3); fine sandy, light medium clay to sandy, heavy clay; dry very firm to very strong; may have few subrounded fine gravels; may have few fine to coarse nodular and soft carbonate; clear to diffuse to - D's (where present) - either whole coloured or mottled, red-brown to yellow-brown or grey brown to dark (5 YR, 7.5 YR 4/3, 4/4, 5/3, 5/4, 5/6, 3/1, 3/2, 4/1, 4/2); coarse sand to sandy, medium clay or light medium clay to heavy clay; may have few subrounded fine to medium gravels; may have many fine to coarse soft and nodular carbonate <u>Comments</u>: Fine sand or sand is present in the Ap or A1 horizon and is common in the B21 and B22? horizons. The B22? horizon appears to form a transition layer from the B21 to the D horizons. The D horizons are recognised by either substantial decrease in texture, often associated with a change in the size of sand present, or by a change to clay layers with no sand present at all. <u>Phase</u>: A gravelly phase, with very few to many subrounded fine to medium gravels in the A, B1, B2 horizons and with few to very abundant subrounded fine to medium gravels in the D horizons, occurs in the north-east of the study area.	Very gently to gently undulating levees; slopes 0.5 to 3%	Extensively cleared; isolated Queensland blue gum, Moreton Bay ash, silver leaved ironbark and sally wattle trees

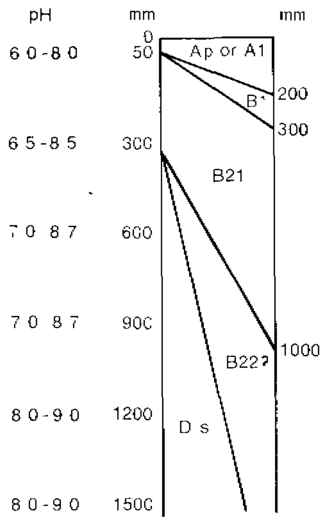


Table 5 continued

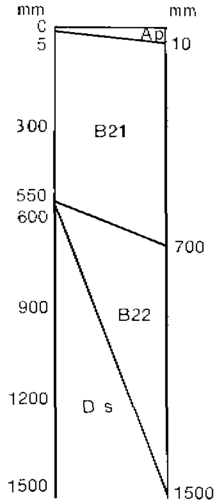
Soil type	PPF	Description	Landscape unit	Vegetation
Woodall	Ug 5.16P Ug 5.17P Ug 5.1P pH 6 3 8 7 8 0-8 5 8 0 8 7 8 5-8 7 8 5 8 7 8 5 8 7 	Black earth: Self-mulching surface and seasonally cracking; gilgai microrelief absent Ap - dark (5 YR, 7.5 YR 2/1, 2/2, 3/1), grey-brown to grey (dry); light medium clay to medium heavy clay; weak to moderate 10 to 20 mm subangular blocky breaking to strong 2 to 5 mm subangular blocky; dry loose; abrupt to clear to - B21 - dark (5 YR, 7.5 YR 2/1, 3/1, 3/2), rarely with few fine distinct brown mottles, medium heavy clay to heavy clay; moderate angular blocky; dry very firm to moderately strong; clear to diffuse to - B22 (where present) - dark to grey-brown (5 YR, 7.5 YR 3/1, 4/1), few fine distinct brown mottles; medium clay to medium heavy clay; moderate lenticular; dry very firm to moderately strong; usually with few to common fine to medium soft and nodular carbonate. D's (where present) - mottled grey-brown with dark or brown (7.5 YR, 5 YR 4/1, 4/2, 3/1, 4/3); sandy clay loam to fine sandy, medium clay; dry moderately firm to moderately strong; very few to common fine to medium soft and nodular carbonate Comments: Some profiles have only incipient seasonal cracking and can be classified Uf 6.32.	Very gently to gently undulating levees; slopes to 0.5 to 6%	Completely cleared

Table 5 continued

Soil type	PPF	Description	Landscape unit	Vegetation
Tognolini	Ug 5.15P Ug 5.16P Ug 5.17P Ug 5.1P Uf 6.32P	<ins>Black earth and dark, non-cracking clay</ins>. Surface crust, usually mulches when disturbed; often seasonally cracking; gilgai microrelief absent Ap - dark (5 YR, 7.5 YR 2/1, 2/2, 3/1, 3/2), grey-brown to grey (dry); light medium clay to heavy clay; weak to moderate 5 to 20 mm subangular blocky breaking to moderate to strong 2 to 5 mm subangular blocky; dry very firm to moderately strong (crust); clear to gradual to - B21 - dark (5 YR, 7.5 YR 2/1, 2/2, 3/1); medium clay to heavy clay; may have few fine to medium distinct brown mottles; moderate 10 to 20 mm angular blocky becoming lenticular with depth; moderately moist very firm; may have few subrounded fine gravels; clear to diffuse to - B22 (where present) - mottled dark to grey-brown with brown to red-brown (5 YR, 7.5 YR 2/2, 3/1, 3/2, 4/1, 4/2 and 3/4, 4/3, 4/4), occasionally whole coloured dark; meaium clay to heavy clay; moderate pedality, moderately moist very firm; very few to common fine to coarse soft and nodular carbonate, may have few subrounded fine to medium gravels; clear to diffuse to - D's (where present) - mottled dark to grey-brown with yellow-brown to red-brown (5 YR, 7.5 YR 2/1, 3/1, 4/1 and 4/3, 4/4, 5/4); sandy clay to fine sandy, medium heavy clay; dry very firm to moderately strong; may have common fine to coarse soft and nodular carbonate, may have few subrounded fine gravels <ins>Comments</ins>: Fine sand and sand may occur in the B21, B22 horizons. Rarely, a dark, whole coloured heavy clay D may occur below the mottled B22.	Intervening alluvial flats and drainage depressions; slopes 0 to 0.5% (Shallow, open drainage depression and backplain)	Completely cleared

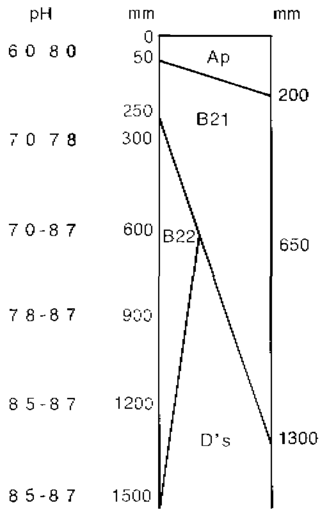


Table 5 continued

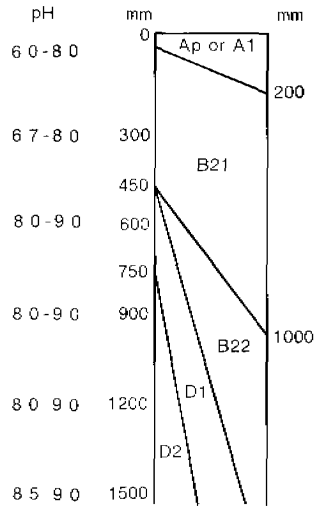
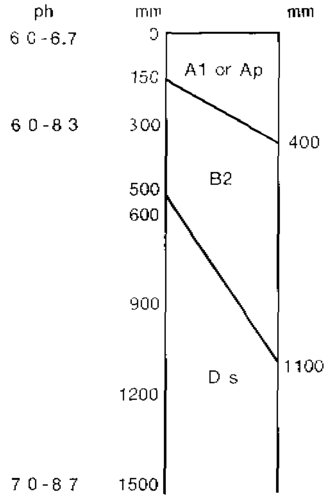
Soil type	PPF	Description	Landscape unit	Vegetation
Melton	Uf 6.32P Uf 6.32 	<u>Dark non-cracking clay</u>: Surface crust; may have few medium subrounded gravels on surface Ap or A1 - dark to grey-brown (5 YR, 7.5 YR 2/1, 2/2, 3/1, 4/1), grey-brown to grey (dry); light medium clay to heavy clay; dry very firm to moderately strong; abrupt to gradual to - B21 - dark (5 YR, 7.5 YR, 10 YR 2/1, 2/2, 3/1), may have few fine distinct brown mottles; medium-heavy clay to heavy clay; moderately moist very firm; may have very few subrounded fine gravels; clear to diffuse to - B22 (where present) - mottled dark to grey-brown with brown to red-brown (5 YR, 7.5 YR 3/1, 4/1, 4/2 and 4/3, 4/4); medium clay to heavy clay; moderately moist very firm to moderately strong; may have very few subrounded fine gravels; very few to common fine nodular and soft carbonate; clear to gradual to - D1 (where present) - either mottled or whole coloured, red-brown to grey-brown and dark (5 YR, 7.5 YR 4/3, 4/4 and 3/1, 4/1); sandy clay to fine sandy, medium heavy clay; moderately moist very firm to moderately strong, may have few fine to medium subrounded gravels; may have few to common fine to medium soft and nodular carbonate; clear to gradual to - D2 (where present) - dark to grey-brown (5 YR, 7.5 YR 2/1, 4/1, 4/2), may have 50% fine distinct brown mottles; light medium clay to medium heavy clay; moderately moist very firm to moderately strong; may have many fine subrounded gravels, may have few medium to coarse soft and nodular carbonate <u>Comments</u>: Fine sand or sand may be present in the A and B21 horizons where adjacent to levee footslopes with Callide soil. <u>Variant</u>: Occasionally the B22 may be whole-coloured and dark.	Intervening alluvial flats and drainage depressions; slopes 0 to 1% (Alluvial flat)	Completely cleared

Table 5 continued

Soil type	PPF		Description	Landscape unit	Vegetation
Channel	Uf 6.32 Uf 6.32P Uf 6.41		<u>Dark non-cracking clay</u>: Surface crust A1 or Ap - dark (5 YR, 7.5 YR 2/1, 2/2, 3/1), grey-brown (dry), light clay to medium heavy clay; weak to moderate 10 to 20 mm blocky breaking to moderate 2 to 5 mm subangular blocky; dry very firm; gradual to diffuse to - B2 - dark (5 YR, 7.5 YR 2/1, 2/2, 3/1, 3/2), may have 20% fine distinct brown mottles; light medium clay to heavy clay; moderate to weak 10 to 20 mm blocky; moderately moist moderately firm to very firm; may have very few rounded fine gravels; clear to diffuse to - D's - mottled grey-brown to dark with brown to red-brown (5 YR, 7.5 YR 4/1, 4/2, 3/2 and 3/3, 4/3, 4/4); sandy clay loam to sandy, heavy clay; moderately moist moderately firm to moderately strong, may have very few fine soft carbonate <u>Comments</u>: Fine sand and sand may occur through the A1/Ap and B2 horizons.	Intervening alluvial flats and drainage depressions; sideslopes 3 to 6% (Deep, open drainage depression)	Completely cleared

Woodall is a dark, cracking clay with self-mulching light medium to medium heavy clay surface soil overlying moderately pedal medium clay to heavy clay subsoil with fine sand evident in the surface soil of some profiles.

A Callide gravelly phase occurs in the north east-corner of the station (blocks V to Z). The phase has a few to very abundant subrounded gravels present in some part of all profiles compared with none to few gravels occasionally present in **Callide** profiles. Spatial distribution is not consistent and the two cannot be mapped separately.

7.3.2 Soils of the intervening level flats and drainage depressions

Level alluvial flats occasionally separate the levees containing **Callide** soil. A dark, non-cracking clay, **Melton,** occurs on these flats. Both **Melton** and **Callide** have neutral to alkaline soil reaction trend and overlie similar buried layers. **Melton** has a heavier texture in the surface soil (light medium to medium heavy clay) and subsoil (medium clay to heavy clay). In contrast with **Callide,** sand is present only in the surface soil of **Melton** where adjacent to levee footslopes.

Shallow open drainage depressions occur within the alluvial flats and between the **Woodall** levees. These depressions contain **Tognolini** soil. **Tognolini** is a dark clay, generally cracking but occasionally non-cracking. **Melton** and **Tognolini** have similar textures, neutral to alkaline soil reaction trend and overlie similar buried layers. In contrast with **Melton,** the **Tognolini** surface soil is self-mulching and seasonal cracking generally occurs. **Woodall** and **Tognolini** have similar morphological properties but have been distinguished due to landform position. **Tognolini** also occupies the area of backplain.

Three deeper drainage depressions have **Channel** soil. **Channel** is a dark, non-cracking clay with neutral to alkaline soil reaction trend. Its features include a surface crust when dry and fine to medium sand often evident through the profile, distinguishing this soil from **Melton.**

7.3.3 Soils of the gently undulating rises

Very shallow (<0.5 m depth) and stony, unnamed, miscellaneous soils occupy these uplands. They are mainly non-cracking clays with dark surface soil and brown subsoil. Soil reaction trend is acid to neutral.

7.4 Soil correlation with previous data

The soils data available to date were published between 1954 and 1968. Since 1981, extensive land planing and drainage works have been implemented to facilitate flood irrigation. The surface soil has probably been substantially modified during this period and it is unlikely that soil profile descriptions taken during this survey entirely match those taken previously.

The previous surveys were of very low intensity aimed at broad regional assessment whereas this is a very high intensity survey. Nevertheless, some approximate correlations are given in Table 6.

Table 6. Approximate correlation of soil types with previously published soils data

Soil type	Soil family (Sweeney 1968)	Soil group (Isbell 1954)	Soil association - landscape Isbell *et al.* (1967)
Hodge	Warrinilla	Alluvial soils	HG4
Callide	Warrinilla, Retro		
Woodall	(a)		
Melton	Retro?		
Tognolini	Vermont		
Channel	(a)		

[a] There is no equivalent for these soils.

Both Sweeney (1968) and Isbell *et al.*(1967) indicate that the dominant soils on the alluvial plain are dark duplex soils. Sweeney (1968) describes them as having thin surface soils, generally 0.10 to 0.15 m thick. It is possible that the considerable ploughing and land planing has converted these soils into dark, uniform non-cracking clays.

7.5 Mapping units

Mapping units are areas of land with a consistent combination of soil types (after Beckett and Webster 1971). Each mapping unit is named after the dominant soil type present.

Any area that consists of a variety of soils with too few descriptions of each to adequately describe soil types is referred to as miscellaneous soils. This term is used to describe the soils of the gently undulating rises.

The enclosed soils map shows the distribution of the mapping units and Table 7 lists the soils that occur in them.

Table 7. Mapping unit composition

Mapping unit[a]	Associated soil type
Hodge	Callide
Callide	Melton, Callide gravelly phase
Woodall	(b)
Melton	Tognolini
Tognolini	Melton
Channel	(b)
Miscellaneous soils	(c)

[a] Named after the dominant soil type present except for Miscellaneous soils

[b] These mapping units are relatively pure, that is, are dominated by only one soil type with very little inclusion of other soils.

[c] Contains a variety of unnamed soils

8. SOILS - CHEMICAL AND PHYSICAL ATTRIBUTES

8.1 Introduction

Ten soil profiles were sampled for detailed laboratory characterisation. These profiles represent the six soil types and one soil phase identified on the station. Location of the ten sampling sites are shown on the enclosed soils map.

All profiles were sampled with a jarret auger in 100 mm increments to a depth of 1500 mm. A bulk 0-100 mm surface sample (composite of 10 subsamples) was also collected for surface fertility assessment. Details of laboratory analyses performed on all samples are outlined in Table 8. The specific analytical methods together with some general data interpretations are listed in Bruce and Rayment (1982).

A correlation matrix was established to initially scan the data for significant relationships between some measured and derived attributes. Simple linear regression equations were calculated for some of the significant correlations. Analysis of variance was used to test for soil differences in total phosphorus and total potassium at each sampling depth; soil means were compared using the protected LSD test.

Detailed morphological and laboratory data for the 10 soil profiles are given in Appendix II.

Table 8. Laboratory analyses performed on the soil samples

Soil analysis[a]	Sample type and depth (mm)						
	Bulk	Profile					
	0–100	0–100	200–300	500–600	800–900	1100–1200	1400–1500
pH, EC, Chloride[b]	x	x	x	x	x	x	x
Exch. cations, CEC		x	x	x	x	x	
Total P, K, S		x	x	x	x	x	
Organic C, Total N	x						
Acid extractable P	x						
Bicarb. extractable P	x						
Extractable K	x						
DTPA extr. Cu, Zn, Mn, Fe	x						
Particle size analysis		x	x	x	x	x	
Moisture measurements –							
% Air dry		x	x	x	x	x	
–33 kPa content		x	x	x	x	x	
–1500 kPa content		x	x	x	x	x	
Dispersion ratio		x	x	x	x		

(a) All analyses described in Bruce and Rayment (1982)
(b) These analyses also performed on all intermediate depths to 1500 mm

8.2 pH and salinity

Surface pH (0-100 mm) ranges from 6.9 to 7.6 but pH increases in all profiles becoming moderately to strongly alkaline at depth. This alkaline reaction trend is represented by the regression equation:

$$pH = 7.1 + .001\ \text{Depth}\ (n = 150,\ r^2 = .72,\ P<.01)$$

where pH is measured on a 1:5 suspension and depth is expressed in millimetres. At 900 mm the pH varies from 7.9 to 8.5 and at 1500 mm the range is 8.1 to 8.7.

Northcote and Skene (1972) established salinity classes for Australian soils using percent chloride as the criterion. All soils on the research station are classified non-saline. They have very low to low chloride (<.03%) throughout, except for **Woodall** where levels increase below 900 mm to a maximum .04 %.

Electrical conductivity (EC) is also used to estimate soil salinity. The EC values are very low to low (<0.45 mS m^{-1}) in all soils.

The linear regression:

$$ECm = 0.04 + 8.05\ Cl\ (n = 150,\ r^2 = 0.90,\ P<.01)$$

where ECm is 1:5 electrical conductivity (mS m^{-1}) and Cl is percent chloride, was calculated from the data. This differs from the theoretical relationship:

$$ECc = 6.64\ Cl$$

where ECc is the EC calculated when all anions present are chloride. The difference suggests that, although chlorides probably dominate the soluble salts, other sources of salinity are present. Shaw *et al.* (1987) use ECm, ECm/ECc and pH to set guidelines for determining the relative contribution of various sources to soil salinity. Their criteria indicate that release of cations from exchange sites due to dilution effects may contribute as well as salts other than chlorides.

8.3 Particle size analysis

The mean sand, silt and clay contents of three soil groups are compared in Figure 3. The soils are derived from alluvium and buried layers occur in every profile at varying depths below 500 mm. Nevertheless, the particle size distribution forms a consistent pattern to at least 1200 mm depth in two of the groups.

The soils of the alluvial flats and drainage depressions have uniform clay profiles with clay content gradually decreasing below 900 mm. There is a considerable silt fraction throughout though the maximum content is in the surface 300 mm. Coarse sand represents only 1-12% of the soil material. **Channel** soil has more fine sand and less clay than the other soils in the group. This is probably due to its landscape position in the deeper drainage depressions. The levee soil **Woodall** is a cracking clay with similar particle size distribution to the soils of the alluvial flats and drainage depressions. Coarse sand accounts for only 2-10% of the soil material.

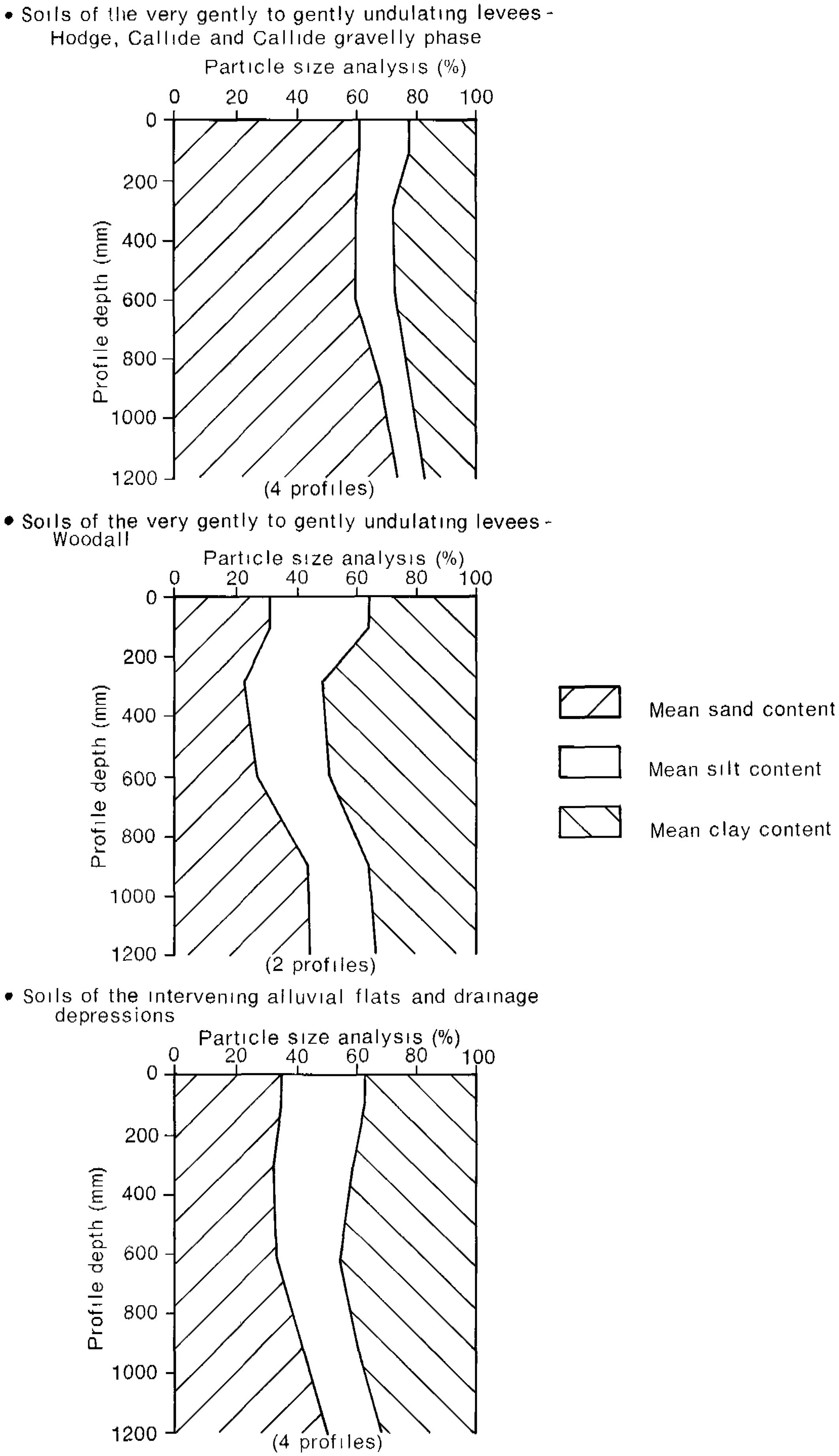


Figure 3 Comparative particle size analyses for three soil groups

The third group consists of the levee soils **Hodge, Callide gravelly phase** and **Callide** and is quite variable. The **Callide** profile is similar to the **Woodall** profiles but with lower clay and silt and higher fine sand fractions. **Hodge** and **Callide gravelly phase** have much less clay and silt and considerably more fine sand than all other profiles. Coarse sand has also increased, representing 8 to 28% of the surface soil and subsoil. The relative amounts of clay, fine sand and coarse sand fluctuate in their buried layers below 500 to 800 mm depth.

The differences in grade and amount of sand can be used as an aid to distinguish several soils in the field (see section 7.3). However, the relatively high silt content of some soils was not recognised while texturing field samples and ground and sieved laboratory samples. Several field textures also overestimated the clay content determined by particle size analysis, especially in **Hodge, Callide** and **Callide gravelly phase.** These samples generally have higher fine sand and lower silt content than those in close agreement.

8.4 Cation exchange capacity and clay activity ratio

The cation exchange capacity (CEC) of a soil indicates the potential storage of nutrient cations that are available for plant growth.

The CEC of each soil is indicated for two sampling depths in Table 9. **Hodge** and **Callide gravelly phase** have the lowest levels; **Woodall, Tognolini** and **Melton** have similar high values while **Callide** and **Channel** are intermediate.

Sanchez (1976) claims that an effective CEC of at least 4 mequiv. 100 g^{-1} is necessary to retain most cations against leaching. The analyses for these soils can be considered as effective CEC which is the CEC determined at the field pH of the soil. The lowest value recorded to 900 mm depth was 12 mequiv. 100 g^{-1} in **Hodge.** All soils should have the ability to retain cations against leaching.

The differences in soil CEC are a reflection of the particle size distributions evident in Figure 3. CEC is significantly ($P<.01$) correlated with clay content ($r = .96$, $n = 50$) and with silt ($r = .82$, $n = 50$).

The clay activity ratio is the CEC of one gram of clay (mequiv. g^{-1} clay) and is often used as an indication of clay mineralogy. Clay activity ratios are given for two sampling depths of each soil in Table 9.

A ratio of 0.8 or higher generally indicates a dominance of smectites, the clays that shrink and swell with changing moisture status. Vermiculite also has a very high ratio but is not known as a major component of any Australian soil group (Norrish and Pickering 1983).

Hodge is the only soil on the station with ratios of 0.8 and above through the profile. The total clay content of the soil is low and shrink-swell phenomena do not occur.

The remaining soils have similar ratios, generally less than 0.75, suggesting a common clay mineralogy, not dominated by smectites. Norrish and Pickering (1983) report that some illitic clays have activity ratios approaching 0.8 and exhibit the shrink-swell phenomena usually associated with smectites. All the soils on the station have a relatively high total potassium content (see section 8.6) suggesting illites may be present.

The high CEC-clay correlation across all soils, mentioned previously, also indicates a common mineralogy.

Table 9. Cation exchange capacity and clay activity ratio at two sampling depths for all soils

Soil type (Profile)	Sample depth (mm)	CEC (mequiv. 100 g^{-1})	Clay activity ratio (mequiv. g^{-1} clay)
Hodge			
(S1)	0-100	20	0.97
	500-600	16	0.91
(S2)	0-100	15	0.80
	500-600	15	0.90
Callide gravelly phase			
(S5)	0- 80	14	0.75
	500-600	19	0.69
Callide			
(S6)	0-100	22	0.65
	500-600	28	0.60
Woodall			
(S8)	0- 50	27	0.73
	500-600	31	0.64
(S9)	0- 50	29	0.80
	500-600	38	0.73
Melton			
(S10)	0-100	29	0.69
	500-600	34	0.65
Tognolini			
(S4)	0-100	29	0.69
	500-600	35	0.71
(S7)	0-100	29	0.71
	500-600	33	0.64
Channel			
(S3)	0-100	24	0.74
	500-600	25	0.73

This conclusion cannot be reconciled with field evidence for the medium to heavy clays. All profiles have analogous clay content, CEC and clay activity ratio but only three (**Woodall** S8, **Tognolini** S4 and possibly **Tognolini** S7) are cracking clays. Shallow (50 mm deep) cracks occurred at the **Woodall** S9 site and a 1 m deep pit adjacent to the **Melton** profile revealed no shrink-swell characteristics.

8.5 Exchangeable cations and base saturation

Levels of exchangeable calcium, magnesium, sodium and potassium are given at two depths for each soil in Table 10. Base saturation, which is the proportion of CEC occupied by these four cations (and expressed as a percentage) is also listed.

Calcium is the dominant cation throughout all soil profiles.

Consolidated Fertilisers Limited (1984) have set threshold limits for calcium and magnesium deficiency for the major crops grown in central Queensland. These are only guidelines as exchangeable calcium and magnesium levels vary widely between soils making absolute amounts unreliable as indicators of plant availability (Bruce and Rayment 1982). All the soils have levels at both the surface and at depth far in excess of any threshold values.

Exchangeable potassium levels are high to very high in all surface samples decreasing to medium-high at depth. The surface values exceed the threshold limits given for the major crops of central Queensland (Consolidated Fertilisers Limited 1984).

In Australian soils sodium is rarely deficient and often affects plant growth due to its presence in excess amounts. This aspect is discussed in section 8.7.

The exchangeable cations calcium, magnesium, sodium and potassium occupy 85 to 98% of the soil CEC in the surface soil. The soils are all base saturated at depth. Base saturation is significantly ($P<.01$) correlated with pH ($r = .86$, $n = 50$).

8.6 Total potassium and total phosphorus

Total potassium levels reflect the parent material, clay mineralogy and age of soils. McDonald and Baker (1977) found that, on the Emerald alluvium, total potassium decreased with increasing soil age. A similar relationship was reported for alluvial landforms at Mackay (Baker *et al.* 1985).

Profile trends of total potassium are shown for three soil groups at Biloela in Figure 4. Apart from **Hodge**, the soils appear to have similar clay mineralogy (see section 8.4) and, as they all occur within the same alluvial plain, probably have similar parent material. The levee soil **Woodall** has significantly less ($P<.05$) total potassium to a depth of 600 mm than the other two soil groups. This material may be older than the corresponding material in the other soils.

Buried layers are encountered between 500 mm and 1100 mm depth. Total potassium levels are not significantly different ($P>.05$) below 600 mm indicating these layers may be of a similar age.

Table 10. Exchangeable cations and base saturation at two sampling depths of each soil

Soil type (Profile)	Sample depth (mm)	Exchangeable cations (mequiv. 100 g^{-1})				Base
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
Hodge						
(S1)	0-100	12	3.9	0.1	1.1	85
	500-600	12	3.8	0.1	0.4	101
(S2)	0-100	9.7	3.5	0.1	1.0	93
	500-600	12	3.9	0.2	0.2	108
Callide gravelly phase						
(S5)	0- 80	8.1	2.4	0.2	1.3	85
	500-600	14	6.8	0.4	0.3	112
Callide						
(S6)	0-100	13	3.8	0.3	1.4	88
	500-600	20	7.0	0.6	0.6	100
Woodall						
(S8)	0- 50	19	5.5	0.2	1.5	96
	500-600	22	10	1.3	0.5	108
(S9)	0- 50	16	7.2	0.4	2.2	91
	500-600	27	13	1.3	0.4	110
Melton						
(S10)	0-100	19	7.9	0.4	1.2	97
	500-600	22	10	1.8	0.6	101
Tognolini						
(S4)	0-100	19	8.1	0.6	1.1	98
	500-600	22	13	1.1	0.4	104
(S7)	0-100	17	5.9	0.3	2.0	85
	500-600	22	8.7	0.7	0.7	96
Channel						
(S3)	0-100	14	5.1	0.2	1.5	90
	500-600	19	5.9	0.2	0.3	101

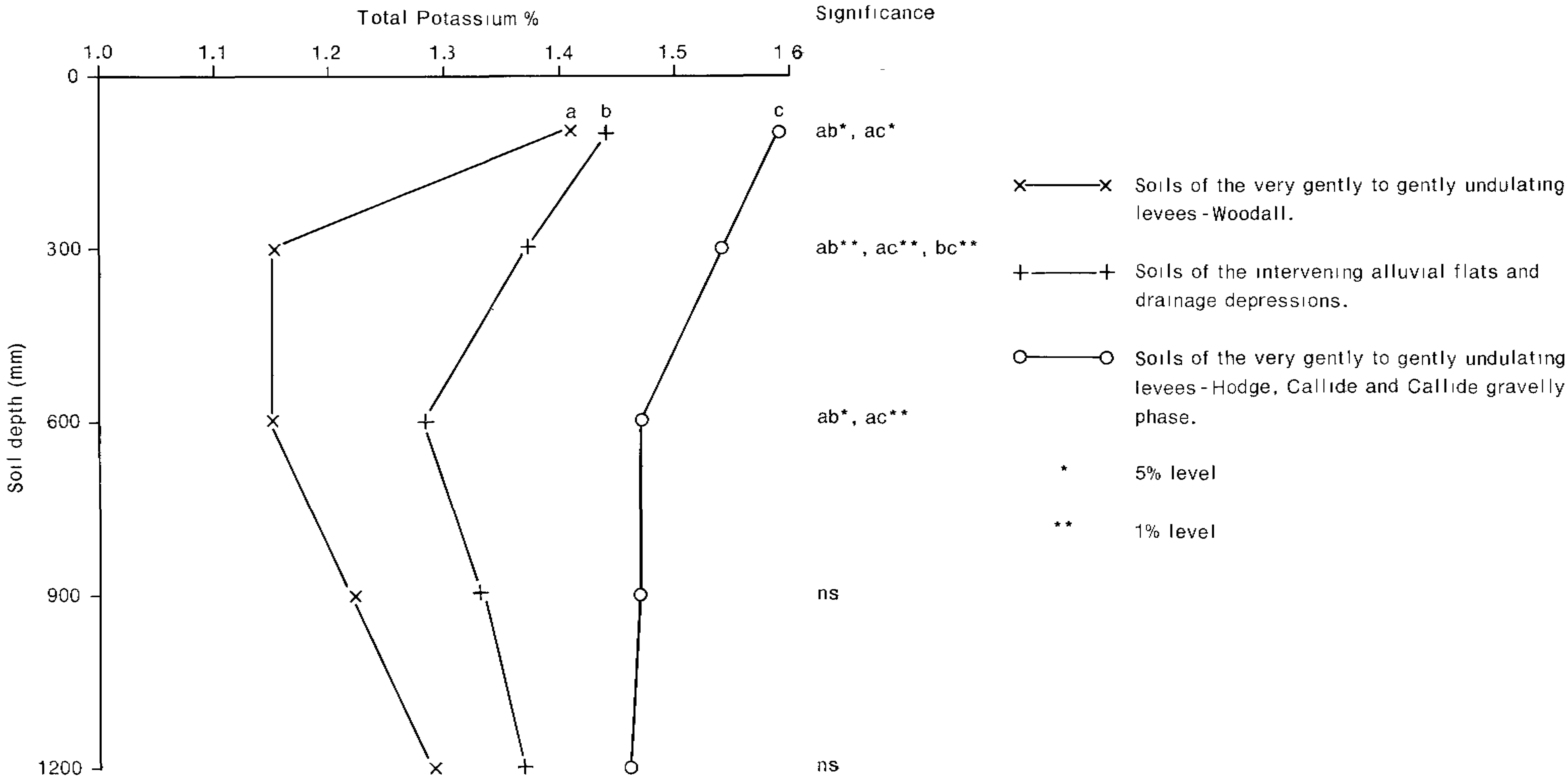


Figure 4 Mean total potassium profiles for three soil groups showing significant differences at the 5% and 1% levels.

Baker *et al.* (1985) also demonstrated an inverse relationship between total phosphorus levels and soil age. However total phosphorus is not significantly different between soil groups at any depth in these soils.

8.7 Sodicity and other indexes of soil dispersion

Several indexes have been used in Australia to indicate soil dispersion. Dispersion results in degradation of soil structure and thus decreased permeability as well as increasing susceptibility to water erosion. These indexes have been calculated for the research station soils and are presented for various depths in Table 11.

Northcote and Skene (1972) used exchangeable sodium percentage or ESP (exchangeable Na. 100/CEC) as a criterion for determining sodicity. Soil material with an ESP of 6 or more is considered sodic and likely to have some structural degradation. The **Woodall** S8 profile has sodic buried layers below 650 mm (ESP 6.2 to 6.4). All other soils are classified non-sodic.

Exchangeable magnesium, in association with sodium, has been shown to aid soil dispersion in some soils (Emerson and Bakker 1973). Clay subsoils with degraded structure but low ESP have been recorded in coastal Queensland by Teakle (1950), Thompson *et al.* (1981) and Baker *et al.* (1985). The magnesium saturation (exchangeable Mg. 100/CEC) of these materials ranged from 64 to 83 %. Stace *et al.* (1968 pp185,187) also include two soils from Glenelg (Victoria) with poorly structured subsoils, low ESP and magnesium saturation in excess of 40%. **Tognolini** S4 is the only profile on the station with a magnesium saturation of 40% or more. This occurs below 800 mm depth.

Emerson and Bakker (1973) also used Mg:Ca ratios to assess the physical performance of some Victorian soils. They suggested that Mg:Ca ratios greater than one associated with relatively low ESP can enhance clay dispersion. All soils on the station have Mg:Ca ratios well below one.

R1 is the ratio of readily dispersible silt + clay to the silt + clay determined by particle size analysis. Baker (1977) used the index to rate soil dispersion in the Burdekin district. A ratio of <0.6 was given a low dispersion rating, 0.6 to 0.8 was considered moderate and >0.8 high. These criteria suggest that the surface sample of the **Callide gravelly phase** is the only highly dispersible material on the station. This is unusual as its ESP, magnesium saturation and Mg:Ca ratio are all quite low. In fact there was negligible correlation between R1 and the other dispersion indexes for all soils.

The ESP, magnesium saturation and Mg:Ca ratio indicate soil dispersion is not a significant factor in any of these soils. This evidence is supported by the very low to low EC values throughout all profiles (section 8.2).

Yet surface crusting is a problem on the furrow irrigated soils (**Callide**, **Melton** and **Tognolini**), especially when cotton is grown. This could be due to management practices, particularly the amount of cultivation, rather than any inherent soil dispersion.

Table 11. Indexes of soil dispersion for selected sampling depths in each soil

Soil (Profile) ratio	Sample depth (mm)	ESP %	Mg/CEC %	Mg:Ca ratio	R1
Hodge					
(S1)	0-100	0.4	19.0	0.31	0.48
	500-600	0.8	23.1	0.31	0.59
	800-900	1.1	27.1	0.31	0.60
(S2)	0-100	0.4	22.7	0.36	0.73
	200-300	0.6	24.1	0.31	0.63
	800-900	1.3	27.5	0.33	0.78
Callide gravelly phase					
(S5)	0- 80	1.2	17.1	0.30	0.84
	500-600	1.8	34.7	0.48	0.65
	800-900	2.6	34.7	0.48	0.73
Callide					
(S6)	0-100	1.3	17.6	0.29	0.70
	500-600	2.1	25.2	0.36	0.43
	800-900	2.7	28.9	0.37	0.60
Woodall					
(S8)	0- 50	0.8	20.4	0.29	0.50
	500-600	4.0	32.3	0.45	0.60
	800-900	6.4	35.5	0.45	0.60
(S9)	0- 50	1.2	25.0	0.43	0.61
	500-600	3.3	33.3	0.45	0.56
	800-900	4.6	34.6	0.50	0.53
Melton					
(S10)	0-100	1.5	27.1	0.42	0.60
	500-600	5.2	30.3	0.48	0.64
	800-900	4.6	33.5	0.45	0.65
Tognolini					
(S4)	0-100	2.1	27.9	0.43	0.59
	500-600	3.0	36.4	0.56	0.72
	800-900	3.4	40.6	0.67	0.71
(S7)	0-100	1.0	20.4	0.36	0.58
	500-600	2.2	26.2	0.40	0.51
	800-900	2.6	31.8	0.38	0.49
Channel					
(S3)	0-100	0.7	21.7	0.36	0.62
	200-300	0.9	23.0	0.32	0.54
	800-900	0.7	24.8	0.31	0.57

8.8 Available water capacity and predicted leaching fraction

Three methods were used to estimate the available soil water capacity (ASWC) of each soil. An ASWC was calculated from the -33 kPa and -1500 kPa water contents. The plant available water capacity (PAWC) was also determined using regression equations of Shaw and Yule (1978) based on either -1500 kPa (PAWCb) or the soil CEC (PAWCc). All three figures were converted to volumetric water using a bulk density calculated from the maximum gravimetric water content, assuming a 3% air content at that point. They were then summed to a depth of one metre. Any peaks in chloride concentrations occur below this depth suggesting water moves through all soils to at least one metre. Results are given in Table 12.

Table 12. Estimated available water capacity (mm) to one metre depth and predicted leaching fraction of all soils

Soil	Estimated available water capacity (mm)			Predicted leaching fraction
	ASWC	PAWCb	PAWCc	
Hodge	215-245	120-125	105-110	(a)
Callide gravelly phase(b)	220	130	115	0.34
Callide	270	135	120	0.19
Woodall	285	135-140	130-140	0.08-0.11
Melton	(c)	140	130	0.11
Tognolini	275-285	135-140	128-135	0.15-0.21
Channel	265	140	135	1.27

(a) Leaching fraction cannot be predicted for this soil
(b) Estimated available water capacity reduced in proportion to gravel content
(c) No data available

The AWSC figures are approximately double both PAWCb and PAWCc values. The ASWC calculation relies on -33 kPa being an accurate estimate of the soil upper storage limit but the estimate has been found unreliable on ground and sieved samples (Thorburn and Gardner, in press). The ASWC figures probably overestimate the actual available water capacity of the soils.

The PAWCb and PAWCc estimates are similar and are comparable to values reported by Williams (1983) for equivalent field textures in a range of Australian soils. The coarser textured soils, **Hodge** and **Callide gravelly phase**, have lower available water capacity than the finer textured soils. **Callide** appears to be intermediate between these two groups. The gravel content of **Callide gravelly phase** can range between 10 and 50% and its PAWC can vary accordingly.

Deep drainage is an important characteristic of irrigated soil as it is a major factor determining whether soluble salts will accumulate in the root zone. One method of assessing deep drainage of a soil is to estimate its leaching fraction, which can be expressed as the ratio of the salinity of output water (or soil salinity at depth) to the salinity of input water.

A model described by Shaw *et al.* (1987) was used to predict a leaching fraction for soils on the station. The ratios are given in Table 12. There are no algorithms available in the model to predict a leaching fraction for soils such as **Hodge.** The model overestimates the value for **Channel** as the ratio should not exceed unity but, nevertheless, indicates this soil has a high leaching fraction. **Callide gravelly phase** has the second highest ratio, **Woodall** and **Melton** have the lowest ratios while **Callide** and **Tognolini** are intermediate.

Hansen and Thorburn (1987) have related the leaching fraction to the relative concentration of soil salinity compared with the salinity of input water. Soils with a ratio below approximately 0.2 have a propensity to accumulate soluble salts. **Melton** and **Woodall** fall within this category and **Callide** and **Tognolini** are marginal.

8.9 Plant nutrients in surface soil

The general fertility ratings of Bruce and Rayment (1982) are given for the soil bulk surface samples in Table 13. Urea was the only fertiliser used on the station prior to sampling except for scattered applications of zinc. The **Tognolini** S4 profile received a dressing of 10 kg Zn ha^{-1} six months before sampling.

Bicarbonate extractable phosphorus levels are high to very high on all soils regardless of cropping history. The coarser textured soils **Hodge** and **Callide gravelly phase** vary from 53 to 80 mg kg^{-1} P while the others range from 120 to 190 mg kg^{-1} P. Acid extractable phosphorus levels are all very high (180 to 470 mg kg^{-1} P).

The extractable potassium levels are a reflection of the high to very high exchangeable levels listed in Table 10.

Zinc levels are rated as medium for all soils except **Melton** which is very high. There are no records of zinc being applied to this site. Further sampling of this soil is warranted. The application of zinc at S4 profile prior to sampling has not resulted in a high value.

Consolidated Fertilisers Limited (1984) have set threshold values as guidelines for assessing zinc deficiency in both acid and alkaline soils for the major crops grown in central Queensland. Three of the ten profiles (S2, S5 and S8) approximate these limits.

Copper levels are medium in all soils; manganese levels are medium to high. A deficiency of either element is unlikely.

The organic carbon levels are mainly low to medium. **Channel** is the only soil with a high value. The range in values is similar for both cropped and pasture sites. Total nitrogen levels are low to very low. Application of urea does not appear to be increasing the soil nitrogen reserves.

Table 13. Plant nutrient ratings (Bruce and Rayment 1982) for the bulk surface samples

Soil type	Extractable phosphorus		Extractable				Organic carbon	Total nitrogen
	Acid	Bicarbonate	Potassium	Copper	Zinc	Manganese		
Hodge	very high	high	very high	medium	medium	medium	low	low
Callide gravelly phase	very high	high	very high	medium	medium	medium	low	low
Callide	very high	very high	very high	medium	medium	medium	low	low
Woodall	very high	very high	very high	medium	medium	medium -high	medium	low
Melton	very high	very high	very high	medium	very high	medium	medium	low
Tognolini	very high	very high	high- very high	medium	medium	high	low- medium	low- very low
Channel	very high	very high	very high	medium	medium	high	high	low

9. IMPLICATIONS FOR FIELD TRIALS

9.1 Soil type homogeneity

The surface fertility of all soils is similar (Table 11). Soil CEC values are all above the minimum considered necessary to retain nutrients against leaching. The levels of exchangeable calcium, magnesium and potassium are also adequate in every soil. All soils can be considered homogeneous with respect to nutrient fertility.

The soil physical characteristics are more variable. Particle size analysis reveals two distinct groups. Subsoil structure varies from massive (in **Hodge**) to weak prismatic (**Callide**) and moderate lenticular in **Woodall.** Field evidence suggests the finer textured soils can be split into self-mulching, cracking clays (**Woodall** and **Tognolini**) and non-cracking clays with a surface crust (**Channel** and **Melton**).

These differences are reflected to some extent in the PAWC estimates. Three soil groups can be delineated on the basis of their relative soil PAWC:

- Low - **Hodge, Callide gravelly phase**
- Intermediate - **Callide**
- High - **Woodall, Channel, Tognolini, Melton**

The PAWC of **Callide gravelly phase** can vary widely depending upon gravel content.

Three different soil groups are obtained when considering deep drainage characteristics. The predicted leaching fractions of **Melton** and **Woodall** indicate these soils have potential to concentrate soluble salts from irrigation water. **Callide** and **Tognolini** have marginally higher leaching fractions and may have some potential as well. **Channel, Callide gravelly phase** (and probably **Hodge**) have much higher values suggesting their potential is minimal.

9.2 Conclusions

As the soils have similar nutrient status, PAWC will be the major soil factor influencing yield variability under rainfed conditions. With irrigation, the principal effect of soil PAWC will probably be to determine frequency of watering rather than total volume applied or plant yields.

Further research is warranted to estimate more accurately soil PAWC and to check whether the differences are of practical or economic significance.

During the interim it is advisable to design rainfed trials so that each replicate is wholly within the three PAWC groups identified. Moreover, it is recommended that **Callide gravelly phase** not be used at all as its PAWC will vary widely with gravel content.

The shallow drainage depressions contain **Tognolini** soil and are run-on areas which may receive more water than other areas during high rainfall. It would be unwise to include these depressions in any trial area.

Channel occurs in deep drainage depressions which are probably former overflow or main channels of Callide Creek. Such run-on areas do not represent a significant portion of central Queensland and this soil could be excluded from crop trials.

Tognolini also occurs in a level back-plain through blocks P1 to P4 and Q1 to Q4. This run-on area is large enough to accommodate a full replicate for most trials.

The accompanying soils map can be used to locate trials. However it must be remembered that apart from **Woodall** and **Channel**, the mapping units are not pure; that is, they contain more than one soil. The soils that may occur in each mapping unit are listed in Table 7. The greatest soil complexity is in the units containing **Callide gravelly phase** which could not be mapped separately. This problem can be avoided by not designing trials in blocks V2, W1, W2, W3, Y and Z.

With long-term irrigation it is probable that **Woodall** and **Melton** will accumulate soluble salts from the input water. It is also possible that **Callide** and **Tognolini** will accumulate salts. Further investigation of this potential hazard is recommended.

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Officers of drafting section of Land Resources Branch prepared the map, figures and diagrams included in this report.

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APPENDIX I

Conventions used in describing and classifying the soil types

PPF (Principal Profile Form)

As in Northcote (1979).

pH

Based on field determinations in A1 or Ap horizon and at 300, 600, 900, 1200 and 1500 mm.

Description

The terminology of McDonald *et al.* (1984) is used to describe the most common range of profile features encountered in the soil type, except for colour. The summary description, for example Black earth and dark non-cracking clay, is from either Stace *et al.* (1968) if the soil fits a great soil group, otherwise from Northcote *et al.* (1975).

Colours

Colour codes are those of Oyama and Takehara (1967) for moist soil while colour nomenclature is that of McDonald (personal communication), which is based on the Value/Chroma rating system of Northcote (1979) and utilises the following table:

Value/Chroma 2a = 4/1 - 4/2 to 6/1 - 6/2
Value/Chroma 2b = 5/3 - 5/4 to 6/3 - 6/4

Value/ Chroma	1	2a	2b	4	5
Hue					
5 Y	dark	grey	yellow-grey	yellow	olive
2.5 Y	dark	grey	yellow-grey	yellow	olive-brown
10 YR	dark	grey	yellow-brown	yellow	brown
7.5 YR	dark	grey-brown	brown	yellow	brown
5 YR	dark	grey-brown	brown	red-brown	red-brown
2.5 YR	dark	grey-brown	red-brown	red	red
10 R	dark	red-grey	red-brown	red	red

APPENDIX II. Morphological and analytical data for sampled soil profiles

SOIL TYPE: Hodge
SITE NO· S1
A.M G REFERENCE· 247 940 mE 7 302 400 mN ZONE 56

GREAT SOIL GROUP· No suitable group
PRINCIPAL PROFILE FORM. Gn2 83P
SOIL TAXONOMY UNIT Typic Torrifluvent
FAO UNESCO UNIT Eutric Fluvisol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS Very few cobbles, subangular unspecified coarse fragments

SUBSTRATE MATERIAL· Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE 1 %
LANDFORM ELEMENT TYPE Levee
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM
DOMINANT SPECIES

ANNUAL RAINFALL: 699 mm

PROFILE MORPHOLOGY
CONDITION OF SURFACE SOIL WHEN DRY Recently cultivated, hard setting

HORIZON	DEPTH	DESCRIPTION
Ap	0 to 20 m	Brownish black (7 5YR3/2) moist, greyish yellow-brown (10YR4/2) dry, no mottles, humic clay loam, sandy, no coarse fragments, massive, dry moderately firm, no segregations Clear to-
B1	20 to 40 m	Brownish black (7 5YR3/2) moist, few fine distinct brown mottles, sandy clay, no coarse fragments, massive, dry moderately firm, no segregations Gradual to-
B21	40 to 80 m	Greyish brown (7 5YR4/2) moist; few medium distinct brown mottles, sandy clay, no coarse fragments, massive, dry moderately firm, no segregations. Abrupt to-
D1?	80 to 1 20 m	Greyish brown (7 5YR4/2) moist, brown (7.5YR4/6) moist; no mottles, sandy medium clay, moderate pedality, dry very firm; very few fine carbonate soft segregations Gradual to-
D2	1 20 to 1 50 m	Dark brown (7.5YR3/4) moist, dull reddish brown (5YR5/4) moist, no mottles, fine sandy medium clay, no coarse fragments, moderate pedality, dry very firm, no segregations

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch Cations meq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk .10	6 9	.05	.001																	
10	6 9	.05	.001	13	54	14	21	20	12	3 9	08	1 1	0 08	1.61	0.03	1.6	28	10	48	
20	7 0	.04	.001																	
30	7 2	.03	.001	26	52	6	15	14	11	3 2	07	62	0 07	1.60	0 01	1 4	17	7	39	
40	7 4	.04	.001																	
50	7 5	.04	.001																	
60	7 8	.04	.001	12	63	7	18	16	12	3 8	13	40	0 06	1.53	0 01	1 8	20	8	59	
70	7 9	.03	.001																	
80	8 1	.07	.002																	
90	8 5	.09	.001	20	53	8	21	14	12	3 9	16	.44	0 05	1 51	0 01	1 5	20	8	60	
1 00	8 5	.08	.001																	
1 10	8 5	.06	.001																	
1 20	8 5	.06	001	12	56	10	21	16	13	4 6	23	.43	0 05	1 49	0 01	2.1	23	9		
1 30	8 5	.06	.001																	
1 40	8 5	.07	.001																	
1 50	8 5	09	001																	

Depth metres	Org C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb	Rep K meq% @105C	DTPA-extr ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	1 1	05	271	65	1.5	36	34	1 6	1 4

SOIL TYPE Hodge
SITE NO S2
A M G REFERENCE 248 640 mE 7 302 860 mN ZONE 56

GREAT SOIL GROUP Prairie soil
PRINCIPAL PROFILE FORM Gn3 42
SOIL TAXONOMY UNIT Ustollic Haplargid
FAO UNESCO UNIT Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS: Very few coarse pebbles, subangular unspecified coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE 1 %
LANDFORM ELEMENT TYPE Levee
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM Tall open tussock grassland
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY

CONDITION OF SURFACE SOIL WHEN DRY Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .15 m	Dark reddish brown (5YR3/2) moist, greyish brown (5YR5/2) dry, no mottles, clay loam,sandy, very few coarse pebbles, subangular unspecified coarse fragments, weak 2-5mm subangular blocky, dry moderately firm, no segregations Gradual to-
B21	15 to .50 m	Brownish black (5YR2/2) moist, very few fine distinct brown mottles, sandy clay, no coarse fragments, moderate 2-5mm angular blocky, dry moderately firm, no segregations Gradual to-
D1	50 to 80 m	Dark reddish brown (5YR3/2) moist, common fine distinct brown mottles, clay loam,sandy, no coarse fragments, dry moderately firm, no segregations Gradual to-
D2	80 to 1 50 m	Dull reddish brown (5YR4/3) moist, few fine distinct yellow mottles, sandy clay loam, no coarse fragments, dry moderately weak, no segregations

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size CS % @ 105C	FS	S	C	Exch Cations CEC meq/100g @ 105C	Ca	Mg	Na	K	Total Elements P % @ 80C	K	S	Moistures ADM % @ 105C	1/3b	15b	Disp Ratio R1	R2
Bulk 10	7 0	03	001																	
10	7 0	03	001	20	51	11	19	15	9 7	3 5	.06	1.0	0 07	1 60	0 02	1 6	22	9	.73	
20	7 1	02	001																	
30	7 4	02	001	12	56	9	23	17	13	4.2	.11	.35	0 06	1.50	0 02	2.4	29	10	.63	
.40	7 7	.02	001																	
.50	7 8	.02	001																	
60	8 0	02	001	28	46	10	20	15	12	3.9	17	20	0 06	1 45	0 01	1.6	20	8	.73	
70	8 0	.02	001																	
80	7 9	02	001																	
90	8 0	02	.001	36	43	5	15	12	10	3 4	15	21	0 05	1 45	0 01	1 6	16	6	78	
1 00	8 0	02	.001																	
1 10	8 1	02	.001																	
1 20	8 0	02	.001	44	38	4	13	9	7.9	2 8	.13	19	0.05	1 45	0.01	2 3	14	7		
1 30	8 0	03	.001																	
1 40	8 1	03	.001																	
1 50	8 2	04	002																	

Depth metres	Org C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus Acid ppm @ 105C	Bicarb	Rep. K meq% @105C	DTPA-extr. Fe ppm @ 105C	Mn	Cu	Zn
Bulk 10	1 1	05	177	53	1 4	38	33	1 5	0.9

SOIL TYPE Channel
SITE NO S3
A M G REFERENCE 248 600 mE 7 302 550 mN ZONE 56

GREAT SOIL GROUP No suitable group
PRINCIPAL PROFILE FORM Uf6 32
SOIL TAXONOMY UNIT Ustollic Camborthid
FAO UNESCO UNIT Haplic Xerosol

TYPE OF MICRORELIEF· No microrelief
SURFACE COARSE FRAGMENTS· No coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL. Almost certain or certain

SLOPE. 0 %
LANDFORM ELEMENT TYPE Drainage depression
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM Tussock grassland
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY·

CONDITION OF SURFACE SOIL WHEN DRY Surface crust

HORIZON	DEPTH	DESCRIPTION
A1	0 to 15 m	Brownish black (5YR2/1) moist, no mottles, fine sandy light medium clay, no coarse fragments, moderate 5-10mm subangular blocky, dry very firm, no segregations Clear to-
B21	15 to 50 m	Brownish black (5YR3/1) moist, no mottles, fine sandy medium clay, no coarse fragments, moderately moist very firm, no segregations. Clear to-
D1?	50 to 1 00 m	Dark reddish brown (5YR3/3) moist, common fine distinct dark mottles, fine sandy light medium clay, no coarse fragments, dry very firm, no segregations slightly calcareous Gradual to-
D2	1 00 to 1 20 m	Brown (7.5YR4/4) moist, brownisn black (5YR3/1) moist, no mottles, fine sandy clay, no coarse fragments, dry moderately firm, no segregations slightly calcareous Gradual to-
D3	1 20 to 1.50 m	Dull reddish brown (5YR4/3) moist, brownish black (5YR3/1) moist, no mottles, fine sandy light medium clay, no coarse fragments, dry very firm, no segregations slightly calcareous

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch Cations meq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk .10	6 9	.07	001																	
.10	7 1	.05	001	4	48	20	32	24	14	5.1	.16	1 5	0 07	1 55	0 03	2 7	31	13	62	
20	7 0	04	001																	
30	7 1	03	001	3	43	24	36	28	20	6 4	26	49	0 06	1 38	0 02	2 9	33	15	.54	
40	7 3	03	001																	
50	7 4	03	001																	
60	7 6	03	001	1	48	22	34	25	19	5 9	24	.33	0 06	1 34	0.02	3 0	33	18	.51	
70	7 7	03	001																	
80	7.8	03	001																	
90	7 9	03	001	1	46	22	34	24	19	5.9	.17	.40	0 06	1.40	0.02	3.3	31	13	57	
1 00	8 0	03	001																	
1 10	7 9	03	.001																	
1 20	8.0	03	001	4	55	17	26	22	17	5.4	.16	34	0.06	1 35	0 02	2 5	30	11		
1 30	8.1	05	001																	
1 40	8.2	05	001																	
1 50	8 3	06	001																	

Depth metres	Org.C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb	Rep K meq% @105C	DTPA-extr ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	2 6	06	344	125	2 6	55	60	2 9	2 8

SOIL TYPE Tognolini
SITE NO· S4
A M G REFERENCE 248 280 mE 7 302 040 mN ZONE 56

GREAT SOIL GROUP Black earth
PRINCIPAL PROFILE FORM Ug5 1P
SOIL TAXONOMY UNIT Mollic Torrert
FAO UNESCO UNIT Chromic Vertisol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL: Almost certain or certain

SLOPE 0 %
LANDFORM ELEMENT TYPE Back-plain
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY Recently cultivated

HORIZON	DEPTH	DESCRIPTION
Ap	0 to 10 m	Brownish black (5YR3/1) moist, greyish brown (5YR5/2) dry, no mottles, medium heavy clay, no coarse fragments, dry moderately strong, no segregations Clear to-
B21	.10 to 45 m	Brownish black (5YR2/2) moist, no mottles, heavy clay, no coarse fragments, moderately moist very firm, no segregations Gradual to-
B22	.45 to 1 10 m	Dark reddish brown (5YR3/2) moist, few fine faint brown mottles, heavy clay, no coarse fragments, moderately moist very firm, very few medium carbonate nodules, very few fine carbonate soft segregations Diffuse to-
D	1.10 to 1 50 m	Brown (7.5YR4/4) moist, common fine distinct grey mottles, fine sandy medium heavy clay, no coarse fragments, moderately moist very firm, few coarse carbonate nodules

Depth	1 5 Soil/Water			Particle Size				Exch Cations					Total Elements			Moistures			Disp Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				meq/100g @ 105C					% @ 80C			% @ 105C				
Bulk 10	7 4	.07	002																	
.10	7 5	.09	002	3	30	35	42	29	19	8.0	61	1.1	0.06	1.36	0 02	3.2	39	17	59	
20	7 5	08	002																	
30	7 6	.08	002	3	30	28	45	33	22	9.7	.79	77	0.06	1.38	0 02	3.6	38	20	67	
40	7 9	07	003																	
50	7 9	07	003																	
60	8 1	.07	004	1	28	25	49	35	22	13	1.0	43	0.04	1.24	0 01	4.9	41	20	72	
70	8 2	.07	004																	
.80	8 3	.10	004																	
90	8 5	.13	004	1	33	22	48	33	21	14	1.1	39	0.05	1 32	0 01	3 9	40	20	71	
1.00	8 6	17	005																	
1.10	8 7	19	005																	
1.20	8 7	.18	004	1	36	26	41	28	18	12	1.2	33	0.05	1.44	0 01	3.9	36	17		
1.30	8 7	19	004																	
1 40	8 7	20	004																	
1 50	8 7	18	005																	

Depth	Org C (W&B)	Tot N	Extr. Phosphorus		Rep K	DTPA-extr.			
			Acid	Bicarb		Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		meq% @105C	ppm @ 105C			
Bulk 10	1.2	04	237	129	1.0	39	32	3 5	2 5

SOIL TYPE Callide gravelly phase
SITE NO S5
A M G REFERENCE 248 600 mE 7 302 550 mN ZONE 56

GREAT SOIL GROUP Prairie soil
PRINCIPAL PROFILE FORM Uf6 32P
SOIL TAXONOMY UNIT Typic Haplargid
FAO UNESCO UNIT Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS Few coarse pebbles, subangular unspecified coarse fragments

SUBSTRATE MATERIAL· Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE 0 5 %
LANDFORM ELEMENT TYPE· Levee
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

CONDITION OF SURFACE SOIL WHEN DRY Surface crust

HORIZON	DEPTH	DESCRIPTION
Ap	0 to .08 m	Dark reddish brown (5YR3/2) moist, greyish brown (5YR5/2) dry, no mottles, humic sandy clay, few medium pebbles, subangular unspecified coarse fragments, massive, dry very firm, no segregations. Clear to-
B21	.08 to .20 m	Dark reddish brown (5YR3/2) moist, very few fine distinct brown mottles, sandy light medium clay; few small pebbles, subrounded unspecified coarse fragments, moderately moist moderately firm, no segregations Clear to-
B22	.20 to .70 m	Dull reddish brown (5YR4/4) moist, brownish grey (5YR4/1) moist, no mottles, sandy medium heavy clay, very few small pebbles, subrounded unspecified coarse fragments, moderately moist very firm; no segregations Clear to-
D1	.70 to 1 00 m	Dull brown (7 5YR5/4) moist, brownish grey (7 5YR4/1) moist, no mottles, sandy light medium clay; very few small pebbles, subrounded unspecified coarse fragments, dry moderately firm, no segregations Clear to-
D2	1 00 to 1 30 m	Brownish grey (7 5YR4/1) moist, no mottles, loamy coarse sand, few medium pebbles, subrounded unspecified coarse fragments, dry loose, common coarse carbonate nodules Gradual to-
D3	1 30 to 1 50 m	Brownish grey (5YR4/1) moist, dull reddish brown (5YR5/4) moist, no mottles, clay loam,sandy, few small pebbles, subrounded unspecified coarse fragments, dry moderately weak, few fine carbonate nodules

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch Cations meq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk 08	6 9	06	001																	
08	7 0	.06	001	22	48	13	19	14 8	1	2 4	17	1 3	0 07	1 58	0.02	1.3	20	8	84	
20	6 9	.05	001																	
30	7 4	.04	001	18	44	9	30	18	12	5 1	25	65	0 06	1 53	0.01	2.4	27	12	64	
40	7 7	.04	001																	
50	7.8	.04	001																	
60	7.9	04	001	8	46	13	28	19	14	6 8	.36	29	0 06	1.38	0.01	2.3	28	12	65	
70	7 9	.04	001																	
80	8 0	03	001																	
90	8.2	03	001	32	39	11	21	15	11	5.3	.40	.21	0 05	1.38	0 01	2.3	20	9	73	
1 00	8 3	03	001																	
1 10	8 4	02	001																	
1 20	8 9	08	001	74	14	4	9	7 5	1	2.2	23	18	0 04	1 38	0.01	1.0	28	13		
1 30	8 9	10	001																	
1 40	8 6	07	001																	
1 50	8 6	06	001																	

Depth metres	Org C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb	Rep K meq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	0 7	.06	229	80	1 6	35	38	1.6	0 8

SOIL TYPE Callide
SITE NO S6
A M G REFERENCE 248 510 mE 7 301 490 mN ZONE 56

GREAT SOIL GROUP No suitable group
PRINCIPAL PROFILE FORM Uf6 32P
SOIL TAXONOMY UNIT Ustollic Haplargid
FAO UNESCO UNIT· Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS Very few coarse pebbles, subrounded unspecified coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE 1 %
LANDFORM ELEMENT TYPE Levee
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY

CONDITION OF SURFACE SOIL WHEN DRY Recently cultivated, surface crust

HORIZON	DEPTH	DESCRIPTION
Ap	0 to 15 m	Brownish black (5YR3/1) moist, greyish brown (5YR5/2) dry, no mottles, fine sandy light medium clay, no coarse fragments, dry moderately strong, no segregations Gradual to-
B21	15 to 60 m	Brownish black (5YR2/2) moist, no mottles, heavy clay, no coarse fragments, moderately moist very firm, no segregations non-calcareous. Gradual to-
D1?	.60 to 80 m	Brown (7.5YR4/4) moist, brownish grey (5YR4/1) moist, no mottles, fine sandy medium clay, no coarse fragments, moderately moist very firm, no segregations slightly calcareous Gradual to-
D2	80 to 1 50 m	Brown (7.5YR4/4) moist, brownish grey (5YR4/1) moist, no mottles, sandy clay, no coarse fragments, dry moderately firm, very few fine carbonate soft segregations, slightly calcareous

Depth	1 5 Soil/Water			Particle Size				Exch Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	%				meq/100g					%			%				
			@105C	@ 105C				@ 105C					@ 80C			@ 105C				
Bulk 10	7 1	08	002																	
10	7 1	06	001	12	25	31	33	22	13	3 8	29	1 4	0 07	1 56	0 02	2.4	28	13	70	
20	7 0	06	001																	
30	7 1	07	003	2	30	26	47	28	18	5.3	.52	72	0 06	1 51	0 02	3 4	36	17	55	
40	7 2	09	005																	
50	7 4	10	007																	
60	7 7	10	007	3	37	21	47	28	20	7 0	.59	61	0 09	1 51	0.02	3 5	36	18	43	
70	8 0	10	007																	
80	8 2	12	009																	
90	8 4	15	013	13	46	13	32	20	15	5 7	52	44	0 08	1 52	0 01	2 8	29	13	.60	
1 00	8 3	.15	.014																	
1 10	8 4	.19	.021																	
1 20	8 4	24	.027	7	55	18	26	19	14	5 7	77	.41	0.06	1.53	0 01	2.8				
1 30	8 4	26	028																	
1 40	8 5	27	027																	
1 50	8 5	26	027																	

Depth	Org C	Tot N	Extr Phosphorus		Rep	DTPA-extr.			
	(W&B)		Acid	Bicarb	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		meq%	ppm			
	@ 105C	@ 105C	@ 105C		@105C	@ 105C			
Bulk 10	1 3	.06	267	119	1 8	38	45	2 8	4 5

SOIL TYPE Tognolini
SITE NO S7
A M G REFERENCE 248 390 mE 7 301 310 mN ZONE 56

GREAT SOIL GROUP No suitable group
PRINCIPAL PROFILE FORM Uf6 32P
SOIL TAXONOMY UNIT Ustollic Haplargid
FAO UNESCO UNIT Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS No coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL: Almost certain or certain

SLOPE 0 %
LANDFORM ELEMENT TYPE Drainage depression
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL· 699 mm

PROFILE MORPHOLOGY

CONDITION OF SURFACE SOIL WHEN DRY Surface crust

HORIZON	DEPTH	DESCRIPTION
Ap	0 to 05 m	Brownish black (5YR3/1) moist, brownish grey (5YR5/1) dry, no mottles, medium clay, no coarse fragments, fragment secondary, parting to moderate 2-5mm subangular blocky primary, dry moderately strong, no segregations Abrupt to-
B21	05 to 60 m	Brownish black (5YR2/1) moist, no mottles, heavy clay, no coarse fragments, moderately moist very firm, no segregations non-calcareous Gradual to-
B22?	60 to 80 m	Brownish black (7.5YR3/1) moist, brown (7.5YR4/4) moist, no mottles, heavy clay, no coarse fragments, moderately moist very firm, no segregations slightly calcareous Gradual to-
D	80 to 1 50 m	Brownish black (7 5YR3/1) moist, brown (7.5YR4/4) moist, no mottles, fine sandy medium clay, no coarse fragments, dry moderately firm, very few medium carbonate nodules, very few medium carbonate soft segregations

Depth	1 5 Soil/Water			Particle Size				Exch Cations					Total Elements			Moistures			Disp Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	%				meq/100g					%			%				
			@105C	@ 105C				@ 105C					@ 80C			@ 105C				
Bulk 10	7 0	09	001																	
10	7 0	09	001	7	23	34	41	29	17	5 9	30	2 0	0 09	1 49	0.02	3 4	37	17	58	
20	7 0	08	.001																	
30	6 9	05	.002	3	25	29	50	30	19	6 6	49	.86	0 07	1 38	0.02	4 3	38	19	57	
40	6 9	05	.003																	
50	7 3	05	003																	
60	7 5	06	004	2	28	21	52	33	22	8 7	.71	69	0.06	1 36	0.02	3 4	40	20	51	
70	7 8	08	005																	
80	7 9	09	007																	
90	8 0	11	008	3	42	19	42	23	19	7 2	58	51	0.05	1 44	0 01	2.9	33	16	49	
1 00	8 3	12	007																	
1 10	8 3	09	007																	
1 20	8 4	07	006	12	45	14	31	19	14	6.1	.54	42	0.04	1 50	0 01	2.1				
1 30	8 4	07	004																	
1 40	8 4	06	004																	
1 50	8 4	06	004																	

Depth	Org C	Tot N	Extr. Phosphorus		Rep	DTPA-extr			
	(W&B)		Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		meq%	ppm			
	@ 105C	@ 105C	@ 105C		@105C	@ 105C			
Bulk 10	2 2	16	412	189	2 2	72	72	3 5	1 8

SOIL TYPE Woodall
SITE NO S8
A M G REFERENCE: 248 880 mE 7 301 270 mN ZONE 56

GREAT SOIL GROUP Black earth
PRINCIPAL PROFILE FORM Ug5 17P
SOIL TAXONOMY UNIT Mollic Torrert
FAO UNESCO UNIT. Chromic Vertisol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS No coarse fragments

SUBSTRATE MATERIAL: Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE· 2 %
LANDFORM ELEMENT TYPE Levee
LANDFORM PATTERN TYPE· Level plain

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY

CONDITION OF SURFACE SOIL WHEN DRY Surface crust, self mulching

HORIZON	DEPTH	DESCRIPTION
Ap	0 to .05 m	Dark reddish brown (5YR3/2) moist, greyish brown (7 5YR4/2) dry, no mottles, light medium clay, no coarse fragments, moderate 5-10mm subangular blocky secondary, parting to moderate 2-5mm subangular blocky primary, dry very firm, no segregations Clear to-
B21	.05 to .65 m	Brownish black (5YR2/2) moist, no mottles, medium heavy clay, no coarse fragments, moderate pedality moderately moist very firm, no segregations slightly calcareous. Diffuse to-
D1	.65 to 1.10 m	Brownish grey (7 5YR4/1) moist, bright brown (7 5YR5/6) moist, no mottles, fine sandy light medium clay, no coarse fragments, dry very firm, few fine carbonate soft segregations Diffuse to-
D2	1.10 to 1.50 m	Brownish grey (7 5YR4/1) moist, bright brown (7 5YR5/6) moist, no mottles, fine sandy clay, no coarse fragments, dry very firm, few fine carbonate soft segregations.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size CS % @ 105C	FS	S	C	Exch Cations CEC meq/100g @ 105C	Ca	Mg	Na	K	Total Elements P % @ 80C	K	S	Moistures ADM % @ 105C	1/3b	15b	Disp Ratio R1	R2
Bulk 10	7.2	07	001																	
05	7 3	05	001	6	21	33	37	27	19	5 5	.21	1 5	0.07	1 40	0 02	3.2	37	15	50	
20	7.5	06	001																	
30	7.0	04	001	2	22	26	53	34	21	8.4	.80	71	0.05	1.18	0.02	3.6	41	21	66	
40	7 1	.05	001																	
50	7 6	06	003																	
60	7 9	08	004	4	30	24	49	31	22	10	1 2	.45	0.06	1.22	0 02	3.9	38	19	60	
70	8 3	11	008																	
80	8 4	23	017																	
90	8 4	35	030	6	46	19	35	23	17	8.0	1 4	.23	0.05	1.28	0 02	2.5	32	14	60	
1 00	8 4	40	038																	
1 10	8 2	39	040																	
1 20	8 1	36	041	7	48	20	31	22	17	7.6	1 3	.23	0.05	1.31	0.01	2.9				
1 30	8 0	36	044																	
1 40	8 0	34	044																	
1.50	8 1	33	041																	

Depth metres	Org C (W&B) % @ 105C	Tot N % @ 105C	Extr. Phosphorus Acid ppm @ 105C	Bicarb	Rep K meq% @105C	DTPA-extr Fe ppm @ 105C	Mn	Cu	Zn
Bulk 10	1 8	10	382	147	2 1	41	52	2 9	0 8

SOIL TYPE Woodall
SITE NO: S9
A M G. REFERENCE 248 180 mE 7 301 240 mN ZONE 56

GREAT SOIL GROUP No suitable group
PRINCIPAL PROFILE FORM Uf6.32
SOIL TAXONOMY UNIT: Ustollic Haplargid
FAO UNESCO UNIT Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS: Very few cobbles, subrounded unspecified coarse fragments

SUBSTRATE MATERIAL. Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL Almost certain or certain

SLOPE 0 5 %
LANDFORM ELEMENT TYPE Levee
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM Tussock grassland
DOMINANT SPECIES

ANNUAL RAINFALL 699 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Surface crust

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Dark reddish brown (5YR3/2) moist, greyish brown (5YR5/2) dry, no mottles, medium clay, no coarse fragments, weak <2mm platy, dry moderately strong, no segregations Gradual to-
B21	.05 to 75 m	Brownish black (5YR2/1) moist, no mottles, medium heavy clay, no coarse fragments, moderate pedality moderately moist very firm, no segregations slightly calcareous. Gradual to-
D1	75 to 1.10 m	Brownish black (7 5YR3/1) moist, dull reddish brown (5YR4/4) moist, no mottles, fine sandy medium clay, no coarse fragments, dry very firm, very few fine carbonate soft segregations. Clear to-
D2	1.10 to 1.50 m	Dark reddish brown (5YR3/2) moist, brownish black (5YR2/1) moist, no mottles; light medium clay, no coarse fragments, dry very firm, no segregations slightly calcareous

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch Cations meq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk 05	7 3	07	002																	
.05	7 3	06	001	10	24	35	36	29	16	7 2	.34	2.2	0 10	1.42	0.03	2 8	39	15	61	
20	7 4	06	002																	
30	7 4	06	002	3	18	28	53	38	23	9 7	1.3	.68	0 06	1.11	0 02	4 5	41	21	58	
40	7 5	06	004																	
.50	7 7	08	006																	
.60	7 9	.11	010	2	20	25	52	38	27	13	1.3	42	0 06	1 08	0 02	5.0	40	21	.56	
70	8 0	17	018																	
80	8 1	27	027																	
.90	8 2	.33	030	9	30	24	40	29	20	10	1 3	24	0.06	1 16	0 02	3.6	35	16	.53	
1.00	8 4	.33	030																	
1 10	8 3	.36	034																	
1 20	8 3	.40	039	10	28	24	40	26	19	9.2	1 5	24	0.05	1.27	0.02	3.7				
1 30	8 2	.37	040																	
1.40	8 2	.36	038																	
1.50	8 2	33	036																	

Depth metres	Org C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb	Rep K meq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	2 0	.07	466	158	2 2	45	50	2.8	1 0

SOIL TYPE Melton
SITE NO S10
A.M G. REFERENCE: 247 680 mE 7 301 300 mN ZONE 56

GREAT SOIL GROUP: No suitable group
PRINCIPAL PROFILE FORM· Uf6 32P
SOIL TAXONOMY UNIT Ustollic Haplargid
FAO UNESCO UNIT· Luvic Xerosol

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS No coarse fragments

SUBSTRATE MATERIAL Unconsolidated substrate materials
CONFIDENCE SUBSTRATE IS PARENT MATERIAL: Almost certain or certain

SLOPE 0 %
LANDFORM ELEMENT TYPE Plain
LANDFORM PATTERN TYPE Level plain

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL· 699 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Surface crust

HORIZON	DEPTH	DESCRIPTION
Ap	0 to 10 m	Dark reddish brown (5YR3/2) moist, greyish brown (5YR4/2) dry, no mottles, medium clay, no coarse fragments, dry moderately strong, no segregations. Gradual to-
B21	.10 to 75 m	Brownish black (5YR3/1) moist, no mottles, heavy clay, no coarse fragments, moderately moist very firm, no segregations slightly calcareous Gradual to-
D1	.75 to 1 30 m	Brown (7 5YR4/6) moist, brownish black (7 5YR3/1) moist; no mottles; fine sandy medium clay, no coarse fragments, moderately moist very firm, very few fine carbonate soft segregations. Gradual to-
D2	1.30 to 1 50 m	Dark brown (7 5YR3/3) moist, black (7.5YR2/1) moist; no mottles, fine sandy medium clay, few small pebbles, subrounded unspecified coarse fragments, moderately moist moderately firm, no segregations slightly calcareous

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations meq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk .10	7 4	10	001																	
10	7 6	08	001	6	28	28	42	29	19	7 9	.44	1.2	0 08	1 36	0.02	3.3	35	16	.60	
20	7.6	.08	001																	
30	7.6	09	002	5	24	29	48	32	20	8 3	1.0	.76	0.07	1 32	0 02	3.8	38	20	53	
40	7 6	10	005																	
50	7.6	.11	006																	
60	7.8	.12	007	4	25	20	53	34	22	10	1.8	58	0.06	1 16	0 02	3 9		22	64	
70	8.0	.12	008																	
80	8.0	.13	010																	
90	8 2	.16	014	5	36	18	40	27	20	9.0	1 2	31	0.07	1 14	0 01	3.5		17	65	
1 00	8 3	.20	.021																	
1 10	8 2	.24	.028																	
1 20	8 2	26	031	11	39	17	34	24	18	8.3	99	24	0 06	1.19	0.01	3.4				
1 30	8 2	20	.024																	
1 40	8 2	21	026																	
1 50	8.2	.23	.028																	

Depth metres	Org C (W&B) % @ 105C	Tot.N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb	Rep. K meq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	1 8	07	401	166	1.7	35	35	3.1	19