SOMALI DEMOCRATIC REPUBLIC
STATE PLANNING COMMISSION

MOGAMBO IRRIGATION PROJECT

Supplementary Feasibility Study

ANNEX 1
Hydrology and Climate
ANNEX 2
Soils

SIR M MACDONALD & PARTNERS LIMITED
Consulting Engineers
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SUPPLEMENTARY FEASIBILITY STUDY

This report comprises the following volumes:-

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Annex 2	Soils
Appendix to Annex 2	Soil and Land Class Maps
Annex 3	Agriculture
Annex 4	Livestock
Annex 5	Engineering
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ANNEX 2

SOILS

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SUMMARY

A semi-detailed soil survey was carried out over a total gross area of 9 559 ha. Soil units have been identified and described in terms of modal characteristics and the land has been classified making use of United States Bureau of Reclamation methods modified to suit the conditions found in the area.

Pre-field air photo interpretation defined the soil landscape units to be investigated and this assisted in the location of the soil survey observations. A total of 419 observation sites were investigated throughout the area of which 78 were pits and 4 termitaria descriptions. Augering to 5 m was carried out at 28 of the pits where samples were collected at 0.5 m intervals for subsequent analysis. A selection of representative pits was sampled by natural horizons, and samples for routine analyses were collected from alternate bore sites at four fixed depths. A programme of tests to determine subsoil saturated hydraulic conductivities (both vertical and horizontal) and surface infiltration rates was conducted to cover a representative selection of the soil types identified. Two major soil landscape units were defined: the Juba flood plain or basin clay unit, and the Juba meander complex, sub-divided into a levee and a depressional sub-unit. Smaller areas of minor levees and terraces were also identified and the western margin of the survey area was defined by the beach remnant and marine plain soils.

The soils of the flood plain and meander complex depressions are heavy clays often with pronounced vertisolic characteristics. This distinctive morphology influences their tillage characteristics, soil water relationships and fertility. The clays expand and contract on wetting and drying, respectively, with considerable self churning within the profile resulting in the development of slickensides or slip faces, prismatic or wedge shaped structures, gilgai micro-relief and carbonate concretions scattered on the soil surface.

The levee soils in the meander complex have more variable textures and considerable topographic relief influenced by high termitaria densities.

Areas of seasonally flooded depressions were identified in the west of the area but not included in the irrigation development planning. On the western margins at the limit of the survey, areas of terrace soils comprising shallow alluvium over marine plain deposits and beach remnant soils developed in red aeolian sands were also mapped.

The project requirements for the land classification were based on the USBR system modified to include land suitable for paddy rice (upland crops) developed under basin irrigated conditions. A special class, 4S, was reserved for land more suitable for overhead sprinkler irrigation, though its alternative classification for rice and upland crops under basin irrigation was also indicated if appropriate. The main limitations identified in the area include: soil characteristics such as texture, profile drainage and structure, especially in the flood plain soils; alkalinity, which is a rectifiable hazard mainly confined to the semi-permanently flooded depressions; salinity, which is another rectifiable hazard, generally only slightly limiting below 0.5 m and localised in occurrence, topographic restraints mainly in the form of termitaria; micro-relief taking the form of well developed gilgai formations on the basin clays and flood susceptibility.

CHAPTER 1

INTRODUCTION

1.1 Location

The project area is located in the south-west of the Democratic Republic of Somalia at 0° 4' to 0° 14' north latitude and 42° 40' to 42° 45' east longitude. It is part of the Lower Juba Shabelle flood plain just west of the present course of the Juba river.

1.2 General Background and Aims of the Study

The Mogambo area lies within the Calangi-Ngumbo reconnaissance soil unit defined by the International Co-operation Administration (ICA) (1961) and Lockwood Survey Corporation/FAO (1968). These are described as fine textured recent alluvial soils by Lockwood/FAO who place them in their flood plain (meander) landform unit. ICA (1961) state that these soils tend to be slightly to moderately saline below 90 cm. Lockwood/FAO consider them to be suitable for irrigation (Class A) and two subsequent studies, Selchozpromexport (1965) and Technital Spa (1975) based on the same reconnaissance information accepted the Calangi-Ngumbo soils as suitable for irrigation, placing them in Class II according to the USDA classification. More detailed soil investigations have been carried out on the lower Juba flood plain by Booker McConnell (1976) and Gitech Consult (1977). Both have found wide variations within the flood plain soil units defined by the earlier reconnaissance studies and the preliminary study of the Mogambo area by TAMS/FINTECS (1977) appears to confirm this. They place 40% of the 7 000 ha project area in irrigation suitability Class II, 45% in Class III and the remainder in Classes IV and V. The current report aims to extend the results of these earlier studies. This is achieved by a more detailed observation network of survey sites in the area in particular within the Juba alluvial soils (five sites/km^2). It also provides more quantitative data on the soil chemical and physical properties as an additional aid in soil classification for planning the development of irrigation in the area. Soil units identified are described in terms of modal characteristics and the variation found within the unit with profile descriptions for all pits and selected auger holes included in Appendices II and III. The nature of the mapped boundaries is fully described.

The land was classified making use of the United States Bureau of Reclamation (USBR) methods, modified to suit the conditions found in the area. Suitability for rice and for field crops other than rice were considered separately and special use Class 4 was used to indicate areas more suitable for sprinkler development. Limitations affecting land suitability are denoted by the use of suitable land class suffix letters.

1.3 The Environment

1.3.1 Physical Features

The Juba flood plain is formed of alluvial material of variable particle size distribution brought down by the Juba and Shabelle rivers since the late Tertiary period, and several hundred metres of Tertiary and Quaternary deposits

have been laid down. The Juba river is set slightly below the surrounding flood plain indicating a recent change or lowering of base level during the Pleistocene era.

The flood plain is flat with a subparallel surface drainage network. The Juba flows into very flat meandering swamps situated at the lower levels where stagnant water pools and depressions occur. Several landforms can be recognised within this flood plain including terraces, channel remnants, levees, meanders, oxbows and slackwater depressions. The most prominent feature is the semi-continuous old channel occupying the western part of the area. This is associated with many of the features indicated above and is formed from somewhat older alluvial material than that found to the east.

Macro-relief is dominated by the old channel courses or farta which are often water filled. Most of the area is very flat with the only abrupt changes of slope being into the farta and on to the marine plain. Micro-relief is more significant with considerable areas of gilgai developed in the clay soils on the eastern side of the old alluvial flood plain. Termite mounds are common especially on the medium-textured levee soils, in some instances these mounds are up to 5 m in height.

1.3.2 Vegetation and Land Use

This area lies within the Sudano-Decanion phytogeographical Region of Eig (1932), the Sudan ecoclimatic zone of Keay (1953) and with only 500 mm annual rainfall it is an extension of the semi-desert grassland area of Edwards and Bogdan (1951).

The vegetation of the alluvial soils responds to the more favourable edaphic conditions not found on the marine plain. It does, however, exist under a higher degree of disturbance, much of the area being settled and farmed. The non-cultivated areas are mainly lightly wooded shrub grassland formations with largely non-thorny tree species augmented by occasional parkland trees such as **Terminalia** sp. and **Hyphaene coriacea.** These occur more frequently along the old meander channel courses. **Acacia** spp and **Comiphora** spp dominate with **Combretum sp, Balanites** sp and **Salvadora persica** common in the more densely wooded shrub grassland communities. Larger emergents in these areas include **Dobera glabra** and **Acacia zanzibaria.**

The marine plain to the west suffers negligible biotic pressure from either local populations or indigenous fauna away from the main villages. Here the dominant formation is mixed shrubland and thicket with a low canopy varying from 1.5 to 3 m. Widely scattered and often stunted trees emerge from the shrub canopy to a maximum height of 6 m. In bare open areas the ground is often scalded or compacted and where grass species do occur they are largely perennial.

Neem (**Azadirachta indica**), kapok and **Cocos** sp are common amenity trees in and around the larger villages. Short-term fallow areas are rapidly colonised by a variety of grasses and dwarf shrubs notably **Hibiscus** spp.

Table 1.1 is based on an analysis of data provided by the bore and pit site observations carried out between March and April 1979 and indicates the approximate percentage breakdown of existing major land usage/vegetation units in the area.

TABLE 1.1

Land Use/Vegetation in Mogambo Area

Category	Observations %
Cultivated	21
Recent fallow (1-5 years)	20
Old fallow (5-10 years)	2
Scrub woodland	27
Grass shrubland	21
Riverine forest	8
Flooded areas	1

CHAPTER 2

SOIL SURVEY

2.1 Methods of Survey

2.1.1 Air Photo-interpretation

A preliminary air photo-interpretation was carried out on the 1 : 33 000 scale air-photographs of the area to establish a basic framework within which to plan the soil survey investigations. All available information on the physical features of the area, soils, vegetation, land use and so on were studied and related where possible to patterns identified on the photographs.

A systematic examination of the photographs was carried out, identifiable patterns delineated, and an API classification and legend established. The major units identified were :

(a) Juba meander complex - Jmx
(b) Juba levees - Jl
(c) Juba flood plains - Jb
(d) Juba depressions - Jd
(e) Juba terrace - Jt
(f) Beach remnant - BM
(g) Marine plain - MP.

Since the air photographs were taken in 1963 it was to be expected that observations on the vegetation cover within the API units would be subsequently modified in the light of field investigations.

(a) Juba Meander Complex

This unit is orientated in a north to south direction through the western part of the study area. It is composed of a major old channel course of the Juba river with many oxbow lakes, meander scars and old levee banks. Several of the channel courses have an intermittent seasonal flow. The topography is uneven, slopes ranging from less than 2% in the level bottomed channels and flatter interfluves to between 5 and 10% on the sides of the major channel depressions. The water filled oxbows and abandoned channels stand out clearly on the air photographs as darker toned areas, the intervening areas of uneven topography frequently have a dense tree and shrub cover and a large number of termitaria. Within this unit it was possible to separate areas of slightly lighter photo tone. Subsequent investigations revealed that these were predominantly levee formations. Levee areas close to the old channel complexes are characterised by a dark spotted appearance related to the high density of doum palms (**Hyphaene coriacea**) in these areas.

(b) Juba Levee

This landform unit was identified in small discontinuous areas along the western and eastern margins of the meander complex. It has predominantly pale tones and finer textures than either the meander complex or the flood plain/depressional

areas. It was also identified along a narrow rise in the east of the area associated with scattered clearings and occasional evidence of old channel courses. The boundary with the flood plain unit is fairly well defined in the east, the latter being darker toned.

(c) Juba Flood Plain

This unit occurs adjacent to the levees and mainly to the east of the meander complex but small areas have been identified within this complex and in the north west.

Tonal variations in this unit were found to be related to significant variations in microrelief. Lighter toned areas, often predominantly grass covered, have the smoothest micro-relief while darker toned areas with a rougher surface texture and often cultivated have significant development of gilgai micro-relief.

(d) Juba Depressions

These are found mainly in the west of the area between the meander complex and the marine plain. They have even very dark tonal signatures and a varying degree of tree cover. It is probable that surface water in these areas is a result of the severe floods of 1977 and under normal conditions only the treeless areas would be permanently under water. There is a marked break of slope into these areas, especially from the marine plain.

(e) Juba Terrace

Small areas of even textured topography were identified adjacent to the marine plain. These appear at slightly higher elevations than the current alluvial deposits. These were identified as older terrace units with a vegetation type transitional between the marine plain and the semi-recent alluvium.

(f) Beach Remnants

Within the Shabelle valley these areas, developed on old aeolian sand dunes, are characterised by trees with very broad flat topped canopies (**Acacia tortilis**) which have a very distinctive appearance on the photographs. Within the Juba valley this characteristic is not recorded and apart from scattered baobab trees (**Adansonia digitata**) the vegetation is more typical of the adjacent alluvium. On the air photographs they have a predominantly lighter tone and the margins which are frequently subject to erosion have a sinuous outline.

(g) Marine Plain

This area with its stunted vegetation cover and even undisturbed tone can also be clearly identified stereoscopically because of its higher elevation vis a vis the semi-recent alluvium. In close proximity to the villages much of the tree cover has been removed and there is a smooth textural appearance.

2.1.2 Soil Survey Techniques

The terms of reference clearly define the type of survey required and the density of observations and sampling programme. Within this framework soil survey observations were carried out along the main east to west trace lines A to Q to achieve an average density of five sites/km^2 (made up of four bores and one pit). The air photo interpretation was used as a guide in the location of these sites. The pits and auger holes were examined to a depth of 2 m and, in addition, at many of the pit sites augering was carried out to 5 m to ascertain the depth to shallow and possibly perched water tables and to obtain information on the distribution of salts in the subsoil. At a number of sites investigations were carried out on termitaria and samples collected for analysis.

In total 419 observation sites were investigated throughout the area of which 78 were pits (35 sampled) and four were termitaria descriptions. It was known from investigations in other parts of the Juba valley (Booker McConnell et alia) that high salinity values present in the subsoil would be expected in termitaria material brought up from that depth. As a result six termitaria were sampled for routine analysis. Four of these were located in the land levelling sample areas. Field measurements making use of a portable EC meter were carried out to confirm the presence of high salt concentrations in such samples.

Augering to 5 m was carried out at 28 of the pits. The sampling programme involved collecting four samples from alternate bore sites at 0 to 25, 25 to 50, 50 to 100 and 100 to 150 cm; and between three and five samples by natural horizons from a selection of representative pits. In addition samples were collected every 0.5 m below 2 m from the 5 m bore sites and a selection of these included in the routine analysis programme.

During the course of the field work it was found possible to identify further mapping units as sub-divisions of the original API units. These are described more fully in Section 2.3 following.

A programme of tests on subsoil saturated hydraulic conductivities (both vertical and horizontal) and surface infiltration rates was conducted to cover a representative selection of the soil types identified. A total of 20 surface infiltration tests were carried out using double ring infiltrometers (USBR, 1953) at representative pit locations. In these tests two steel cylinders were used, an inner cylinder with a diameter of 300 mm and an outer cylinder with a diameter of 500 mm. Both cylinders were driven into the soil to a depth of 150 mm and at each test site three sets of rings were employed. Water was poured into the rings to maintain a fairly constant head in a ring. Hourly infiltration rates were measured on the inner ring over a period of two days, although during the night it was not practicable to maintain a constant head when the equipment was left unattended.

Hydraulic conductivity tests were carried out in order to estimate both horizontal and vertical hydraulic conductivity rates at a number of representative sites. Measurements of horizontal hydraulic conductivity were made using the single auger hole pour in test (USBR, 1953) and theory suggested by Boersma (1965). For this test an auger hole of known dimensions is excavated to the required depth and filled with coarse gravel. A constant head of water is then maintained coincident with the soil horizon under test by means of periodic additions of a fixed volume of water required to compensate for the flow from the hole. Once equilibrium conditions have been achieved (normally after approximately four hours) measurements of time increments between the periodic

additions of water enabled horizontal hydraulic conductivity rates to be calculated. Preparatory saturation of the soil horizon under test was found to enhance the accuracy with which equilibrium conditions could be identified. Most tests were conducted around soil horizons at the 1 m depth, and a total of 21 tests were carried out. Double ring infiltrometers were used to determine vertical hydraulic conductivity rates in excavated pits with compact clay subsoils. In each of four sites triplicate tests were carried out at or about 1 m depth in order to provide estimates of percolation rates below this depth. Observations were continued over a two day period although infiltration rates were found to stablise after six or seven hours in most case.

The measurements of EC_e values using a field EC meter indicated that in common with other areas in the Juba valley there is a significant increase in salts in the subsoil below 1 m. Experiments to determine which salts might be leaching to depth were set up at four sites. Unfortunately owing to repeated interference by the nomad population it was only possible to continue the tests at three of these sites. At these microleaching test sites metal containers were inserted into the soil and kept topped up with Juba river water of known quality. These sites were sampled at fixed depths to 1 m within the container and alongside after a two month interval. Routine analyses were carried out on the 16 samples collected from within the ring to ascertain which salts may have leached within the profile over the period.

In addition to the formal soil survey procedures carried out information on land use and vegetation patterns (especially tree density) were also collected during the course of field work.

2.2 Soil Genesis

The present characteristics of the soil result from the interaction of several natural agencies. The major soil forming factors are recognised as climate, parent material, topography, vegetation and time.

Climate is a soil forming factor of great complexity. The climatic data included in Annex 1 refer to the present day conditions and any estimates of the climatic variability over the long time sequences involved in soil formation are largely conjectural. Temperature and rainfall are probably the most important climatic factors affecting soil formation in the area. Temperatures remain relatively high throughout the year with rainfall concentrated in the two wet seasons although in many years the dry period is relatively brief. These factors encourage microbiological activity and accelerate the speed of chemical reactions. As a result, the processes of decomposition of organic and mineral matter in the biosphere are rapid; mineralisation keeps abreast of organic matter formation and thereby prevents its accumulation. In most soils examined organic matter present is well humified and incorporated into the soil matrix.

The parent materials in the area are predominantly alluvial and originate from the catchment areas to the north of Somalia. The dominant rocks of the source region are highly calcareous and gypsiferous limestones and shales. The weathering products of these rocks are generally deficient in coarse aggregates. The redistribution of these materials has resulted in medium and fine textured soils in which clay, silt and fine sand fractions are dominant. This applies to at least 5 m as shown in the deep bores. No gravels were encountered in the area. In the areas adjacent to the Juba alluvium, soils are developed on older

marine and aeolian deposits. The beach remnant soils are frequently eroded and truncated, severely leached at the surface and pass into banded weathered coral limestone at depth. The soils of the marine plain are developed on marine clays rich in carbonates.

The topography is generally subdued with slopes of less than 2 to 3% throughout the alluvial plains. In these areas variations in micro-relief are particularly important due to their effect on drainage. This is exemplified by the sequence from moderately well drained conditions on the levees grading into conditions of increasingly restricted drainage in the depressions. This topographic sequence has been used as a basis for the soil mapping.

The vegetation has been discussed in Section 1.3. Removal of the vegetation cover in the levee areas where soil surfaces are liable to cap results in increased run-off and decreased infiltration of rainfall into the soil with the result that these soils remain dry for relatively longer periods of the year. In the vertisolic clay soils a drying out period is beneficial since it leads to a greater degree of vertical cracking and water penetration at the beginning of the wet season.

The time factor has an important effect on the development of the soils in the area. The period of weathering and leaching has been relatively brief in the alluvial soils whereas the soils of the beach remnant and marine plain have been exposed to the factors of degradation for a much longer period. Leaching is evidently a very important process in the pedogenesis of all the soils. This is confirmed by the relative increase in plant nutrient concentrations down the profiles shown by the chemical analyses. During field investigations clay cutans of varying thickness and continuity were observed coating the pores and ped faces in the B horizons of most soil profiles. These clay cutans suggest that clay movement or illuviation is active in these soils.

These soils have developed in recent and semi-recent alluvial deposits which, after changes in the course of the river over time, have become dewatered. This process has resulted in both surface shrinkage exhibited in subsidence and lateral shrinkage, which has caused a strongly developed system of vertical fissures. These extend to depths below 2.5 m in the finer textured soils. The degree of subsidence and shrinkage is directly proportional to the amount of clay present in the soil. Much of the shrinkage that takes place in dewatering is irreversible and the soils do not swell to their original volume on rewetting.

2.3 Soil Mapping Units

The soil classification adopted for this study makes use of physiographic units where the soil units are based on the major geomorphic units identified. This approach makes full use of all available information and produces an easily mappable logical sequence of soil units. The addition of topographic factors to soil factors in the mapping procedure results in a closer relationship between land suitability classes and soil unit boundaries. Figures 2.1 to 2.3 illustrate the relationship between the soil mapping units and some cross-sections through the area.

Major mapping units identified were the meander complex (Jmx) made up of a series of levee ridges and where these were persistent with only small intervening hollows they were mapped as the levee unit (Jmxl). Where the series of broad flat depressions often synonymous with former channels were separated

by very low levee formations or old bars these were mapped as depression units (Jmxd). Areas at higher elevations on the margin of the meander complex are generally levees (Jl). While down slope from these levee crests are broad flat plains with no micro-relief (Jb1 unit) or with micro-relief (Jb2 and Jb3 units). These grade eastwards into the present Juba levee backslope deposits of more recent red-brown clays. In the west substantial areas of flooded depressional clay soils have been identified adjacent to the marine plain and isolated beach remnant soils. Table 2.1 summarises the main characteristics of these mapping units, and Table 2.2 provides a correlation between these and previous surveys.

2.3.1 Meander Complex Soils

(a) Levee Unit

These soils are developed on weakly undulating old levee bars. They occur throughout the meander complex. Slopes are generally less than 0.5% except in the vicinity of channel courses where 1 to 5% slopes may occur. Micro-relief is marked by the high density of termite hills often up to 5 m high and 15 m circumference with a density of 8 to 10 per hectare. Surfaces are dry and hard with a few sink holes, rare surface cracks and frequent capping. Profile drainage is generally moderate. Natural vegetation, when uncleared, consists of dense riverine woodland or gallery forest, after clearing the regrowth is scrub woodland, main crops are sesame and maize. The major limitation for irrigation development is topography. Colours are typically 10YR at the surface with low values (3 to 4) and chromas (2 to 3). The subsoil has characteristically higher values and chromas (4), and often becomes 7.5YR. These soils contain significant proportions of very fine sand and silt with the clay fraction and textures range from silt clay loam to very fine sandy clay loam. Significant depths of sandy material are only normally encountered below 2 m. Calcium carbonate nodules and secondary carbonates are normally found in greater quantities in the lower horizons though their distribution is often a function of deposition rather than pedogenesis. In the same way structural development in these soils, though generally following the pattern of weak finely structured surface horizons over more massive subsoils, is often more erratic with more finely structured horizons occurring below a massive horizon.

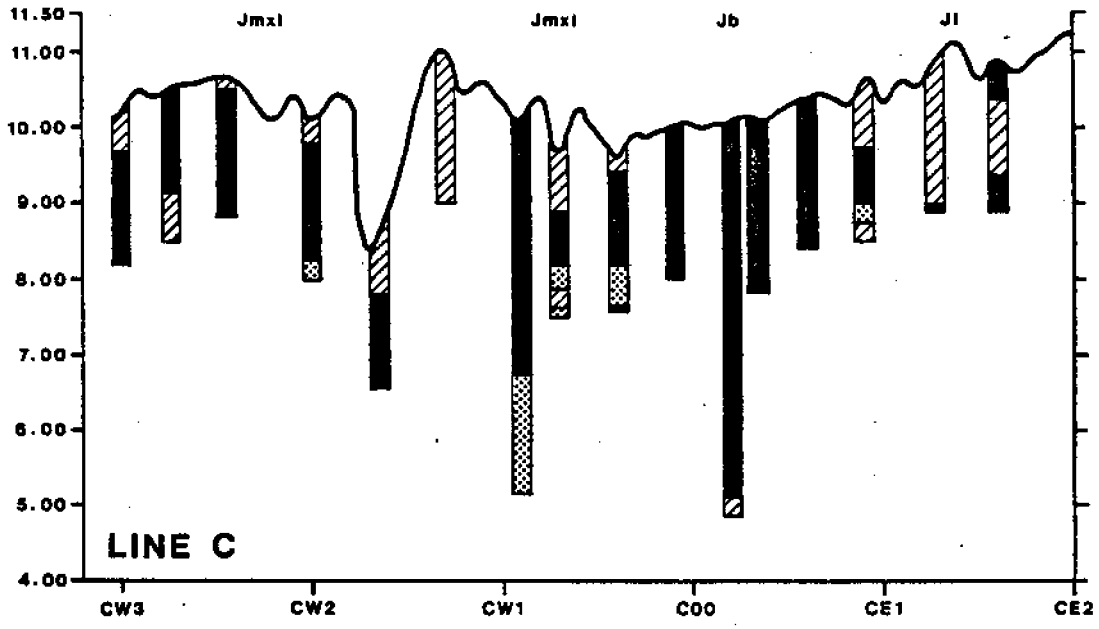
Modal profiles in Appendix II are T021, T135.

(b) Depression Unit

This unit includes soils developed in broad hollows between the levee rises in the meander complex. They are broad flat depressional areas often with a marked break of slope into the levee complexes. Topography is generally flat with occasional areas of moderately developed gilgai micro-relief and termitaria near the levee margins. Surfaces are generally dry and hard, grey brown in colour with occasional deep, coarse vertisolic cracking. Textures are predominantly clay loams or clays passing into sandy horizons within 2 m. Profile drainage is imperfect and occasionally poor. The vegetation is moderately dense woodland with occasional stands of riverine/gallery forest, large areas are cleared and developed with sesame, maize and tobacco. The main limitation to their development is their low elevation and liability to flood. Matrix colours in the surface horizons are 10YR with low values and chromas (2 to 3) whilst the sandy subsoils are usually 7.5YR with values and chroma of 4. Textures range from very fine sandy clay loam to clay loam and clay above the sandy horizons, which vary

Soil profile cross section

2.1



Vertical scale in metres AMSL

Horizontal scale 0 500 1000 1500 2000 2500 metres

Soil textures (after FAO)

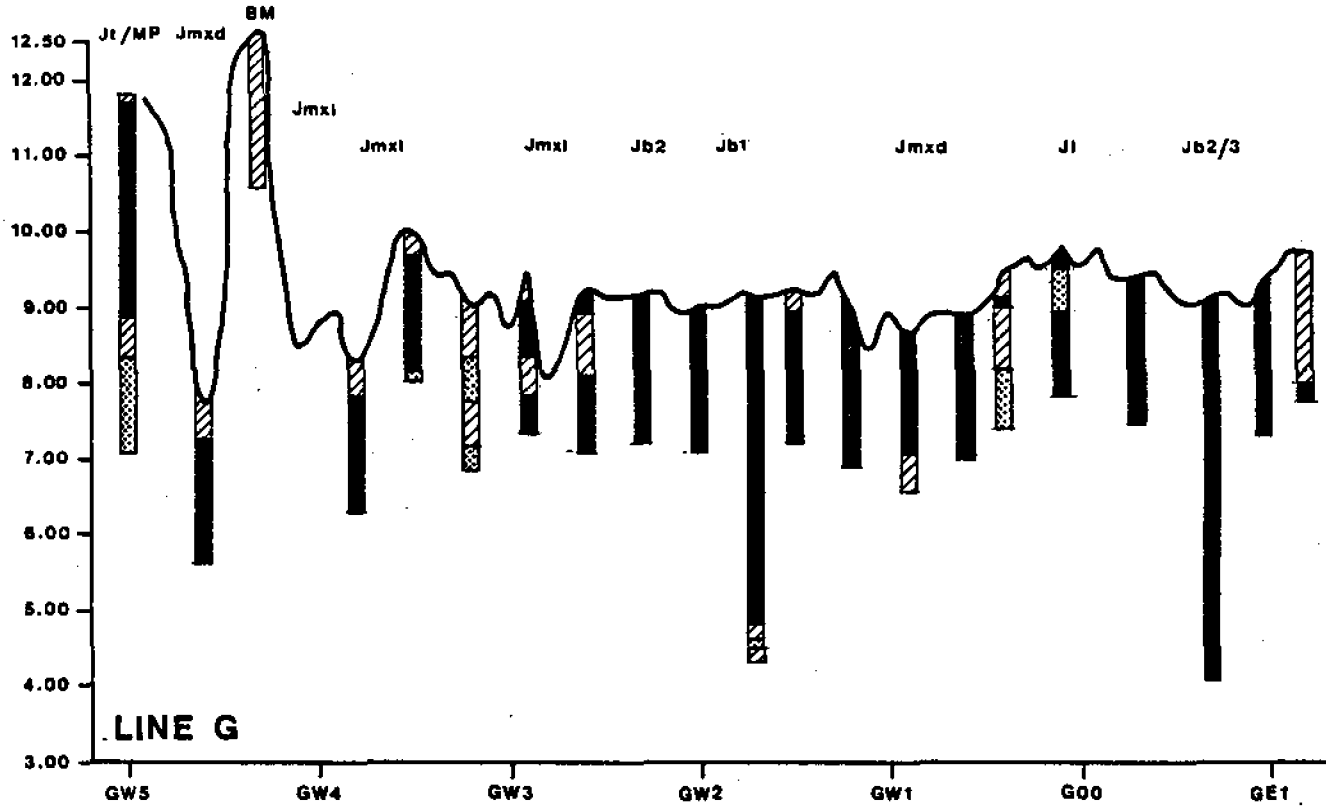
- Coarse
- Medium
- Fine

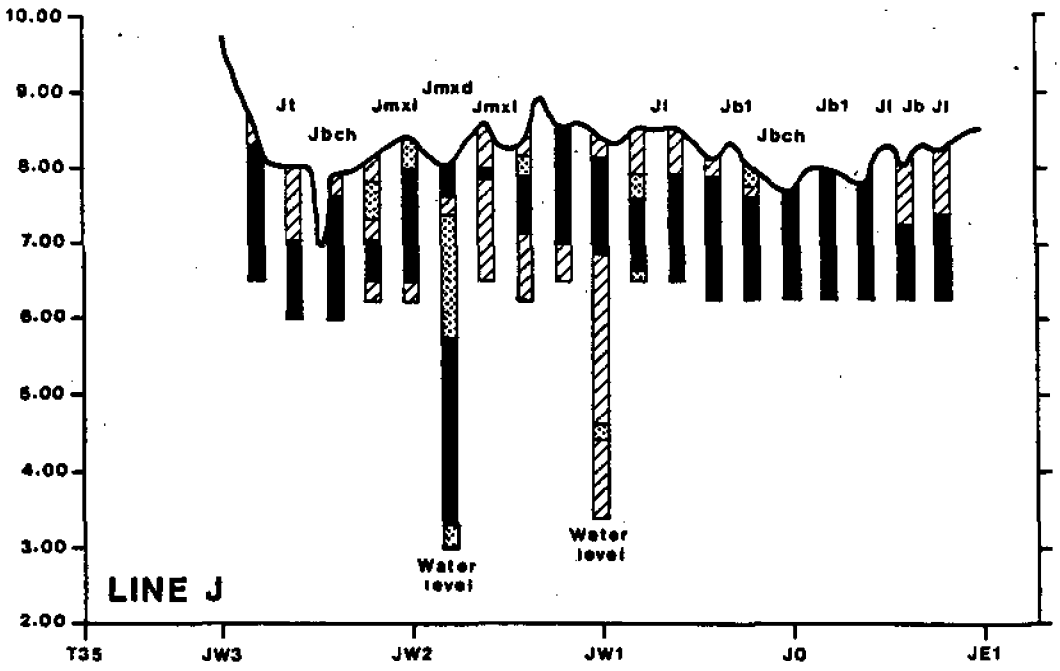
Soil types

Jb1,2,3	Juba basin
Jl	Juba levee
Jmxl	Juba meander complex - levee unit
Jmxd	Juba meander complex - depression unit
Jt	Juba terrace
Jd	Juba depression
Jbch	Juba channel
BM	Beach remnant
MP	Marine plain

Soil profile cross sections

2.2



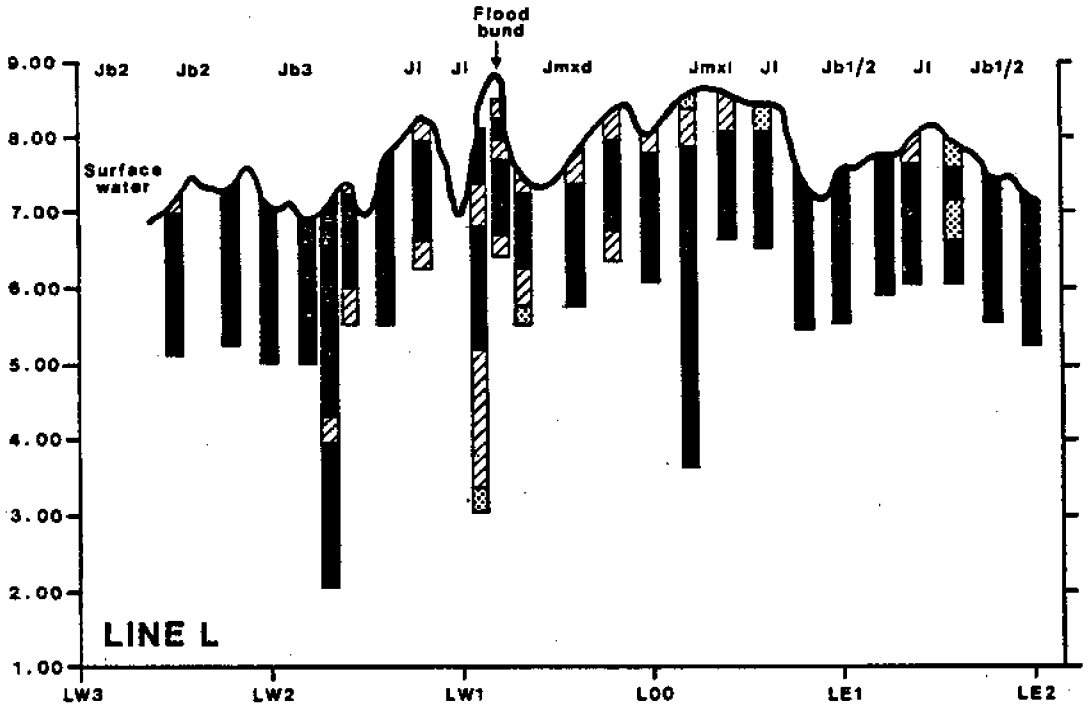


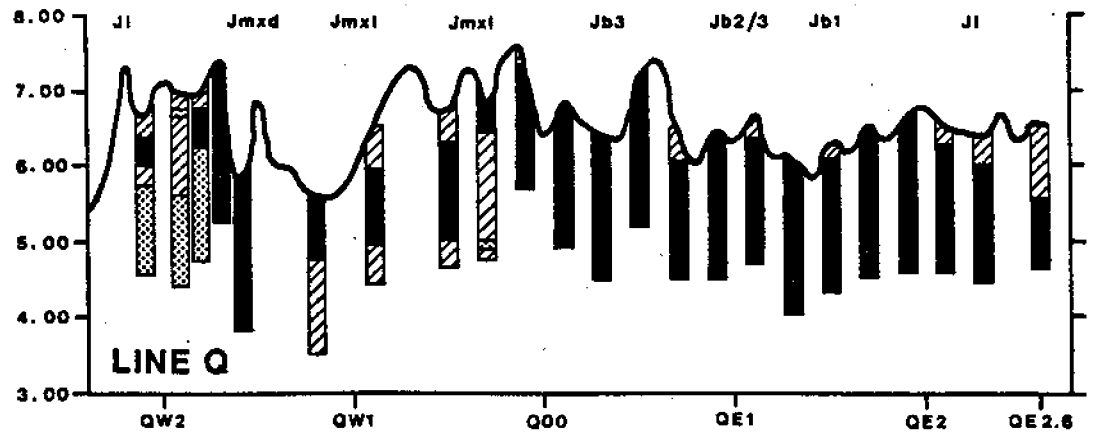
Vertical scale in metres AMSL

Horizontal scale 0 500 1000 1500 2000 250 metres

Soil profile cross sections

2.3





Vertical scale in metres AMSL

Horizontal scale 0 500 1000 1500 2000 2500 metres

For explanation of symbols see Figure 2.1

TABLE 2.1

Soil Mapping Units

Geomorphic unit	Soil mapping unit	Symbol	Physiography	Micro-relief	Soils	Natural vegetation	Present land use
Juba flood plain	Juba levees	Jl	Slightly raised areas adjacent to channels, slopes rarely exceed 1%.	Even	Variable with fine textures dominant, occasional sandy layers. Red brown to grey brown colours	Mostly cleared grass shrubland	Grazing
	Juba backslope and cover flood plain	Jb	Gently sloping (0.5 to 1%) areas extending below levees.		Similar to Jl but generally finer textured, moderately well structured clay loams over wedge/massive clays with deep cracks. Brown to grey brown colours.	Shrub grassland with occasional isolated mature trees largely cleared or seasonally burned	Commonly cultivated, maize and sesame dominant
		Jb1		Even			
		Jb2		M1 to M2 gilgai			
		Jb3		M3 gilgai			
	Juba depressions and backswamps (shallow)	Jb1	Concave broad depressions flat floored with slopes up to 1% flooded for short periods	Slight gilgai common (M1)	Dominantly clay, grey brown to grey colours	Largely cleared annual shrubs and grasses on fallow areas, dense Acacia nilotica thickets	Receding flood cultivated sesame dominant
	Juba depressions (deep)	Jd2	As above but permanently flooded under present hydrological conditions.	Under water	As above, mainly under water	Floating grasses and water lilies	Fishing
	Juba meander complex	Jmxl	Slightly raised areas with irregular relief and many termiteria, slopes rarely exceed 1%.	Uneven	Variable with fine textures dominant, occasional sandy layers, brown to grey brown colours	Originally riparian woodland mostly cleared	Maize
		Jmxd	Broad depressions flat floored with side slopes of up to 1%, flooded for short periods	Slightly uneven	Dominantly clay often with sandy subsoils, grey brown colours	Largely cleared, annual shrubs and grasses on fallow areas	Sesame as flood waters recede, some maize, tobacco
Juba terrace	Juba terrace	Jt	Irregular flat areas on margin of marine plain	Even	Variable textures mainly clays, some sandy lenses, grey brown to olive grey colours	Similar to marine plain Acacia sp and non thorny thickets	Rain-fed maize and sesame
Channel remnants	Channels	Ch	Remnants of former river courses passing through meander complex often water filled for long periods	Slightly uneven	Variable textures, much sand wash down profile	Acacia nilotica thickets and riparian woodland	Some cleared land, sesame on residual moisture
Beach remnant	Beach remnant	BM	Slightly elevated areas between Juba flood plains and marine plain	Slightly uneven av. amplitude 20 cm.	Reddish brown sand loams and sandy clay loams calcareous at depth with limestone fragments	Wooded shrubland open tree canopy, Adansonia digitata common	Grazing
Marine plain	Marine plain	MP	Flat plain, slopes rarely exceed 0.2% except on margin with alluvium	Slight-moderate gilgai, amplitude	Clay loam or clay surface over massive/wedge structured olive clays	Acacia spp. and non thorny shrubland, few small Dobera glabra	Grazing

TABLE 2.2

Soil Classification: Correlation With Previous Studies and International Systems

Mapping unit and symbol	Previous studies			International systems	
	ICA (1961)	Lockwood/FAO (1968)	Selchozpromexport (1965)	USDA (1975)	FAO/UNESCO (1974)
Juba alluvium					
Jl Jb1 to Jb3 Jd1 and Jd2	Calangi-Ngumbo Soil Association			Ustifluvents Chromusterts and pellusterts	Calcaric fluvisols Chromic and pellic vertisols
Jmxl				Ustifluvents	Calcaric fluvisols
Jmxd Jt	Calangi-Ngumbo Soil Association		Soils of gallery forests	Chromusterts Chromusterts	Chromic vertisols Chromic vertisols
Channel remnant Ch	Not separately mapped	Channel remnant	Not recognised	Ustifluvents	Mainly calcaric fluvisols
Beach remnant BM	Not separately mapped	Beach remnant	Red brown soils products of weathering of limestone	Camborthids	Eutric regosols
Marine plain MP	Umboi-El Gode and Camsuma-Amino soil Association	Tarba soil Umboi soil El Gode soil	Grey consolidated soils of savanna	Torrerts	Pellic and chromic vertisols

from very fine sandy loam to coarse sands. Profiles with a high clay content in the surface have more strongly developed structural features but structure tends to be related more to depositional sequence than profile development. The presence of secondary calcium carbonate and nodules in the sandy horizons would suggest that some leaching has taken place from the upper horizons.

Modal profiles in Appendix II are T136 and G137.

2.3.2 Levee Soils

These are very weakly undulating to flat discontinuous areas adjacent to the meander complex and other old channel courses in the east of the area. Micro-relief is generally even with only occasional termite hills. Surfaces are dry and hard frequently capped and yellowish brown in colour. Soil profiles tend to be stratified with medium textures passing into clays rather than sands at depth. Profile drainage is moderate. These areas are predominantly grass plains with **Dobera glabra** trees. Main limitations for agriculture are the tendency for soil surfaces to cap because of the high silt contents and the heavy textured subsoil. Colours at the surface are 10YR with low values and chroma (3 to 4), textures are predominantly silt clay loam to clay loam over clay. Strong brown and yellowish brown mottles occur in the subsoil. There is a moderate degree of profile development with moderately well structured surface horizons overlying wedge to massive structured subsoils.

The transitional zone between these soils and the basin soils is often marked by dual profiles with semi-recent and recent alluvium overlaying the basin clays. In the west of the area in the semi-recent alluvium values and chroma decrease (2 to 3). To the east the recent alluvium has 5YR and 7.5YR colours with low values (3 to 4) and high chroma (4 to 6). Subsoil horizons are much darker and greyer with 2.5YR and 10YR colours, values below 4 and low chroma (2 to 3). In these profiles the vertisolic cracking properties associated with the underlying basin clays frequently exert a significant influence on the structural development of the upper horizons. The recent alluvium is characterised by strong fine conchoidal structures. Finely divided carbonates and fine nodules are found throughout the profiles in all levee soils with gypsum crystals appearing at depth. The major limiting factor in most of these soils is heavy texture.

Modal profile in Appendix II is T009.

2.3.3 Basin Soil

These occur in a north to south belt along the eastern side of the meander complex, as small discrete units in and to the west of the meander complex and in a more extensive area in the north-west of the area. They are flat plains with barely perceptible slopes away from levees. There is a marked absence of micro-relief except for small areas of less than 25 cm amplitude in the Jb1 unit. The Jb3 areas have more strongly developed gilgai up to 50 cm amplitude. The surface is pale grey brown to dark brown self mulching and finely cracked with occasional sink holes. The Jb3 mapping units have more pronounced surface cracking especially over the gilgai mounds.

These soils are predominantly clay loams and clays extending to considerable depth. Profile drainage is imperfect. The natural vegetation ranges from open shrub grassland to moderately dense scrub wooland, cleared areas are planted to

maize and sesame. Main limitations for development are heavy textures, profile drainage and in the Jb3 unit strongly developed micro-relief (gilgai).

Soils of the clay basin Jb1 unit are predominantly clay loam to clay in texture with 10YR colours and low values (2 to 3) and chroma (2 to 4). Structures are moderately well developed at the surface, predominantly sub-angular blocky with fine vertical cracks. In the subsoil below about 1 m cracking becomes more diagonal associated with weakly developed slickensides and wedge shaped peds. Clay basin soils with more strongly developed micro-relief are mapped as Jb2 and Jb3, these have simlilar textures and colours to the Jb1 mapping unit but with lower values and chroma (2 to 3). Vertical cracking is strongly developed at the surface with coarse prismatic Bt horizons. The subsoil has moderate wedge structures with well developed diagonal cracks and slickensides. Fine carbonate nodules are distributed throughout the profile becoming ferromanganese coated at depth with secondary carbonate filaments and gypsum crystals present along crack faces.

Modal profiles in Apendix II are T020, G052.

2.3.4 Depression Soils

These occur within broad flat floored areas at low elevations in the west of the area. There is a gentle slope towards the centre of this area marked by minor secondary channel development, and usually by large bodies of surface water. Micro-relief is not markedly developed except on the extreme margins of the area, adjacent to the basin soils, where moderate gilgai development (up to 30 cm) has taken place. Profiles examined in the current study had only recently dried out after flooding, surfaces were dry and hard, rarely cracked with a fine surface mulch. These soils are characteristically dark grey to olive grey silt clays and clays with poor or very poor profile drainage. Frequently flooded areas are non-vegetated; other areas subject to intermittent flooding of short duration support dense **Acacia nilotica** woodland. A wide range of crops is grown on residual moisture on the margins of these areas. The main limitations to development are the flood hazard and the very low surface permeabilities. These heavy textured clay soils with 10YR and 5Y colours have low values (3 to 4) and very low chroma (1 to 2). Structural development in the profile is strongly related to the degree of drying out and cracking that has taken place. Strongly developed structures, deep cracks and gilgai formations are rare in areas which only dry out for relatively short periods between the rains. On the extreme margins of the depressions where these soils grade into the clay basins strongly developed vertical cracks and M2 gilgai are common. Subsoils below 1 m are rather massive clays. Fine carbonates are found throughout these soils, usually in the form of ferromanganese coated nodules, which often occur in discrete lenses as well as scattered through the horizons. Fine gypsum crystals appear below 1 m.

Modal profile in Appendix II is T081.

2.3.5 Terrace Soils

These are soils developed on very weakly undulating to nearly flat margins to the marine plain, and as outliers in the meander complex. There is a general slope to the east of less than 1% but outliers have a domed appearance. Micro-relief is marked by very weak gilgai development. Finely developed cracks develop on the dry hard yellowish brown surfaces. These sorts are fine sandy

clays to silt clays and olive brown in colour. Profile drainage is imperfect. Vegetation is a non-thorny scrub woodland and there is little cultivated land. Main limitations for development are topographic.

These soils have only been mapped in small areas in the west of the area on the margin of the marine plain and as one outlier in the south. Textures are mainly fine sandy clay or silty clay with 2.5Y colours, medium values (4 to 5) and chroma (4). Surface structures are moderately well developed mainly subangular blocky becoming more massive below 60 cm. Fine ferromanganese coated carbonate nodules are found throughout the profile with secondary carbonate and gypsum in the deeper subsoil.

Modal profile in Appendix II is T038.

2.3.6 Beach Remnant Soils

These fringe the marine plain adjacent to the Juba valley and are very weakly undulating relic aeolian sand dunes occasionally reworked by the river into minor levee formations. Slopes are less than 2%, with smooth even micro-relief. Surface colours are characteristically red or yellow red, dry hard and slightly capped. Textures are fine sands throughout with red brown and yellowish brown colours and moderate profile drainage. Natural vegetation is composed of baobab trees in a low shrub/grassland cover. These soils are generally out of command and have textural and topographic restrictions.

Modal profile in Appendix II is T032.

2.3.7 Marine Plain

This is a flat level plain which forms the western limit to the soil survey area. The marine plain is composed of fine textured sediments laid down under predominantly lagoonal conditions. Although some weathering has occurred in these deposits the nature of the clays and the semi-arid climatic conditions have favoured an accumulation of salts in the profile. Surface horizons are very dark grey brown to dark brown fine sandy clays. Subsoils are olive brown with considerable quantities of calcium carbonate and gypsum salts. The former are often associated with hard nodular forms of ferromanganese coated carbonates. Cracking is developed to more than 1 m depth with coarse prismatic structures becoming wedge shaped in the subsoil and accompainied by well developed slickensides. Fine ferromanganese coated gravels frequently litter the soil surface which is characterised by weakly developed micro-relief, sink holes and is slightly self mulching.

Modal profile in Appendix II is T028.

Figures 2.4 and 2.5 summarise graphically the main characteristics of the soil mapping units.

2.3.8 Area Measurements and Sampling Analysis

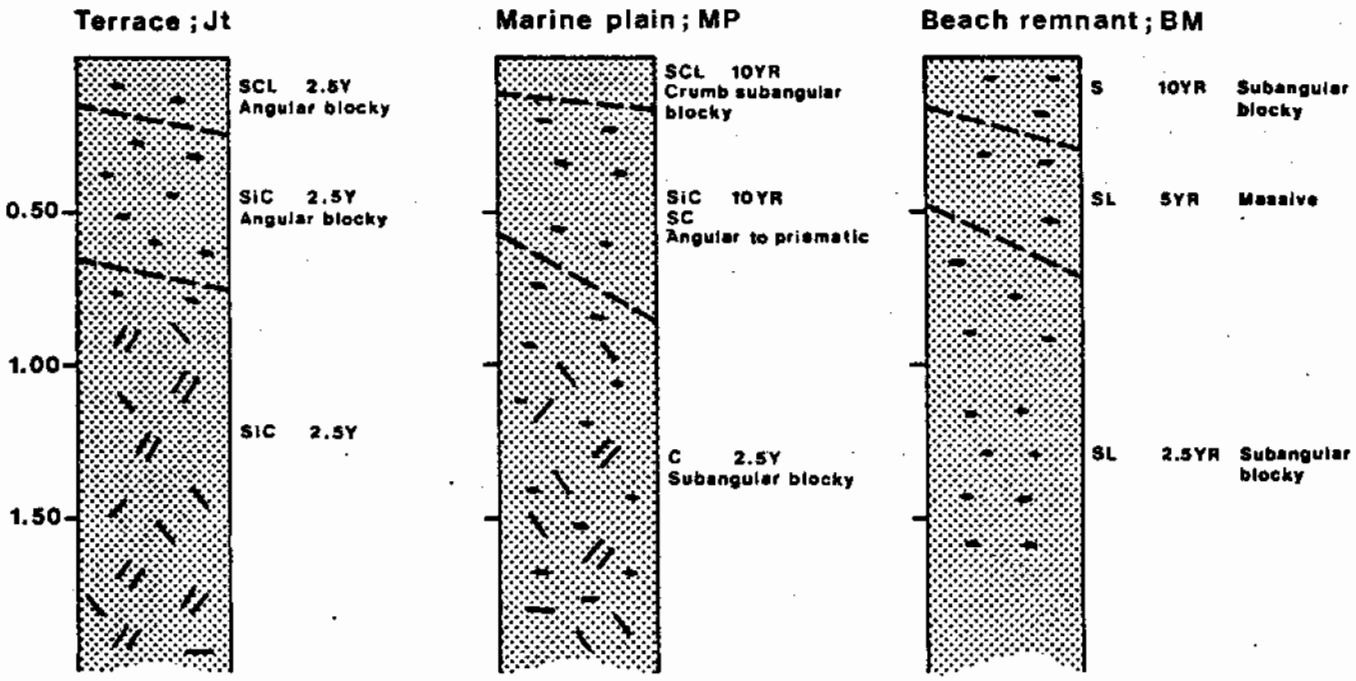
The data collected from the field survey were plotted on the 1 : 10 000 scale topographic maps. The soil mapping units were delineated and are shown on Plates Nr 27 to 30 from which the areas shown in Table 2.3 were measured. Table 2.3 also shows the percentage of the total number of sampled and non-sampled sites

TABLE 2.3

Soil Mapping Unit Areas and Analysis of Survey Sites

Mapping unit	Symbol	Hectares	Per cent total area	Percentage of total observations			
				Not sampled		Sampled	
				Pits	Bores	Pits	Bores
Levee	Jl	874	9.0	7.5	9.5	18.5	5.0
Basin clays	Jb1	2 417	25.0	20.0	22.5	29.5	20.5
	Jb1-2	326	3.5	-	3.0	2.5	2.5
	Jb2	327	3.5	7.5	8.0	-	6.5
	Jb2-3	32	0.5	-	-	8.0	2.5
	Jb3	738	8.0	15.0	5.0	2.5	6.5
Meander complex							
Levee	Jmxl	2 611	27.0	32.5	22.5	13.0	25.0
Depression	Jmxd	1 039	11.0	15.0	19.0	8.0	22.0
Depressions	Jd1	337	3.5	-	3.0	10.5	2.0
	Jd2	311	3.5	-	1.0	-	1.0
Terraces	Jt	102	1.0	-	3.5	2.5	3.0
Channel courses	Ch	340	3.5	-	-	-	-
Beach remnant	BM	106	1.0	2.5	3.0	2.5	3.0
Marine plain - forms limit of survey in west						2.5	0.5
Gross Survey Area		9 560	100	100	100	100	100

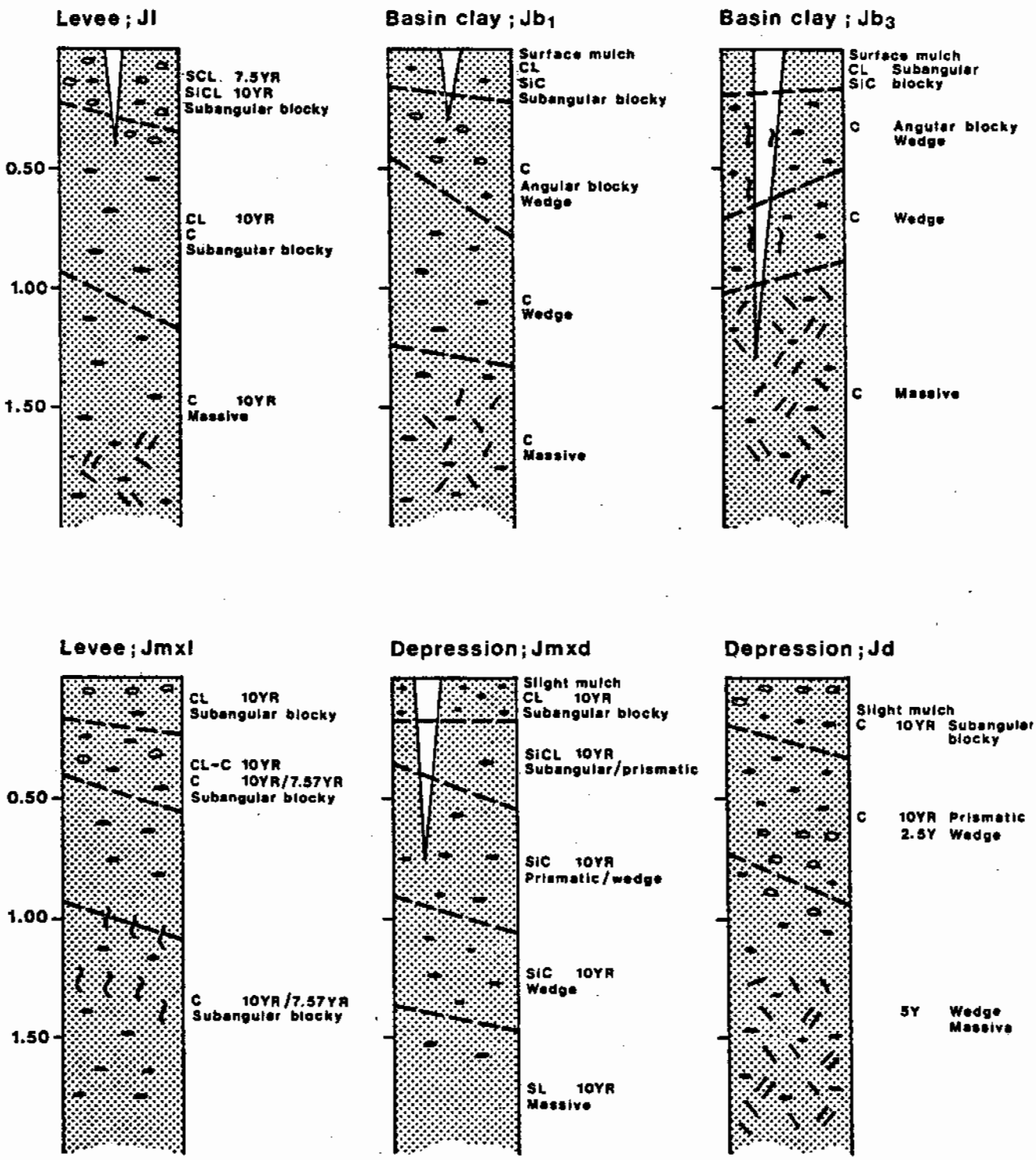
Profiles of soil units



Depth in metres

Gypsum crystals	
$CaCo_3$ nodules	
$CaCo_3$ filaments	
Shell fragments	
Cracks	
Colour (Munsell hue)	10YR
Texture (FAO)	CL

Profiles of soil units



Depth in metres

that fall within the different soil mapping units. 51% of the area is occupied by basin clays of the Juba flood plain including 11% within the meander complex depression sub-unit. Levee soils represent 36% of the area of which only 9% are generally flat Jl soils, the remainder belong to the levee sub-unit in the meander complex. The depressional soils which would prove difficult and costly to develop only occur in 7% of the total survey while a further 2% of the area is occupied by the beach remnant and terrace soils in the west of the area.

2.4 Soil Physics

2.4.1 Infiltration

Table 2.4 shows the values obtained for the mean infiltration characteristics of soil units. Optimum final infiltration rates for gravity irrigation purposes range from 7 to 35 mm/h. Most of the soils have values within this optimum range with the exception of the heavy clay soils of the depressions where problems exist in the soil chemistry (alkalinity) which affects infiltration rates.

Initial intake rates, which will be important at the start of the irrigation cycle, are especially high in the flood plain basin clays. This is directly related to the degree of cracking and drying that has taken place in these soils. However, although these rates are high at first, they rapidly decrease when the soil is wet and the cracks close. Tests were conducted on wetted profiles that had been disturbed and show that, as would be expected under semi-puddled conditions, much lower intake rates were achieved indicating that these are conditions more suitable for rice cultivation.

Figure 2.6 illustrates graphically the range of data obtained in these tests. The coarse textured aeolian sands of the beach remnant soils have very high terminal intake rates. The alluvial soils have very similar curves, while the least cracked soils show the most marked slow down in terminal intake rates. The more deeply cracked and the stratified levee soils of the meander complex (Jmxl) are characterised by somewhat higher final intake rates over the same time period.

2.4.2 Hydraulic Conductivity in the Subsoil

The average hydraulic conductivity of a soil profile is used for the determination of subsurface drainage and in evaluating the possibility of the development of perched water tables. The study of vertical hydraulic conductivities in the subsoil is also important in determining the capacity of the soil to be leached of possible harmful salts. Table 2.5 indicates the mean hydraulic conductivities of the main soil units. There is a considerable range of values for all the tests. It is significant that texture and especially structure have a strong influence on the rates recorded. All tests were conducted on saturated profiles details of which are given in Appendix V.

Usual minimum values for successful irrigation are in the range of 24 to 48 mm/d. Subsoil values obtained in the current experiments have proved consistently higher than this with the exception of depression soils. These values are not expected to affect crop production adversely and should be adequate for leaching purposes.

TABLE 2.4

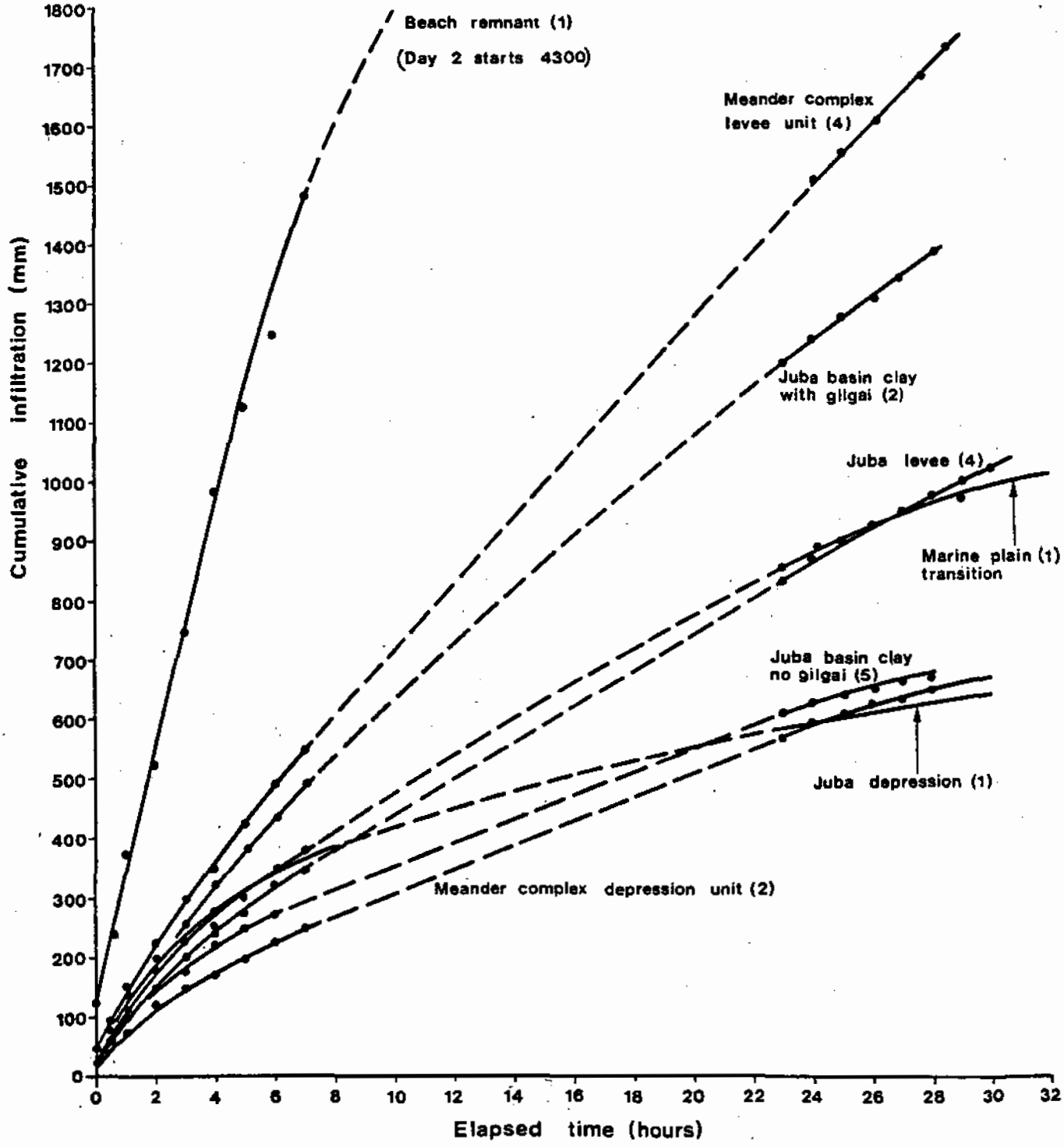
Mean Infiltration Characteristics of Soil Units

Soil unit[1]	Nr of sites in unit[2]	Approximate initial intake rate[5] (mm/h)	Approximate final intake rate[5] (mm/h)	Approximate time required[5] for infiltration of 50 mm (h)	50 mm (min)	100 mm (h)	100 mm (min)	150 mm (h)	150 mm (min)
Jb1	5	145	15	0	10	0	55	2	10
Jb2-3	2	220	35	0	10	0	35	1	15
Jl	4	120	27	0	15	1	10	2	00
Jmxl[3][4]	4	145	53	0	15	0	35	1	10
Jd[1]	1	250	6	0	10	0	35	1	25
BM	1	654	167	-	-[6]	-	-[6]	0	15
Jmxd	2	90	14	0	30	1	35	3	10
MP	1	282	20	0	10	1	00	1	50

Notes:
(1) Refers to soil unit defined in text.
(2) Triplicate tests carried out at each site unless otherwise stated.
(3) Two tests at sites D008, T081.
(4) Single test only at site T024.
(5) Values estimated from graphs.
(6) Not measured - extremely rapid intake rates.

Mean cumulative infiltration rates

2.6



Numbers in parenthesis after classification indicate number of test sites

TABLE 2.5

Mean Hydraulic Conductivity Characteristics of Soil Units

Soil unit	Depth range (cm)	Nr of tests	Textural range[3]	Structural groups	Hydraulic conductivity (mm/d) Range	Mean
Jb1	50 - 200	4[1]	SiCL(h) - CL - C	pr, w, sbk, abk	2.0 - 39.0	12.07
Jb2-3	80 - 200	3[2]	VFSC - C - SiCL(h)	w, pr, sbk, abk	10.0 - 12.3	11.17
Jl	70 - 200	3	SiC - C	pr, sbk, abk	2.1 - 39.0	21.03
Jmxl	10 - 150	4	FSL(h) - C - SiCL(h)	pr, sbk	42.2 - 11 739.0	3 334.33
Jdl	150 - 200	1	C	m	one test only	1.30
BM	30 - 200	2	FSCL - SL	m, sbk	0.0 - 33.0	16.50
Jmxd	60 - 200	2	VFS - VFSL - C	m, w	10.5 - 778.0	394.25
MP	100 - 200	1	SiC	m, sbk	one test only	3.00

Notes: (1) Test at T008, Jb, (11 - 50 cm) excluded because of excessively high intake rates which were not quantified. (Thus total number of tests was 5.)

(2) Includes supplementary site G141 - see Table 2.6.

(3) Indicates extremes encountered within textural profile, as defined by lightest and heaviest textures encountered.

Textural range classes:

SiCL	-	silt clay loam	VFSC	-	very fine sandy clay	VFS	-	very fine sand
CL	-	clay loam	SiC	-	silt clay	VFSL	-	very fine sandy loam
C	-	clay	FSL	-	fine sand loam			
(h)	-	heavy	FSCL	-	fine sandy clay loam			

Structural groups:

pr	-	prismatic	sbk	-	subangular blocky	m	-	mass
w	-	wedge	abk	-	angular blocky			

TABLE 2.6

Comparison between Vertical and Horizontal Hydraulic Conductivities at Four Test Sites

		Vertical hydraulic conductivity[1]		Horizontal hydraulic conductivity	
Test site	Soil mapping units	Depth of surface under test (cm)	Vertical conductivity (mm/d)	Depth tested (cm)	Horizontal conductivity [3] (mm/d)
T139	Jb1	100	27.0	75 - 125	1.90
T020	Jb1	80	88.0	80 - 140	2.70
G052	Jb2-3	100	30.0	100 - 200	10.00
G141	Jb3	90	41.1[2]	80 - 180	11.20

Notes: (1) Values are means of triplicate tests except where otherwise stated.

(2) Mean of 2 sets of observations.

(3) Refer to separate tests carried out at site during vertical conductivity test.

Table 2.6 compares vertical and horizontal hydraulic conductivity values at four test sites. The disparity between the measurements where the horizontal conductivities are between 0.5 and 4.0% of the vertical conductivities at similar depths are primarily related to the structural effects of vertical cracking in the clay soils. In view of the nature of the clays occurring in these experiments it is likely that under irrigation vertical conductivity values will more closely approximate to the horizontal rates.

2.5 Microleaching Experiments

Table 2.7 presents the changes found at the microleaching experiment sites. The data from which these changes are derived are presented in Appendix IV. The overall changes for each analysis have been calculated in percentage terms and averaged for the three sites examined to give an overall impression of the salt movements that took place in the profile. The results reflect to a large extent the limitations of carrying out an exercise of this type. However, one or two salient points emerge. As expected there has been a build up of calcium sulphate and magnesium salts in the surface horizons, while the more soluble chloride ions have moved down the profile to a significant extent. There has also been a general tendency for the movement of soluble anions and cations out of the 25 to 50 cm horizon. Calculated sodium adsorption ratios (SAR) all show a moderately significant increase but actual values show a wide range of variation and are generally not limiting for crop growth.

Significant differences between the degree of soluble anion and cation movement at the three sites are attributed to differences in the structural development of the soils at these sites. Most movement has taken place in the deeply cracked Jb3 profile with strong vertisolic characteristics with least movement in the less well structured Jb1 sites. It is also noticeable that most movements are limited to the top 50 cm of the profile.

TABLE 2.7

Percentage Changes in EC_e, Soluble Cations and Anions at Microleaching Experiment Sites

Sample depth (cm)	EC_e	Soluble cations				Soluble anions			
		Ca	Mg	Na	K	HCO_3	SO_4	Cl	SAR
0 - 25	+167	+141	+107	+93	+7	+10	+466	-0.3	+36
25 - 50	-32	-58	-64	-26	-7	+78	-33	-31	+32
50 - 75	+18	-16	-21	+18	+10	+70	+26	+13	+44
75 - 100	+6	-14	-20	+8	+4	+56	+1.4	-15	+24

CHAPTER 3

LAND CLASSIFICATION

3.1 Introduction

The purpose of the land classification was to produce a basis for the planning of future irrigated land use in the area. As required by the terms of reference, the system adopted is based on the United States Bureau of Reclamation (USBR, 1954) classification for irrigated land use, which ranks land according to its anticipated repayment capacity under irrigation. The main USBR classes are defined briefly as follows:

(a) Class 1 - Arable

Lands that are highly-suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops. These lands potentially have a relatively high repayment capacity.

(b) Class 2 - Arable

Lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity, adapted to a somewhat narrower range of crops. They are not so desirable nor of such high values as lands of Class 1 because of certain correctable or non-correctable limitations. They have intermediate repayment capacity.

(c) Class 3 - Arable

Lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics than described for Class 2 lands. They are expected to have adequate repayment capacity.

(d) Class 4 - Special Use or Limited Arable

Lands which are suitable for irrigation only if used for special crops or systems of irrigation. Class 4 lands may have a range in repayment capacity greater than that for associated arable lands.

(e) Class 5 - Non-arable

Lands in this class are non-arable under existing conditions.

(f) Class 6 - Non-arable

Lands considered non-arable under the existing project because of failure to meet the minimum requirements for the other classes of land. The lands do not have sufficient repayment capacity to warrant consideration for irrigation.

These USBR classes provide a convenient basis on which to classify land but it is also essential to accommodate the special attributes and requirements of an area under consideration.

The project requirements for the classification system were based on the USBR system but important modifications were made to suit the local conditions. In this instance the cropping pattern envisaged and the method of irrigation to be employed were at variance with the use of one class suitability system. In this study therefore the land classification has been modified to include land suitable for rice and crops other than rice (upland crops) developed under basin irrigated conditions. Class 4 has been reserved for land suitable for crops developed under overhead sprinkler irrigation. The sub-division into rice and upland crops is advantageous where rice is to form an important part of the cropping pattern since it has certain different requirements from those of other field crops. Whereas restricted profile drainage and a relatively impermeable soil surface to conserve water in the paddy field are essential for rice crops; upland crops require well aerated rooting conditions. Within much of the area it should be possible and may be desirable to alternate the two crop groups and a dual suitability classification indicates where the optimum performance can be achieved within these two crop groups.

Under sprinkler irrigation it is possible to include many areas of land which do not meet the minimum requirements of the rice and upland crop classifications. Within the Mogambo area it was felt desirable to develop certain areas under sprinklers. By including a separate definition an indication is provided of the location of land suitable for this form of irrigation. The soils of the area have been examined specifically in relation to irrigated agricultural land use in order to evaluate the effects of soil characteristics on land productivity and management requirements. Many of the technical data found in the appendices at the end of this volume have been interpreted and analysed to provide the data required in the land classification procedure. The following paragraphs first discuss the relevance of these data in land classification and then the application of specific criteria to the land classification process.

3.2 Characteristics Affecting Land Evaluation

3.2.1 Texture

Soil texture is the most commonly limiting factor. Land is downgraded if the soil is excessively coarse or excessively fine textured. Soils with coarse textures have low water holding capacities and excessive infiltration rates which reduce the irrigation efficiency. Fine textures adversely affect aeration and the root penetration for most crops. Soils with loam to friable clay textures are preferred. Soils dominated by montmorillonitic clays are therefore automatically downgraded to Class 2 or 3 depending on their permeability and structure. Profiles with significant depths of medium textured horizons within the top 120 cm are acceptable for Class 1.

The high percentage of fine sands and silts in these soils, especially on the levees, is also a limiting factor. It is a major cause of the widespread capping observed. This is of importance to irrigation since this cap will need to be broken between irrigation applications and the high silt contents will make access difficult on moist or wet soils. The cap will affect seeding emergence for small seed crops, though others such as cotton will break through regardless. On the levee soils, by careful management of the irrigation schedule, it should be possible to preserve top soil moisture thus minimising capping and improved seedling emergence and infiltration.

3.2.2 Structure Consistence

The soils of the Mogambo area are characterised by many of the featues attributed to vertisols and many are vertisols. These soils have a distinctive morphology which influences their tillage characteristics, soil water relationships, chemistry and fertility. The expanding lattice (montmorillonite) clays of the vertisols have the capacity to expand and contract on wetting and drying respectively. In the dry state the soil develops a shallow friable surface mulch and vertical cracks to a depth of at least 0.5 m. These cracks separate the prismatic structural units and some of the friable surface washes down the cracks. When the soil is rewetted and expands pressure develops in the lower horizons giving rise to a churning effect in the whole profile. This churning is reflected in the development of slicknesides or slip faces, wedge shaped structures in the subsoil, gilgai micro-relief, and the presence of ferromanganese coated $CaCO_3$ concretions scattered over the surface.

Observed structure in these clay soils is largely a reflection of the soil moisture content at the time of survey. Structural development is best expressed in the dry state but in this condition the soils are very hard. When wet the clays slake causing the disintegration of structural aggregates producing a soil which is sticky and plastic.

These variations have important implications for tillage practices. The range of moisture contents within which tillage is feasible are limited, in the dry state cultivation is difficult due to the hardness producing cloddy surfaces and, if mechanical cultivation is used, a high demand for power. Tillage under wet conditions results in a puddled and massive soil with the attendant risk of clogging up wheeled equipment, so tracked equipment is preferred and is in fact in use in much of the area at present. These soils have a self-mulching property, that is the capacity to form a friable surface layer some 200 to 300 mm thick. This effect achieved under conditions of alternate wetting and drying, can be used to good effect to reduce the need for tillage. It produces a fine seed bed through which water can move freely and enables the rapid development of the initial root system. It was noticeable that the local population preferred cultivating soils with this phenomenon rather than soils with a hard surface crust.

The expansion forces at work in the subsoils can have an adverse effect on root development causing compression and splitting of individual roots. Careful management of irrigation applications should ensure that severe contraction of soil aggregates does not occur. In most profiles the major limitation to crop rooting depths was the massive subsoil structures and higher bulk densities in these horizons rather than the effects of differential expansion and contraction forces.

3.2.3 Gypsum and Carbonates

(a) Gypsum

Gypsum occurs mainly in the subsoil horizons. Amounts and distribution varies significantly between sites but an examination of the data provides no real statistical significance. It takes two main forms:

(i) fine to very fine crystals;

(ii) fairly large lenticular crystals with dull faces.

The latter occur predominantly in the deeper subsoil layers.

Levels of gypsum in the soils of the Mogambo area are not sufficiently high to constitute a hazard and cause problems to crops, to effect subsidence by solution in the subsoil or to have adverse effects on irrigation structures.

(b) Carbonates

Calcium carbonate commonly accumulates in soils developed under arid and semi-arid climates. In the soils of the study area it was noted to occur in four main forms:

(i) small hard rounded whitish concretions usually up to 2 mm in diameter;

(ii) medium hard round whitish concretions up to 6 mm in diameter, occuring in only a few profiles;

(iii) very small crystals occurring as streaks or distributed throughout the soil profile. In certain profiles carbonates were found in fine crystalline form throughout the soil matrix;

(iv) very hard dark grey ferromanganese coated concretions up to 5 mm in diameter.

In general the presence of calcium carbonate affects both the physical and chemical characteristics of a soil. Discrete particles of carbonates can affect moisture characteristics and create an unfavourable environment for plant roots. However, carbonate concretions or nodules such as are found in the current survey area are less active than similar concentrations in a diffused form especially when the majority are larger than the critical size (0.02 mm).

The presence of carbonates in the soil reduces the ability of the soil to retain moisture especially at high tensions. It is noticeable that the moisture retention curves of highly calcareous soils, regardless of texture, are similar to those of coarse textured non calcareous soils. These characteristics imply more frequent irrigation applications at relatively low moisture tensions (less than 1 atmosphere.) Massoud (1973) has also noted that increased percentages of calcium carbonate in the soil result in the precipitation of carbonates in the pore space thus reducing diffusivity.

Though slight capping has been observed in the levee soils it is likely that this is probably due to binding by heavy rain drops and there do not appear to be any serious crusting problems with these soils due to high carbonate contents. However, there will be some effect on tillage of the basin clay soils, since while the aggregates are stable and consolidated when dry they tend to disintegrate when wet. As a result there is a need for careful timing of tillage and seedbed preparation.

3.2.4 Soil Salinity

High salt contents in soils affect plant growth in different ways. One effect of high salinity is to increase the osmotic pressure of the soil/water solution. This effectively increases the tension with which water is held in the soil against the extraction effort of plant roots. This effect is most critical at tensions representing the upper limit of easily available water. At a conductivity value of the soil saturation extract of 4 mmhos/cm the osmotic pressure of the soil solution is increased by 2.4 atmospheres above one having only very small amounts dissolved salts.

The second major effect of high salinity concerns the direct toxic effect of the individual constituents of the soil/water solution. There is some evidence to suggest that for root crops, chloride is rather more harmful than sulphate. Within this area the dominant soluble salts are calcium and sodium sulphates.

In evaluating the soils for sustained irrigation the importance of the initial level of salt varies according to the ease with which salts can be leached from the root zone. The presence of high salt contents in permeable easily leached soils has much less significance than a much lower salt content in soils of limited permeability which are difficult to leach.

For the optimum yield for a wide range of crops it is desirable that the EC_e of the root zone should not exceed 4 mmhos/cm. Two major factors control the equilibrium salt content that may be expected to develop under irrigation, the quality of the irrigation water, and the amount of water that can be expected to pass through and out of the profile as deep percolation losses. The quality of the irrigation water from the Juba river is very high, some values are given in Table 3.1.

Calculation of leaching requirements under different forms of irrigation are detailed in Annex 5, Chapter 5.

The actual deep percolation losses that can be expected through the soils have been determined for four sites in the basin clays, and estimates from the subsoil permeability experiments would suggest that subsoil permeabilities are satisfactory in all soils of the area for leaching requirements. Also in practice in vertisols salt transfer occurs laterally. After drying and cracking salts move laterally to the face of the peds where they accumulate to be washed downward during subsequent irrigation.

Salinity values for the routine samples analysed during the current study have been summarised in Table 3.2. Salinity classes have been adopted from FAO standards. 71% of the samples have a negligible salinity class with a value of 2.4 mmhos/cm or less; only 16% of samples fall in the low salinity class with values of less than 4.9 mmhos/cm. A small percentage of samples have moderate

TABLE 3.1

Chemical Analysis of Juba River Water Samples

Date of sample	EC x10^3	pH	TDS (ppm)	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Silt (g/l)	B (ppm)	SAR	River Flow (m^3/s)
				(milli equivalents per litre)											
8.2.79	0.4	8.0	180	2.9	0.8	1.1	0.05	0	2.4	1.1	1.6	0.04	0.14	0.6	-
16.2.79	0.4	7.8	370	4.7	0.7	1.0	0.07	0	3.1	0.9	1.4	0.13	0.14	0.3	90
4.3.79	0.4	7.7	320	2.4	0.6	1.5	0.05	0	2.1	0.9	2.0	0.09	0.14	0.9	65
11.3.79	0.3	7.9	225	2.7	0.6	1.2	0.07	0	2.6	0.9	1.4	0.1	0.06	0.7	46
16.3.79	0.3	8.0	200	2.9	0.7	0.7	0.07	0	2.3	0.7	1.6	0.1	-	0.4	37
25.3.79	0.5	7.9	365	2.9	0.8	1.9	0.09	0	2.0	1.0	2.2	0.01	0.08	1.0	42
1.4.79	0.6	8.2	595	2.7	1.2	1.9	0.1	0	2.7	1.3	3.2	0.2	0.05	0.9	52
4.4.79	2.7	7.7	2 080	10.6	3.3	15.8	0.1	0	1.8	9.0	18.4	0.4	0.1	2.2	72
6.4.79	0.7	7.8	560	5.0	1.1	2.4	0.05	0	1.9	2.6	2.4	1.1	-	0.8	84
8.4.79	0.8	7.8	550	5.5	1.7	2.7	0.1	0	2.1	5.8	2.4	1.4	-	0.7	278
9.4.79	0.6	8.1	385	3.2	0.9	1.5	0.1	0	2.7	2.4	2.0	8.7	-	0.7	205
10.4.79	0.4	8.3	330	3.0	0.7	0.9	0.08	0	3.0	0.8	2.0	12.1	0.09	0.5	160
12.4.79	0.5	7.7	420	4.2	0.7	1.5	0.09	0	2.8	1.4	2.0	5.5	-	0.6	92

Note: Samples taken from 1.4.79 onwards clearly show effect of first flush in river at start of gu season.

and high salinity values. Figure 3.1 indicates the average salinity values for different sample depths examined in the study. It is significant that, although there is a steady increase in salinity with depth, average values at 150 cm do not exceed 4 mmhos/cm which is accepted as a critical level affecting crop growth in the land classificaton.

TABLE 3.2

Summary of EC_e (mmhos/cm) Values by Salinity Classes and Soil Mapping Units

Salinity Class (after FAO)		Maximum EC_e value	Survey area	Percentage of total observations: Mapping units Jl	Jb	Jmxl	Jmxd	Jd	Jt	BM
I	Negligible	2.4	71	70	71	63.5	81	66.5	59	90
II	Low	4.9	16	15	15	22	12.5	16.5	23	0
III	Moderate	7.4	7	15	5.0	8.5	6.5	8	4.5	0
IV	High	9.9	4	0	5.5	4	0	4.5	9	0
V	Very high	+9.9	2	0	3.5	2	0	4.5	4.5	10

Some high EC_e values were observed in samples collected from pits some time after they had been opened. Efflorescence on ped faces is a common phenomenon in these soils indicating that under conditions of evaporation of soil moisture the salts were moving through the profile to the pit face. This phenomenon has been reported elsewhere (HTS, 1978) where expected EC_e values of 4 to 8 mmhos/cm actually exceeded 13 mmhos/cm.

Investigations within the Juba valley (Booker, 1978) have shown that material brought to the surface by termites to produce their familiar termitaria contains a considerable salt content derived from the subsoil horizons. Table 3.3 indicates some field values obtained for $EC_{1:5}$ determinations and against these are plotted the laboratory determinations of EC_e in mmhos/cm. Such high values will have an adverse effect on crop growth initially when the material is levelled. However, there are no indications to suggest that such salts will not effectively leach back into the subsoil even under sprinkler irrigation.

TABLE 3.3

Analysis of Termite Soil Samples

Site/Sample number	Depth (cm)	Field EC (micromhos/cm)	Laboratory EC_e (mmhos/cm)
MW1/1	Surface	-	0.7
MW1/2	Surface	-	1.1
G149/1	0-50	-	2.8
G149/2	50-100	-	2.6
G149/3	100-150	-	2.2
G149/4	150-200	-	2.1
G148/1	0-50	4 920	5.8
G148/2	50-100	6 600	7.8
G148/3	100-150	6 250	7.7
G148/4	150-200	5 525	5.7
G148/5	200-250	2 600	3.7
G148/6	250-300	3 600	3.6
G147/1	0-50	3 000	5.1
G147/2	50-100	4 800	7.8
G147/3	100-150	4 750	9.1
G147/4	150-200	7 050	8.9
G147/5	200-250	6 000	9.0
G147/6	250-300	5 950	8.8
G146/1	0-50	-	7.8
G146/2	50-100	-	10.0
G146/3	100-150	-	11.4
G146/4	150-200	-	12.0
G146/5	200-250	-	11.9
G146/6	250-300	-	12.0

Table 3.4 indicates that EC_e values do not increase significantly on average in the subsoil.

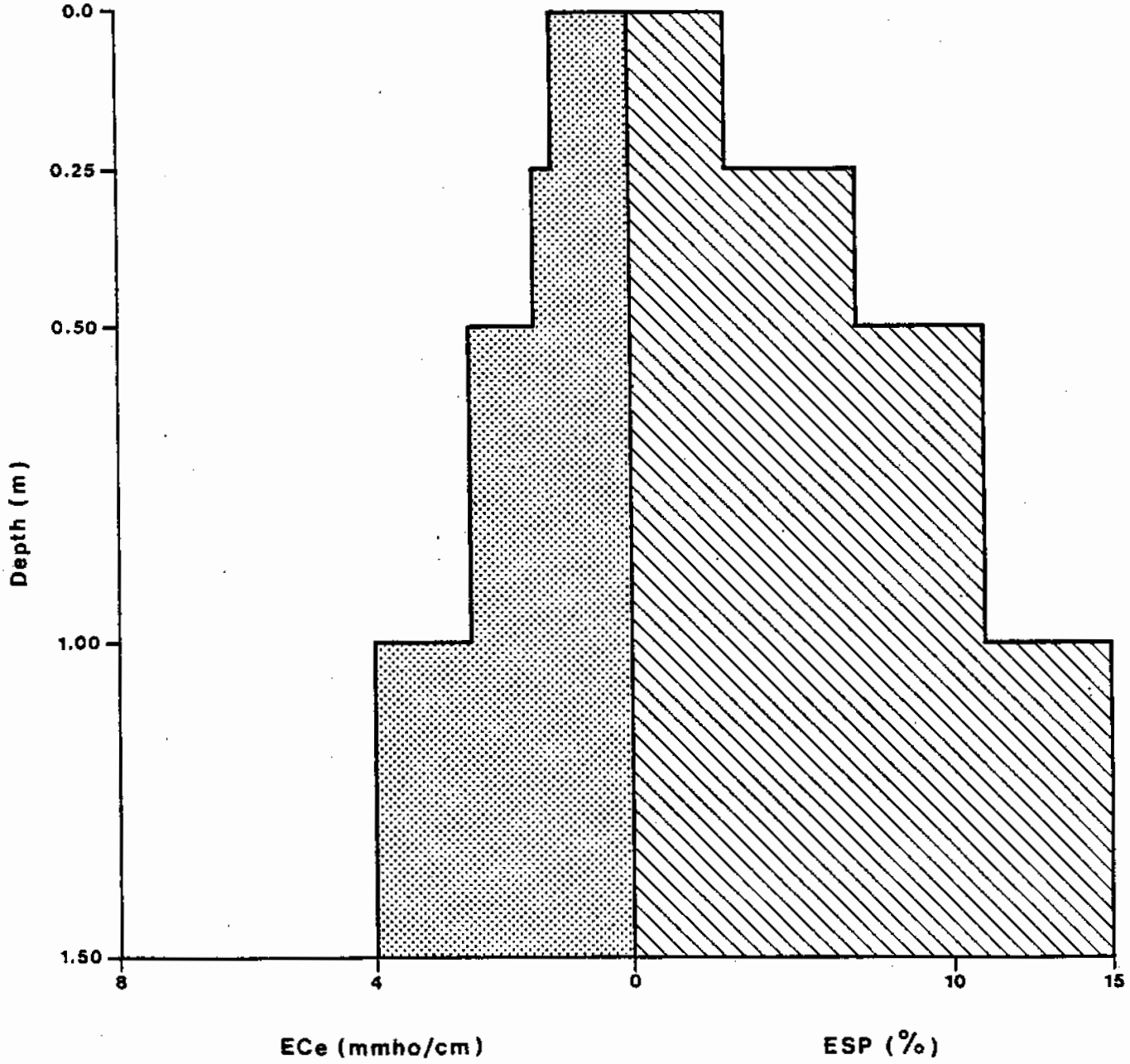
TABLE 3.4

Average EC_e Values in mmhos/cm for Deep Subsoil Samples

Depth (cm)	EC_e (mmhos/cm)
200-250	6.3
250-300	7.6
300-350	7.6
350-400	7.4
400-450	7.0
450-500	8.3

Variation in ECe and ESP with depth

3.1



Notes:- 1. Results are average of all routine samples

TABLE 3.5

Range of pH Values by Soil Mapping Units by Numbers of Samples

pH value / Mapping unit	< 7.0		7.1-7.5		7.6-8.0		8.1-8.5		8.6-9.0		> 9.0	
	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl
Jl	-	-	-	-	4	19	13	1	3	-	-	-
Jb1	-	-	1	5	27	81	67	13	17	-	-	-
Jb1-2	-	-	-	-	5	12	5	-	2	-	-	-
Jb2	-	-	-	2	8	57	38	7	9	-	-	-
Jb2-3	-	-	-	-	1	16	8	-	3	-	-	-
Jb3	-	-	-	4	8	58	50	-	5	-	-	-
Jd1	-	-	-	4	8	15	9	-	2	-	-	-
Jd2	-	-	-	-	2	4	2	-	-	-	-	-
Jmxl	-	-	-	5	49	150	102	10	12	3	3	-
Jmxd	-	1	2	13	44	123	86	6	10	-	1	-
BM	-	4	6	4	4	9	4	3	6	-	-	-
Total observation	0	5	9	37	160	544	384	40	69	3	4	0

3.2.5 Soil pH

Soil pH (acidity/alkalinity) was measured in 1 : 2.5 soil to water suspension and potassium chloride (KCl) suspension in the laboratory. The pH values measured using KCl are believed to be closer to the field pH of the soil solution and plant roots, they are usually lower by 0.5 to 1.0 units than those measured in an aqueous suspension (Table 3.5). In this instance most values fall within these limits. The median value is clearly between 8.1 and 8.5. There is no consistent relationship between pH and soil depth. It is unusual for non-sodic soils to have pH values exceeding 8.5 but these levels can occur under particularly low carbon dioxide concentrations.

It is noticeable that a sharp usually downward change in pH between different depth samples often indicates a sharp increase in EC_e value; pH values for samples in the deeper subsoil show no appreciable increases.

3.2.6 Alkalinity

The degree of alkalinity in soils is most commonly expressed in terms of exchangeable sodium percentage (ESP). ESP is the percentage of the cation exchange capacity which is occupied by exchangeable sodium. The main effect is in the dispersion of the clay causing the soil to be dense and difficult to work, reducing the permeability and infiltration rates and in general making it a poor medium for plant growth. Finely dispersed clay may be washed down the profile increasing the clay content in the deeper layers. A soil is considered alkaline when the ESP exceeds 15. This is also generally accepted as the limit beyond which deterioration in the soil's physical properties will excessively affect crop performance and cultivation. However, evidence from the Sudan and elsewhere (Dudal, 1965) suggests that in soils dominated by the swelling and shrinking properties of expanding lattice clays, little effect on yield results until ESP values are as high as 30. This is probably due to the fact that since the structure and permeability qualities depend almost entirely on the cracks which develop in the dry soil, high levels of sodium will not greatly alter this and movement of dispersed clay is likely to be very slow in these soils and again would have little effect in reducing permeabilities so long as the soil cracks. Some deleterious effect on tillage is likely but expanding lattice clay soils are not easily tillable irrespective of the level of exchangeable sodium.

The effect of irrigation on soils in respect of alkalinity depends on various factors. Soils with high ESP, but containing few soluble salts or alkaline earth carbonates will not improve on leaching, unless special ameliorating agents like gypsum, sulphur or carbonates are used. There is then sufficient calcium progressively to replace sodium on the exchange complex as leaching proceeds. However when the soil itself contains gypsum in significant amounts there is enough calcium present to allow the ESP to be lowered naturally in leaching. The quality of the irrigation water is also important, SAR levels are often used to categorise the quality of water in respect of dangers of increasing the exchangeable sodium in the soil.

The SAR values of the Juba river for the samples listed in Table 3.1 are all low indicating the high quality of the water for irrigation requirements. They only limiting period is of short duration after the first heavy rains when SAR values exceed 1.0.

In terms of soil chemistry leaching would pose no problems as sodium and chloride ions which account for much of the soil salinity are mobile. The soils themselves contain considerable reserves of gypsum and exchangeable calcium and have low SAR values indicating that leaching of sodium ions should not have any adverse effect on soil permeability.

Table 3.6 summarises the main ESP values obtained from the routine samples. Most of the values fall below 15% and most of the upper horizons have values of less than 5%. Only a few values have been obtained from the deeper subsoil with critical values indicative of alkalinisation. These are mainly found in the depressions and adjacent to the marine plain. An analysis of the samples obtained from natural horizons in the pits confirms these observations.

There has been some discussion (Gitec Consult, 1978) on the adverse effects of high magnesium plus sodium ratios to calcium in the exchange complex. An examination of the data for the current study indicates that the ratio of Ca to Na + Mg is mainly more than 1 : 1 and that only a few samples show a ratio of less than 2 : 1. These occur in the subsoils of the basin clays, the meander complex levee sub unit and the levee soils. Average values for all the samples show no unfavourable characteristics.

TABLE 3.6

Summary of ESP Values by Soil Mapping Units

ESP groups	Percentage of total routine samples	Percentage of total observations Mapping units						
		Jl	Jb	Jmxl	Jmxd	Jd	Jt	BM
15	93.8	99.7	97.7	98.2	99.5	99.6	99.9	99.8
15-25	3.2	0.1	1.3	1.0	0.4	-	0.1	-
25-30	1.7	-	0.7	0.4	0.1	0.3	-	-
30-35	0.3	-	0.1	-	-	-	-	0.1
35-40	0.3	-	0.1	-	-	0.1	-	-
40-45	0.3	-	0.1	-	-	-	-	0.1
45-50	0.1	-	-	0.1	-	-	-	-
50	0.3	-	-	0.3	-	-	-	-

3.2.7 Topography

(a) Macrotopography

The overall landform of the study area is flat with slopes generally less than 0.5%. However, local irregularities exist such as the major channel remnants where 1 to 5% slopes may occur on either bank.

(b) Microtopography

This is a more serious constraint to development and has been identified in two forms :

(i) dense termitaria
(ii) strongly developed gilgai phenomena.

(i) Termitaria

These are confined almost exclusively to the loamy textured soils of the levee units in the meander complex. The mounds built up over long periods of time are often up to 5 m high. Many still contain active termite colonies which are continually adding to the stature of the mounds. Densities may approach 8 to 10 hills per hectare and it is proposed than in most of the levee areas sprinkler irrigation development will be a more practical alternative than basin irrigation and will exclude the need for very expensive levelling requirements. (Methods for dealing with termitaria are discussed in Annex 5, Chapter 3.)

(ii) Gilgai Formations

Gilgai and sink holes are widespread features of the vertisolic soils identified in the flood plains of the basin mapping units (Jb). Gilgai consist of a complex pattern of convex ridges and intervening depressions, orientated in a polygonal pattern, resulting from the alternate swelling and shrinking of the clays. Ridges are 0.2 to 0.5 m high with amplitudes of 2 to 5 m. Sink holes often form in the centre of depressions forming cavities 0.2 to 0.3 m in diameter. The strongest form of this development has been mapped in the Jb3 unit on the semi-recent alluvial clays. Levelling these areas will prove costly and may bring horizons with adverse chemical characteristics closer to the surface. However, investigations have shown (HTS, 1978) that the cracking pattern and consequent gilgai formation is unlikely to develop under conditions of almost constant moisture regimes associated with irrigation. Severe gilgai formations are unlikely to reform in these soils unless they are allowed to dry out for significant periods. In most of these soils chemical characteristics detrimental to crop growth are rectifiable hazards and rarely occur above 0.5 m depth in the soils.

3.2.8 Derived Characteristics

(a) Soil Water Reactions

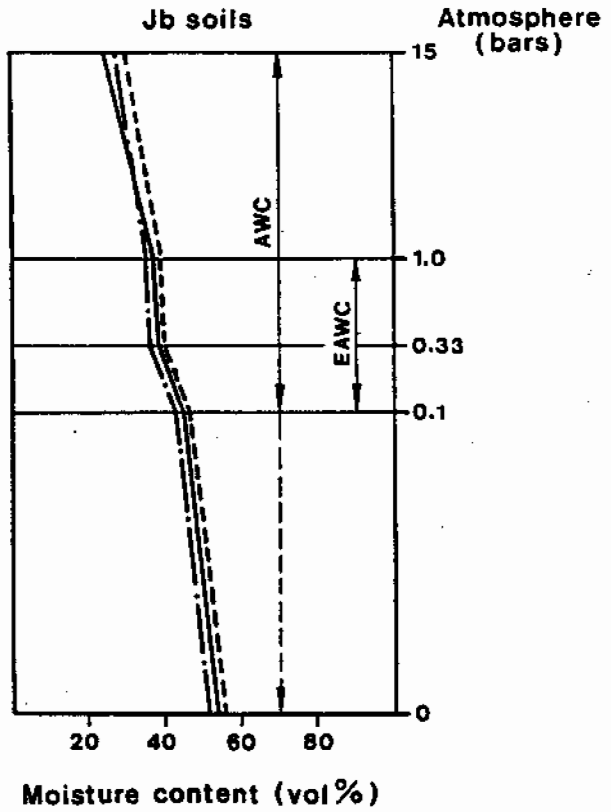
The predominance of the vertisol characteristics of very fine textures and expanding lattice clays have a profound influence on soil water relations which is particularly significant for irrigation agriculture. Due to the observed tendency for soil aggregates to slake on wetting, little stable macroporosity exists in the saturated soil and transmission of water is confined almost entirely to the very fine pores between the clay particles. The particular problems associated with irrigated land use on vertisols therefore involve water movement, specifically the efficiency of :

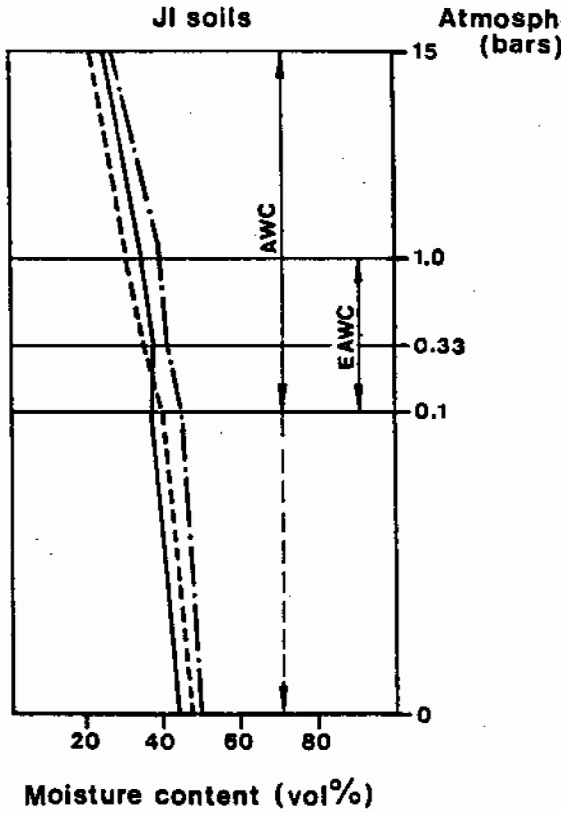
(i) entry of sufficient water to meet gross water requirements;

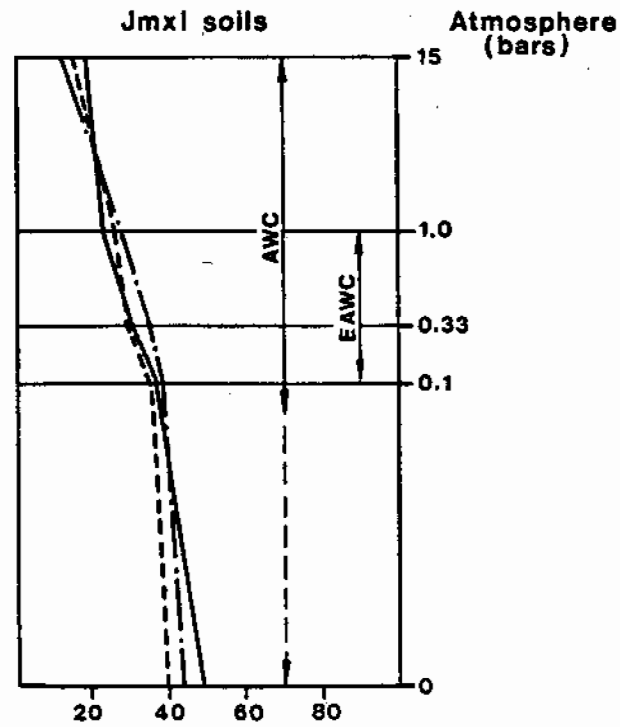
(ii) removal of sufficient water to meet drainage requirements.

0.00 - 0.25m
0.25 - 0.50m
0.50 - 1.00m
AWC = Available water
EAWC = Easily available water

Soil moisture characteristics







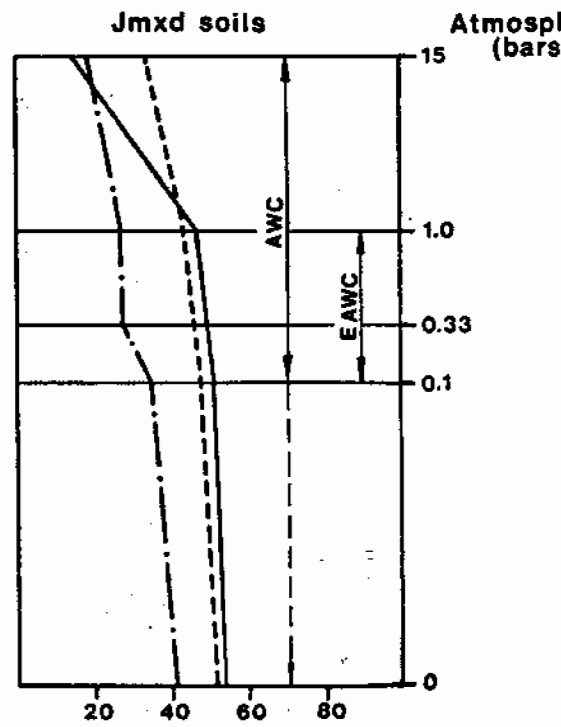


TABLE 3.7

Bulk Density Aeration Porosity and Available Water Capacity

Soil units	Bulk density[1]	AP[2] (%)	AWC 1[3] (mm/1.2 m soil) 0.1 - 15 bar	AWC 2[3] (mm/1.2 m soil) 0 - 15 bar	EAWC[4] (mm/1.2 m soil)	EAWC as percentage of AWC 1	EAWC as percentage of AWC 2
Jb	1.35	7.3	217	306	73	34	24
Jl	1.36	5.0	199	294	73	37	25
Jmxd	1.30	2.3	273	315	72	26	23
Jmxl	1.43	7.0	217	341	112	52	33
Jd	1.56	-	-	-	-	-	-

Note :
(1) Bulk density values are means.
(2) AP is calculated as the difference in moisture content between saturation (00 bar) and field capacity (0.1 bar) for non vertisolic soils.
(3) Field capacity concept is difficult to apply to vertisols as a result saturation (00 bar) is often adopted as the lower limit of water availability in these soils, data have also been calculated for the 0.1 bar tension which is usually taken as field capacity for non vertisolic soils.
(4) EAWC is moisture held between 0.1 bar and 1 bar.

Lower subsoil values for infiltration tests in the subsoil indicate anisotropic conditions especially in the greyish clays. Such conditions could be expected in the lower horizons of soils derived from stratified alluvial clays but at 50 cm it is anticipated that some residual cracking would have persisted. Booker McConnell (1976) suggest that cracks persit as minor features even after saturation of the soil and consequently aid drainage.

HTS (1978) investigations of Shabelle alluvial soils have found that although water can be transmitted several metres laterally through the cracks of an initially dry soil, the cracking pattern which reforms after complete saturation of the soil is different from the original pattern. This tends to indicate that fissures and planes of weakness along which cracks could develop do not persist in the saturated state and that cracking cannot be depended on to significantly aid drainage in these soils.

(b) Water Holding Capacity

The capacity of a soil to retain water available to plants has a direct bearing on the required depth and frequency of irrigation. In the current study the different water requirements of the upland and rice crops have an important effect in the land classification. Available water holding capacity is not a limiting factor for rice which obtains its nutrients under anaerobic conditions. For upland crops available water capacity (AWC) and easily available water capacity (EAWC) have been defined separately for each land class.

In general available water is water held in the soil against a pressure of up to approximately 15 bars. The pattern of water availability in the soil throughout the range from near saturation to wilting point is important. Soil water holding capacity and weight percentage at specific tensions have been obtained for a number of samples at 0.1, 0.33, 1.0 and 15 bars. These values have been converted to volume percentages by multiplying by the bulk density of the soil and have been plotted against the corresponding tensions in Figure 3.2 to obtain soil moisture characteristic curves. A number of the samples obtained from the experiment when placed in water failed to adsorb sufficient water to enable successful higher suction pressure tests to be carried out. It was significant that these samples were from the deeper subsoil horizons in the clay basin sites.

The data in Figure 3.2 and Table 3.7 are based on information provided in Appendix V. One of the problems of assesing available and easily available moisture contents in vertisols is the definition of the concept of field capacity. Farbrother (1972) adopted the view that to calculate available water capacity in these soils the difference between saturation (0 atmosphere) and the 15 bars percentage moisture contents should be used. Values for this concept have been included under AWC 2 in the table while conventional values for the difference between 0.1 and 15 bars are included under AWC 1. The difference between the values is significantly greater in the non vertisolic levee soils of the meander complex. Easily available water capacity which is used in calculations of irrigation interval requirements is based on the moisture held between 0.1 bar and 1 bar. In these soils the significant difference lies between the basin clay and the levee unit of the meander complex. Values for the basin clay soils are generally adequate and allow a maximum irrigation interval from 10 to 14 days for crops with rooting depths of 0.8 to 1.2 m, respectively. This assumes a maximum crop consumption of 5 mm/d and assumes no losses due to percolation.

Calculation of figures for irrigation interval on the levee soils in the meander complex indicate that a somewhat longer interval between applications could be achieved. However, in view of the limitations discussed in Section 3.2.2 it is probably preferable to maintain a shorter irrigation cycle and to maintain higher soil moisture levels and so resrict the development of surface crusts.

3.2.9 Soil Fertility and Toxicity

Table 3.8 summarises all the chemical data for the major mapping units in terms of surface and subsoil horizons. It is based on the detailed analyses outlined in Appendix II. Aspects of soil fertility are considered to be correctible and have not therefore been included in the land classification criteria.

Most of the soils have high clay contents with 2 : 1 expanding lattice clays. These have moderately high cation exchange capacity (CEC) values and therefore a favourable capacity to retain mineral nutrients against leaching. The CEC values are moderately high for all soils and with clay contents on average of 50% CEC/clay contents are about 60 meq/100 g. This value suggests a mixed clay mineral assemblage which includes some montmorillonite and also significant amounts of illite. This correlates with observations elsewhere in the Juba and Shabelle alluvium.

The results of analyses of organic carbon, total nitrogen and total and available phosphorus are summarised Table 3.8. Carbon/nitrogen ratios indicate that there is a fairly rapid incorporation of organic matter in these soils and problems of poor nitrogen availability should not be encountered also there is little variation between mapping units. However, organic matter conservation measures such as ploughing in crop residues or incorporation of grazing animals in the rotation system should not be overlooked as a means of improving soil fertility status.

Levels of organic carbon and total nitrogen are fairly low and nitrogen fertilisers will be necessary to maintain yields under an intensive cropping systems.

Total phosphorus levels are fairly high but only a very small amount is in the available fraction. Phosphate fixation in these soils is related to the relatively high pH values recorded and results in the formation of poorly soluble calcium phosphates. Crops should respond to phosphate fertiliser applications with a fairly intensive cropping system.

Exchangeable potassium is considered deficient when values fall below 0.5 meq/100 g but high levels of exchangeable calcium and magnesium values give high (Ca + Mg)/K ratios which may reduce the potassium availability. However, levels of exchangeable potassium are fairly high and there should be no major requirement for potassium fertilisers.

Levels of water extractable boron are appreciable in the surface horizons suggesting that close watch should be maintained for symptoms of boron toxicity. Toxicity can occur at boron levels of between 0.3 and 4.0 mg/l although annual crops are generally more tolerant of boron toxicity and perennial crops more susceptible.

Levels of available zinc and copper are not expected to present any problems.

TABLE 3.8

Average Chemical Characteristics of Surface and Subsoil Horizons in Major Soil Mapping Units

Mapping unit	Nr of sites	EC (mmhos/cm)	pH soil water 1:2.5 susp.	pH KCl	CEC meq/100 g soil	ESP
Jb	15 surface	1.1	8.3	7.9	29.0	3.2
	subsoil	4.3	8.1	8.0	28.1	12.5
Jd	3 surface	1.0	8.0	7.4	33.2	2.0
	subsoil	3.8	7.9	7.8	29.9	10.3
Jl	6 surface	0.9	8.3	7.8	23.9	0.4
	subsoil	4.5	8.3	8.0	22.6	6.2
Jmxl	5 surface	1.9	8.1	7.8	24.3	0.9
	subsoil	2.1	8.3	8.0	18.2	0.8
Jmxd	3 surface	1.4	8.3	7.8	28.7	0.8
	subsoil	8.0	8.4	8.2	21.0	3.6

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
33.2	7.8	1.1	1.0	1.0	4.4	1.4	5.1	0.2
43.4	12.4	3.3	0.6	-	12.4	-	-	-
43.3	7.5	0.6	1.1	1.6	7.8	1.3	2.7	0.2
32.1	9.8	3.1	0.5	-	13.0	-	-	-
26.2	6.0	0.2	1.3	1.3	7.1	1.8	2.9	0.6
32.1	10.1	1.8	0.8	-	17.0	-	-	-
30.3	6.6	0.3	1.3	1.2	14.3	5.2	20.2	0.6
36.1	7.4	0.2	1.5	-	11.8	-	-	-
29.5	6.5	0.7	1.6	2.1	9.4	2.3	3.4	0.3
32.1	6.7	0.9	0.6	-	-	-	-	-

TABLE 3.8 (cont)

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	C:N ratio	Soluble anions (meq/litre) CO_3	HCO_3	Cl	SO_4
13.2	76.8	2.0	0.06	0.9	15	0	2.7	5.2	5.4
13.6	-	0.6	-	-	-	-	-	-	-
2.8	43.4	1.2	0.05	0.8	16	0	2.9	3.5	6.9
2.2	-	0.4	-	-	-	-	-	-	-
12.1	90.6	4.1	0.05	0.7	14	0	2.9	3.9	5.1
13.8	-	-	-	-	-	-	-	-	-
6.0	101.2	6.9	0.06	0.9	15	0	2.4	13.5	6.0
12.3	-	4.0	-	-	-	-	-	-	-
10.1	92.1	3.5	0.06	0.8	13	0	2.3	3.7	10.2
18.5	-	0.7	-	-	-	-	-	-	-

Extractable Zn (ppm)	Cu (ppm)	Total gypsum (%)
0.8	0.3	0.03
-	-	0.25
1.6	1.1	0.03
-	-	0.3
0.6	0.2	0.02
-	-	0.3
0.6	0.2	0.1
-	-	0.3
1.0	0.4	0.03
-	-	0.7

TABLE 3.9

Land Classification Specifications for Upland Crops and Special Class 4S Sprinklers

Criteria	Symbol	Class U1 *highly suitable*	Class U2 *suitable*	Class U3 *moderately suitable*	Class U4S *special use (sprinklers)*	Class U6 *unsuitable*
Soil Factors						
Texture in upper 100 cm *(root zone)*	s	Sandy loam to clay or medium *textures*	Loamy sand (less than 15% clay) to permeable *clay, loamy sand* less than 300 mm	Loamy sand (less than 15% clay) to slightly *permeable clay. Loamy* sand less than 0.6 m	Fine sand through permeable clay, loamy *below 300 cm* permeable clay *if* drainage adequate	Land which fails to meet the *minimum requirements* of other land classes
Profile drainage		Well to excessively well	Moderately well or better	Imperfect	Not limiting	
Structure		Well structured	Well to moderately well	Moderately well	Not limiting	
Alkalinity (0 to 40 cm depth)	a	< 10	< 15 100 to 150	< 15 to 100 15 to 25 100 to 150	< 25	
Salinity	e	< 4 mmhos throughout	4 mmhos to 100 cm 4 to 8 mmhos 100 to 150	4 to 8 mmhos 50 to 100 < 8 mmhos 100 to 150	8 to 12 mmhos	
Topographic Factors						
Slope	t	Less than 2%	Less than 2%	Less than 4%	5 to 8%	
Micro-relief	g	None (M0 to M1)	Very weakly undulating moderate gilgai (M1 to M2) slight levelling required	Weakly undulating or slightly dissected, gilgai (M2 to M3), moderate levelling, average 0.5 m cut and fill	Not limiting	
Flood susceptibility		None	None	Periodic but relatively infrequent floods of *short duration*	None	
Derived Characteristics						
Permeability in upper 1.0 m Permeability in subsoil Infiltration final intake rate		0.03 to 0.10 *m/d* 0.03 to 0.10 m/d -	0.01 to 0.10 *m/d* 0.01 to 0.3 m/d 2 mm/h	*Less than 0.03 m/d* Less than 0.01 m/d More than 1 mm/h	*More than 0.01 m/d* More than 0.01 m/d Less than 12 cm/h	
Available water holding capacity (AWC)		More than 120 mm	80 to 120 mm	50 to 80 mm	Not limiting	
Easily available water *holding capacity (EAWC)*		*More than 65 mm*	30 to 65 *mm*	*Less than 30 mm*		

Notes: M1 slight gilgai 0 - 0.25 m
M2 moderate gilgai 0.25 - 0.5 m

FAO Textural Classes

Fine texture SC, C, SiC, Cl , heavy, SiCL heavy
Medium SCL, CL, SiCL, L, SiL, Si, SL heavy

TABLE 9.10

Land Classification Specifications for Rice

Criteria	Symbol	Class R1 highly suitable	Class R2 suitable	Class R3 moderately suitable	Class 6 unsuitable
Soil Factors					
Texture: Surface: 0 to 30 cm	s	Medium or fine textures	Medium or fine textures	Loamy sands or finer throughout profile (loamy sand less than 150 mm)	Land which fails to meet the minimum requirements of other land classes
Profile 30 to 120 cm		Fine texture with less than 300 mm medium provided profile drainage requirement is met	Medium or fine textures with more than 300 mm of fine fine texture		
Profile drainage		Poor to moderately well	Less than well drained	Not limiting	
Structure		Moderately well or better	Moderately well	Moderately well	
Alkalinity (0 to 40 cm depth)	a	< 15	15 to 25	15 to 25	
Salinity (0 to 40 cm depth)	e	< 4 mmhos	< 8 mmhos	< 8 mmhos	
Topographic Factors					
Slope	t	Less than 2%	Less than 2%	Less than 4%	
Micro-relief	g	None	Slight levelling M1 or M2 gilgai	Weakly undulating or slightly dissected, gilgai (M2 to M3), moderate levelling, average cut and fill 0.5 m	
Flood susceptibility	d	No restriction	Periodic but relatively frequent floods of short duration	Periodic but relatively frequent floods of short duration	
Derived Characteristics					
Permeability in upper 1.0 m		–	–	–	
Permeability in subsoil		Less than 0.06 m/d	Less than 0.10 m/d	Less than 0.10 m/d	
Infiltration final intake rate		Less than 10 mm/h	Less than 10 mm/h	Less than 15 mm/h	
Available water holding capacity (AWC)		Not limiting	Not limiting	Not limiting	

Notes: M1 slight gilgai 0 - 0.25 m

FAO Textural Classes:
Fine texture C, SC, SiC, CL heavy SiCL

3.3 Land Classification Criteria

Five main classes have been recognised and applied to rice and upland crops:

Class 1 - Highly suitable arable

Class 2 - Suitable arable

Class 3 - Moderately suitable arable

Class 4 - Special use - sprinklers (not rice)

Class 6 - Non arable

Tables 3.9 and 3.10 indicate the relationships between the different criteria, discussed in the following paragraphs, and the main land classes.

3.3.1 Soil Factors

Soil texture is the most commonly limiting factor and land is commonly down-graded if the soil is excessively coarse or excessively fine textured. Soils with coarse textures have low water holding capacities and excessive infiltration rates, features which reduce irrigation efficiency. Fine textures adversely affect aeration and root penetration for upland crops.

In the classification the coarsest acceptable texture is a sandy loam containing at least 15% clay. Textures coarser than this have limited available water holding capacity and low CEC values. Soils with textures as coarse or coarser than loamy sand are considered to be unsuited for irrigation development and even under sprinklers a limit of at least 30 cm of medium or fine textures over coarse sand has been accepted. Soils which are predominantly fine textured or contain signficant fine textured horizons in the profile are considered most suitable for rice development while medium textured soils are preferred for upland crops. In view of the predominance of montmorillonitic expanding 2 : 1 clays in these soils most have been down-graded to Class 2 or 3 for upland crops.

3.3.2 Alkalinity

Exchangeable sodium has been recognised as a soil factor liable to limit crop productivity. This limitation derives from a combination of the toxic effects of the sodium ion on plant nutrition and the deleterious effects on the soil physical conditions resulting from a relatively high proportion of sodium in the exchange complex. The exchangeable sodium percentage (ESP) is considered to be a more reliable yardstick for expressing the amount of sodium on the exchange complex relative to calcium and magnesium. An ESP of more than 15 in the root zone is normally considered to be injurious to crops (Russell, 1973) and this initial value has been used in the classification to down-grade lands from Classes 1 or 2 to Class 3 for upland crops. Rice is more tolerant of alkali conditions and an upper limit of 25 has been set for Classes 2 and 3. (The majority of the soils have exchangeable sodium values of less than 5% in the surface horizons and below 15% in the subsoil horizons).

3.3.3 Salinity

In these areas salinity is considered to be a rectifiable hazard. The quality of the water available for irrigation and the high content of available gypsum in the soil should allow sufficient movement of ions through the profile to prevent a salinity build up and correct any deficiencies. However, in areas where a Class U3 salinity hazard is combined with a Class U3 permeability characteristic the possibilities of effectively and economically removing the salts are very limited, and in such cases the land has been down-graded to Class 6. For rice crops it is assumed that salinity build up under conditions of low deep percolation will not be so hazardous as for upland crops. However, rice is sensitive to salinity particularly at germination though this hazard can be overcome by growing in nursery beds and then transplanting. In the short term one would expect reduced yields at EC values of 4 to 8. In the longer term due to leaching overall EC will reduce and rice yields will not be subject to yield reduction due to salinity.

3.3.4 Topography

The main limitation to land development within this factor arises not from slopes but from uneven microrelief which requires considerable levelling before irrigation can be effectively developed. It is expected that much of the levelling that takes place will be carried out by mechanical graders. In this context areas where only slight levelling is required with less the 0.25 m cut and fill are placed in Class 2, areas with an average cut and fill of up to 0.5 m cut have been placed in Class 3. However, when classifying lands on topographic limitations, the removal of soil should be considered. In the deep alluvial soils of the clay basin units there are no problems in the removal of surface soil and productivity should be relatively quickly restored. In areas of severe micro-relief development, where more levelling and soil removal may need to be carried out an additional hazard is exposure of more variable or limiting soil horizons. This produces a resultant decrease in efficiency of irrigated water use. Hence land down-graded to Class 3 on topographic grounds cannot automatically be graded/levelled and placed in Classes 1 or 2. In particular it is felt that the uneven relief of the meander complex soils will result, under levelling, in exposure of more variable textures. However, an analysis of very fine sandy loam and coarser textures within the profile descriptions indicates that these were not limiting factors alone at 68% of sites. The remaining 32% of limiting horizons by textures were only effectively limiting for land classification criteria above 1 m at four bore sites. The special use Class 4 will include these areas under sprinkler development since in this case micro-relief is not a limiting factor. Few areas of sloping land were encountered.

Susceptibility to flooding within the area may be caused by direct flooding from the river or by accumulation of run off water by a combination of both factors. An attempt has been made to separate lands which are usually annually subjected to prolonged deep inundation due to their topographic location and those which suffer periodic but relatively frequent floods of shorter duration. The latter are flooded due to their location in minor topographic depressions.

Reclamation of the lands periodically flooded and relatively permanently flooded from the Juba river can only be achieved by expensive drainage and flood control works at the project level and a high degree of managerial efficiency at the farm level. Upland crops are very susceptible to waterlogging and lands are down-graded if there is a danger of flooding during the growing season. Most

minor depressions if not placed in Class U6/R6 because of relatively permanent waterlogging are place in Class U3 for upland crops and R2 or R3 for rice.

High water tables such that they could significantly affect crop growth were not encountered anywhere in the study area.

3.3.5 Permeability

This factor is based on a combination of observed soil profile characteristics and measured values for horizontal and vertical hydraulic conductivities. Profile drainage characteristics are largely determined by the soil texture and surface drainage. The limits of the drainage class specifications are intended as guides; land which would have been down-graded on poor internal drainage according to these specifications would probably have already been down-graded because of heavy textures or poor surface drainage.

The limits for the classes refer to horizontal hydraulic conductivity values in the upper metre and the subsoil. They provide guidelines within which each soil unit is assessed. Deficiencies in this factor are considered to be permanent or non-rectifiable. Particular emphasis is placed on the drainability criteria in this study in view of the seriousness of drainage problems which have occurred elsewhere in Somalia.

3.3.6 Infiltration

Excessively rapid rates of surface infiltration do not occur and this classification makes use of increasingly slower rates of infiltration. A good upland crop class soil would be expected to infiltrate the normal crop irrigation requirement in an eight hour period, this being the length of the normal working day. Optimum infiltration rates for gravity irrigation purposes are in the general range of 7 to 35 mm/h (USBR, 1953). Most soils in the study area have much slower rates than this and have been down-graded accordingly.

3.3.7 Available Water Capacity

This criterion is considered in terms of the total available water capacity (AWC) and the easily available water capacity (EAWC). Each is based on data for the upper 100 cm of the profile .

Upland Class 1 soils possess a value of 120 and 65 cm for the AWC and EAWC, respectively, these are intended to ensure sufficient moisture reserves to allow flexibility in irrigation interval design. Available water capacity is not considered limiting for rice crops. Discussion in Section 3.2.7 indicates the relationship between this factor, infiltration rate and irrigation interval.

3.4 Land Classes and Sub-classes

As shown in Table 3.11 no Class 1 land has been delineated. Even the best of the clay soils on the levee areas have sufficiently low infilitration and permeabilities and are sufficiently difficult to cultivate to exclude them from Class 1. The highest land class shown on the map is Class 2. This land class includes all the soils of the Jl and Jbl mapping units and those areas of the terrace soils (Jt) with no topographic restrictions. Soils of the Jb3 and

TABLE 3.11

Land Class Area Measurements (hectares)

Upland Class 2		Upland Class 3		Upland Class 4S		Upland Class 6	
Sub-classes	Area	Sub-classes	Area	Sub-classes	Area	Sub-classes	Area
U2s/R1	46	U3s/R2g	1 703	U3se/R2st	285	U6d/R2sg	6
U2s/R2s	65	U3s/R2s	9	U3s/R3st	828	U6ase/R3g	17
U2s/R2t	125	U3s/R2t	159	U3st/R3st	209	U6d/R6d	10
U2s/R2g	250	U3st/R2t	8	U3set/R3t	130	U6st/R6st	42
U2se/R2g	25	U3st/R2st	48	U3se/R3st	674	U6ad/R6ad	648
U2s/R2sg	17	U3s/R2sg	34	U3es/R3st	248	U6est/R6st	60
U2ste/R2t	100	U3se/R2g	853	U3est/R3st	28	U6dt/R6dt	341
U2s/R3s	204	U3es/R2g	755				
U2st/R3st	259	U3es/R2se	63	Total	2 402 ha (25%)	Total	1 124 ha (12%)
		U3es/R2ge	325				
Total	1 091 ha (12%)	U3s/R3s	107				
		U3sg/R3g	809				
		U3se/R3g	15				
		U3et/R3et	32				
		U3ste/R3st	22				
		Total	4 942 ha (51%)				

meander complex depressions are considered to belong to Class 3. Certain areas of depressions in the meander complex with a significant flood hazard which is related to their topographic position have been further down-graded. Within the levee areas more extensive uneven microtopography related to termitaria have resulted in these being down-graded one class. Most of the semi-permanently flooded Jd depressions are placed in Class 6, as are all the major channel courses identified.

On the map the factors which either singly or in combination result in land being designed to a particular land class are shown using the following sub-class symbols:

- s - soil characteristics - texture, profile drainage and structure
- a - alkalinity hazard
- e - salinity hazard
- t - topographic restraint including termitaria
- g - micro-relief - gilgai formations
- d - flood susceptibility

The main sub-classes identified and the specific limitations imposed within these classes are as follows.

Class 2 - suitable

- 2g gilgai moderately well developed.
- 2e EC_e of 4 to 8 mmhos/cm between 1.0 and 1.5 m.
- 2s soil characterisitcs, water movement and root development slightly impeded.
- 2se soil characteristics and EC_e 4 to 8 mmhos/cm between 1.0 and 1.5 m.
- 2ste soil characteristics, very weakly undulating topography and EC_e 4 to 8 mmhos between 1.0 and 1.5 m.
- 2st soil characteristics and very weakly unudulating topography.
- 2t very weakly undulating topography.
- 2sg soil characteristics and moderate gilgai development.

Class 3 - moderately suitable

- 3s soil characteristics, water movement, root development impeded.
- 3st soil characteristics, weakly undulating topography.
- 3se soil characteristics, EC_e 4 to 8 mmhos/cm between 1.0 and 1.5 m.

3es soil characteristics, EC_e 4 to 8 mmhos/cm between 0.5 and 1.0 m.

3et EC_e 4 to 8 mmhos/cm between 0.5 and 1.0 m, weakly undulating topography.

3g strongly developed gilgai formations.

3sg soil characteristics and strongly developed gilgai formations.

3ste soil characteristics, weakly undulating topography and EC_e 4 to 8 mmhos/cm between 1.0 and 1.5 m.

3ge strongly developed gilgai and EC_e 4 to 8 mmhos between 1.0 and 1.5 m.

3est EC_e 4 to 8 mmhos/cm between 0.5 and 1.0 m soil characteristics and weakly undulating topography.

For the above sub-classes it should be noted that specific limitations for upland and rice crops are the same except for salinity where any limitation applied will fall within 0.40 m of the surface.

4S areas within the levee sub-unit of the meander complex have uneven Class 3 topographic limitations and more stratified soil horizons. They are generally recommended for sprinklers by the designation 4S. EC_e values of up to 12 mmhos/cm in the subsoil have been allowed in these soils. The alternative land capability is shown in parenthesis after the 4S designation. Where appropriate the salinity hazard (e) indicates levels of salinity in the sub-soil as in land class 2 and 3. No values were found to exceed 8 mmhos/cm in these areas.

Class 6 lands have been identified in areas where the minimum requirements of the other land classes are not met in respect of topography, salinity and alkalinity.

3.5 Mapping Procedures

The land class maps were prepared from the soil maps and generally the land class boundaries correspond to divisions between soil units except where factors not directly attributable to the soils such as flooding or topography are limiting. The land class boundaries enclose lands with similar crop suitability characteristics. The soil and land class information at 1 : 20 000 scale is shown on Plates number 23, 24 and 25. Plates number 27 to 30 and 31 to 34 illustrate the soil classification and land suitability classification, respectively, at 1 : 10 000 scale.

3.6 Land Classification and Recommended Cropping Patterns

The formulation of optimum cropping patterns for the lands in the study area is a logical extension to the land class classification procedure. With this in mind it is possible to group the land sub-class units identified and measured in Table 3.11 on the basis of similar characteristics suitable for particular

cropping patterns. At an early stage in the studies the decision was taken to develop the levee sub-unit of the meander complex under sprinkler irrigation for upland crops. For the remaining areas falling within upland Classes 2 and 3 most of the soils are suitable or moderately suitable for upland crops and rice. As a result these areas can be developed under alternating paddy rice/upland crops with the latter category including maize and sesame. The alternation of rice and upland crops in these soils should form an essential feature of the cropping pattern. A drying out (oxidation period) is very necessary after a rice crop to remove toxic compounds. Under the predominatly anaerobic conditions of paddy rice production $CaSO_4$ will be reduced and sulphides formed with ferrous iron, manganous manganese and sulphides.

APPENDIX I

REFERENCES

APPENDIX I

REFERENCES

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APPENDIX II

SOIL PROFILE DESCRIPTIONS

AND

LABORATORY DATA

APPENDIX II

SOIL PROFILE DESCRIPTIONS AND LABORATORY DATA

II.1 Methods of Laboratory Analysis

Analyses of soil samples were performed at the Hunting Technical Services' Environmental Chemistry Laboratory in the United Kingdom. The methods of analysis used are described briefly in this appendix; these derive from the USDA Handbook 60 (USDA, 1954) and the FAO Soils Bulletin 10 (FAO, 1970).

II.1.1 Sample Preparation

Each soil sample was air-dried and sieved to pass a 2 mm screen before being despatched to the laboratory. This fine earth fraction was used in subsequent analysis. No particles coarser than 2 mm were recorded. A sub-sample of the fine earth fraction of each surface horizon was ground in a mechanical mortar to pass an 80 mesh sieve for use in determinations of carbon, nitrogen and phosphorus.

II.1.2 Particle Size Analysis

A sample of 40 g of soil was dispersed by shaking overnight with sodium hexametaphosphate and water.The suspension was then transferred to a 1 l cylinder, made up to volume and stirred. A Bouyoucos hydrometer, calibrated in g of soil/l was used to take readings of the density of the soil suspension at the following settling times:

(a) 46 s to give coarse silt + clay content.

(b) 4 min 48 s to give silt + clay content.

(c) 6.5 h to give clay content.

The density readings were corrected for temperature variations and dispersing agent content. The soil suspension was then washed through an 80 mesh (0.2 mm) sieve and the coarse sand weighed after drying.

II.1.3 Electrical Conductivity of Saturation Extract

Distilled water was added to the soil until the saturation point was reached. The saturated soil paste was then extracted using suction, to obtain a saturation extract. The electrical conductivity of this extract was then measured and the results expressed in mmhos/cm as the electrical conductivity of the saturation extract (EC_e).

II.1.4 pH Determination

A glass electrode was used for the determination of the pH of a 1 : 2.5 soil-water suspension.

2 ml of one-eighth molar calcium chloride was added to the suspension to bring the effective concentration to M/100.

The suspension was restirred, equilibrated for 1 h and the pH read again.

The pH was also measured in a 1 : 2.5 soil/potassium chloride suspension.

II.1.5 Cation Exchange Capacity - Bascombe's Method

Two grams of soil were shaken twice with triethanolamine-buffered barium chloride solution (pH 8.2), in order to replace all exchangeable cations with barium. Excess barium was removed by shaking with water. The sample was then shaken with a solution of magnesium sulphate of known concentration. This replaced the exchangeable barium by magnesium, at the same time removing barium from solution by precipitating barium sulphate. Magnesium remaining in solution was determined by titration. The cation exchange capacity is derived from the difference between the amount of magnesium added and the amount remaining in solution.

II.1.6 Exchangeable Bases

Four grams were extracted by shaking with 20 ml of N-ammonium acetate solution, buffered at pH 7.0. Calcium and magnesium were determined by atomic absorption spectroscopy using strontium chloride as a releasing agent to overcome interference by aluminium or phosphate. Sodium and potassium were also determined using atomic absorption methods, utilising strontium chloride as an ionization buffer. The exchangeable cation values were corrected to allow for soluble salts.

II.1.7 Soluble Cations in Saturation Extract

Soluble calcium, magnesium, sodium and potassium were measured in the saturation extract utilising atomic absorption techniques in the presence of strontium chloride.

II.1.8 Soluble Anions in Saturation Extract

(a) Carbonate and Bicarbonate

A portion was titrated against dilute hydrochloric acid using phenolphthalein as indicator. When the pink colour had been discharged the amount of acid was measured, methyl orange indicator added and the titration continued to the end point.

(b) Chloride

Chloride was measured using an EEL chloride meter, which automatically titrates the chloride against silver ions.

(c) Sulphate

The sulphate was precipitated as barium sulphate in the presence of a stabilised gel. The opaque suspension was then measured using a nephelometer.

II.1.9 Boron

Boron was determined as 'hot water soluble boron'. 10 g of air-dried fine earth was refluxed with 20 ml of deionised water for five minutes, and the resulting slurry was centrifuged to obtain a clear extract. An portion of this extract was taken and the boron content determined by the Curcumin method. Portions of the river water samples were determined for boron by the same method.

II.1.10 Gypsum

Calcium was determined in saturation extract and also in a 1 : 5 soil/water extract. Knowing the saturation percentage of the soil, the increased solubility of calcium in the 1 : 5 extract was used to calculate gypsum content.

II.1.11 Total Nitrogen Content

A weighed sample of finely ground soil was digested with concentrated sulphuric acid containing potassium sulphate, to raise the temperature, and selenium as a catalyst. After digestion the sample was made alkaline and the ammonia released was steam distilled into boric acid containing bromocresol green/methyl red indicator. After distillation, the ammonia dissolved in the boric acid was back-titrated against standard sulphuric acid, and the result expressed as per cent total nitrogen.

II.1.12 Total Phosphorus

Soil (5 g) was mixed with 1 g of powdered magnesium acetate and ignited at 550° C overnight. This treatment renders titanium compounds insoluble and allows complete recovery of phosphorus (Beckwith and Little). The soil was then digested with concentrated hydrochloric acid by heating for 2 h on a boiling water bath. The acid extract was filtered and made up to a known volume. A portion was taken and the yellow vanadomolybdo-phosphoric colour developed in a hydrochloric acid system. The vanadatemolybdate reagent is made up in an acid free solution.

The intensity of the yellow colour was measured on a spectro-photometer at a wavelength of 470 nm.

II.1.13 Available Phosophorus

A weighed sample of soils was extracted by shaking for 0.5 h with 0.5 molar sodium bicarbonate solution at pH 8.5. The extract was decolorised with activated charcoal and filtered to obtain a clear solution. Phosphorus was determined colourimetrically by the molybdenum blue method.

II.1.14 Total Potassium

A suitable portion of the hydrochloric acid extract, obtained during the determination of total phosphorus, was diluted and analysed for potassium using atomic absorption techniques in the presence of strontium chloride as ionisation buffer.

II.1.15 Cation Exchange Capacity

Calculated by summation of values for all exchangeable cations.

II.1.16 Organic Carbon Content (Walkly-Black Method)

A weighed sample of finely ground soil was digested with a known amount of potassium dichromate and concentrated sulphuric acid. Excess dichromate, remaining after digestion was complete, was titrated against standard ferrous ammonium sulphate using ferroin as indicator. In the calculation of the result, expressed as per cent organic carbon, it was assumed the only 77% of the organic carbon present had been oxidised.

II.1.17 Total Carbonate

A weighed sub-sample of soil is mixed with dilute hydrochloric acid and the volume of gas evolved in the reaction is measured by calcimeter. The per cent total carbonate is obtained by calculation.

II.1.18 Determination of Copper and Zinc

This method involves extraction with dilute hydrocholiric acid. 10 ml of hydrochloric acid is added to a 2.5 g finely ground sample and shaken for 1 h. It is centrifuged at 4 000 rpm for a few minutes or until clear and the determination carried out on the atomic absorption unit.

II.1.19 Moisture Retention Characteristics

Undisturbed soil cores 50 mm in diameter were collected in the field using a special sampling device. The dry weight of the undisturbed soil in the core was determined and the bulk density calculated. The cores were saturated with water and their moisture content measured. They were then placed on the porous plate apparatus and subjected to a suction of 7.6 cm of mercury (0.1 bar). When the moist sample reached equilibrium with the suction and water ceased to flow from the chamber, the sample was removed and weighed to determine the moisture content. The determination was repeated at suctions of 25.4 cm of mercury (0.3 bar) and 76 cm of mercury (1.0 bar). The samples were then transferred to the high pressure chamber (pressure plate) and the soil moisture content determined when in equilibrium with a suction of 15 bar.

II.1.20 Bulk Density

The weight of dry soil in the core was determined and the bulk density calculated.

II.2 Interpretation of Results

II.2.1 Chemical Analyses

The following chemical data interpretation classes are based on those of Black and Berger (1965); modified where necessary to allow for conditions encountered in the project areas.

Determination	Interpretation class		
	Poor	Average	Good
Total organic matter %		10	40
Total nitrogen %		0.1	0.2
Total phosphorus mg/100 g		70	90
Exchangeable calcium meq/100 g		0.3	10
Exchangeable magnesium meq/100 g		0.1	2
Exchangeable potassium meq/100 g		0.1	0.5
Base saturation		30	60

SOIL PROFILE DESCRIPTIONS

Pit Nr:	D008
Soil class:	J1 (Jmx1)
Land class:	U3s/R2st
Location:	Line B 0.35W
API legend:	Jmx
Topography:	Slightly undulating levee area in meander complex
Micro-relief:	Very slightly undulating
Vegetation:	Scrub woodland, **Dobera glabra, Thespesia daria**
Surface:	Slightly powdery, pale reddish brown
Profile drainage:	Imperfect
Depth to water table:	480 cm

Brief Description:

Moderately structured dark brown silt clay to silt clay loam surface horizons pass into weakly structured prismatic and wedge shaped silt clays to clays. There is well developed porosity and fine cracks to 1 m, roots extend throughout. Fine carbonates often ferromanganese coated occur below 10 cm gypsum crystals below 100 cm.

Horizon	Depth (cm)	Description
A1	0-10	Dark brown (10YR 3/3) silt clay loam, moderate medium subangular blocky structure, dry slightly hard, few fine vertical cracks, many fine pores, many fine, few medium roots. Very few very fine shell fragments. Gradual smooth boundary to :
IB1	10-23	Dark brown (10YR 3/3 to 7.5YR 3/3) with few fine faint red brown (5YR 4/3) mottles, light silt clay, moderate medium subangular blocky structure, slightly moist very firm; common fine vertical, few fine horizontal cracks; many fine pores; many fine, few medium roots. Common fine $CaCO_3$ and manganese nodules. Gradual smooth boundary to :
IIB2	23-41	Dark brown (7.5YR 4/4) silt clay, weak medium prismatic structure, slightly moist very firm, few medium vertical cracks; few fine, medium and coarse pores, few medium roots. Common very fine $CaCO_3$ nodules, occasionally ferromanganese coated. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
IIIB3	41-79	Dark brown (7.5YR 3/3) with common fine faint red brown (5YR 4/3) mottles, clay, weak medium wedge structure, slightly moist extremely firm, few medium vertical cracks, few fine pores, few medium roots. Few weak slickensides. Common fine $CaCO_3$ nodules occasionally ferromanganese coated. Gradual smooth boundary to :
IVC1	79-106	Dark brown (7.5YR 3/4) with few fine faint yellow brown (10YR 5/4) mottles, silt clay loam, weak medium subangular blocky structure, slightly moist extremely firm, very few fine vertical cracks, few fine pores; few fine, few medium roots. Few coarse powdery patches secondary carbonates and fine $CaCO_3$ nodules, very few fine gypsum crystals, few weak cutans. Gradual smooth boundary to :
VC2	106-150	Dark brown (7.5YR 3/4) with few fine faint red brown (5YR 4/3) mottles, silt clay loam, weak fine angular blocky structure, moist firm, common medium pores, common fine roots. Common powdery carbonates and fine gypsum crystals, common fine manganese stains considerable termite acitivity. Clear smooth boundary to
VIC31	150-260 200 + augered	Strong brown (7.5YR 4/6) with few fine and medium faint red brown (5YR 4/3) mottles, very fine to fine sandy clay loam, massive structureless, slightly moist firm, many fine pores, common medium roots. Abundant fine 1 to 5 mm gypsum crystals, few large and abundant small powdery $CaCO_3$ concretions, few hard $CaCO_3$ nodules.
VVC32	260-280	Strong brown (7.5YR 5/6) with few fine faint red brown (5YR 4/3) mottles, very fine sandy clay loam, moist firm, few large gypsum crystals, abundant powdery carbonates few fine $CaCO_3$ nodules.
VIC33	280-420	Dark yellowish brown (10YR 4/4), very fine sandy loam, slightly moist loose, few hard $CaCO_3$ nodules at 380 cm, occasional lenses less than 5 cm very fine sandy loam.
VIC34	420-500	Yellowish brown (10YR 5/4) with few fine faint red brown (5YR 4/3) mottles very fine sand, slightly moist becoming wet at 480 cm. Faint manganese stain banding in sands occasionally visible; abundant mica sand flakes.

Profile Nr: D008

Classification: Jmxl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-10	6	27	15	22	30	1.8	8.3	7.7	26.2
P2	10-23	6	29	10	17	38	0.8	8.3	7.8	23.9
P3	23-41	6	24	8	12	50	1.6	8.2	7.9	22.4
P4	41-79	4	16	5	27	48	3.7	8.0	7.7	24.0
P5	79-106	6	14	2	53	25	3.0	7.9	7.8	16.0

Exchangeable cations meq/100 g soil

Ca	Mg	Na	K	B (ppm)
33.2	4.2	0.06	1.8	0.9
30.1	5.7	0.10	1.9	1.0
25.6	6.3	0.10	1.9	-
33.7	2.4	0.10	2.0	-
100.0	7.5	0.20	1.5	-

Soluble cations (meq/l)

Ca	Mg	Na	K
15.1	2.98	5.25	1.05
5.5	1.60	1.71	0.58
13.3	-	-	-
35.0	-	-	-
26.2	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
2.0	99.6	6.0	0.10	1.0
3.5	91.0	1.5	0.06	0.5
7.6	-	-	-	-
12.0	-	-	-	-
13.4	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	4.0	8.4	11.1
-	2.2	3.2	4.7
-	-	-	11.7
-	-	-	53.5
-	-	-	37.7

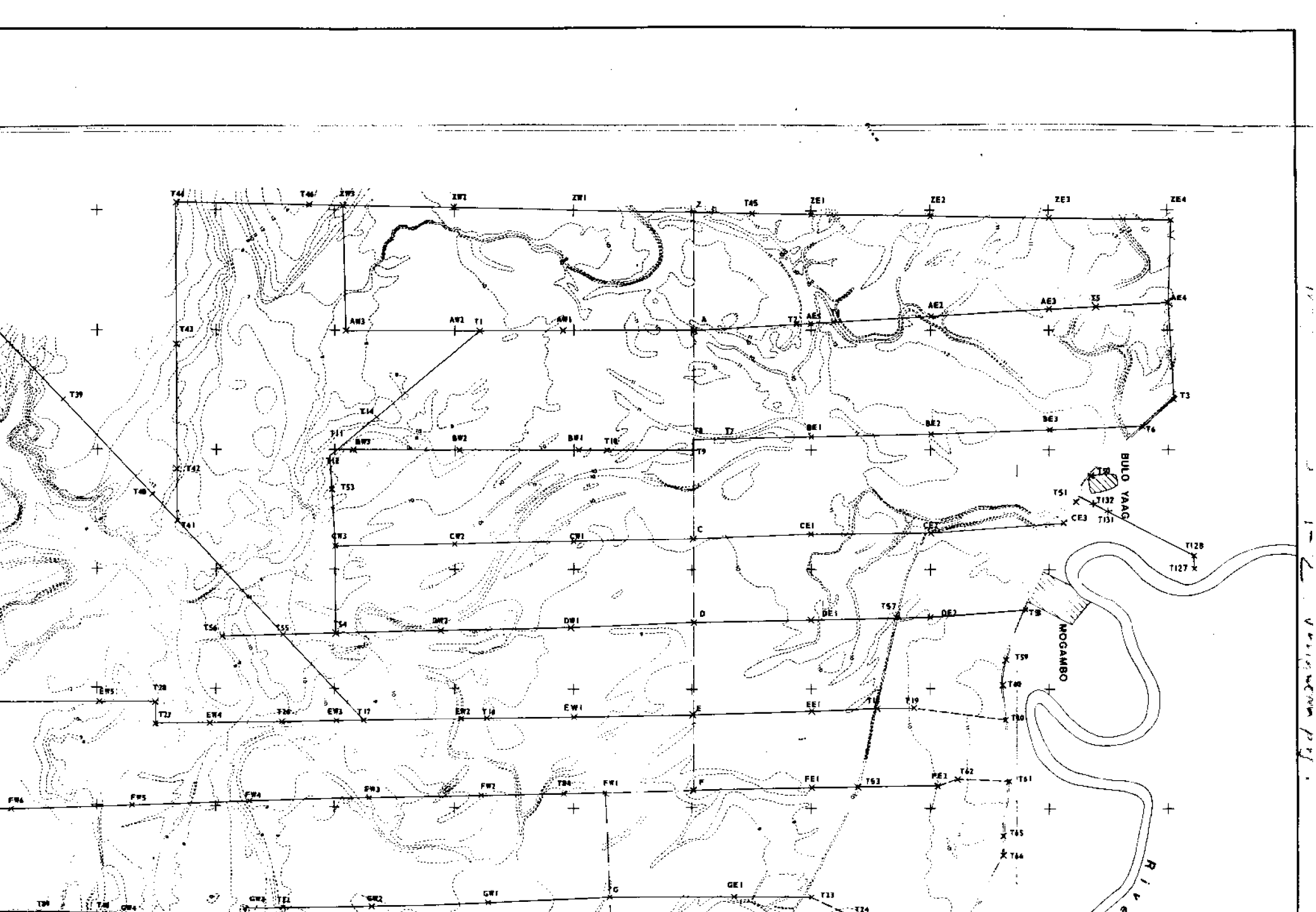
Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.8	0.3	-	-
0.7	0.2	0.01	-
-	-	-	-
-	-	0.90	-
-	-	1.30	1.0

Pit Nr:	D012
Soil class:	Jb1
Land class:	U2s/R2g
Location:	Line A 2.45E
API legend:	Jb
Topography:	Slightly undulating plain
Micro-relief:	Slight undulation (M1)
Vegetation:	Open scrub woodland, **Dobera glabra, Acacia** sp
Surface:	Thin leaf litter medium cracks in slight depressions
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A moderate to strongly structured dark grey brown to brown clay soil. Vertical cracking is well developed with strong prismatic and wedge structures in the subsoil associated with well developed slickensides. Fine ferromanganese and carbonate nodules occur throughout with fine gypsum crystals below 22 cm. Roots extend to 2 m.

Horizon	Depth (cm)	Description
	0-22	Very dark greyish brown (10YR 3/2) clay, low organic matter content, moderate medium subangular blocky structure, dry very hard; few very fine vertical cracks; common very fine pores, common fine and medium roots. Common fine $CaCO_3$ nodules and shell fragments. Gradual wavy boundary to:
	22-59	Dark greyish brown (10YR 4/2) clay, strong coarse prismatic breaking to medium angular blocky structure, moist extremely firm, common medium vertical and fine horizontal cracks, few fine pores; common fine, few medium roots. Well developed slickensides and cutans, common very fine $CaCO_3$ nodules, few fine ferromanganese coated $CaCO_3$ nodules, few shell fragments, few fine patches gypsum. Gradual smooth boundary to:


BULO YAAG
MOGAMBO
RIVER

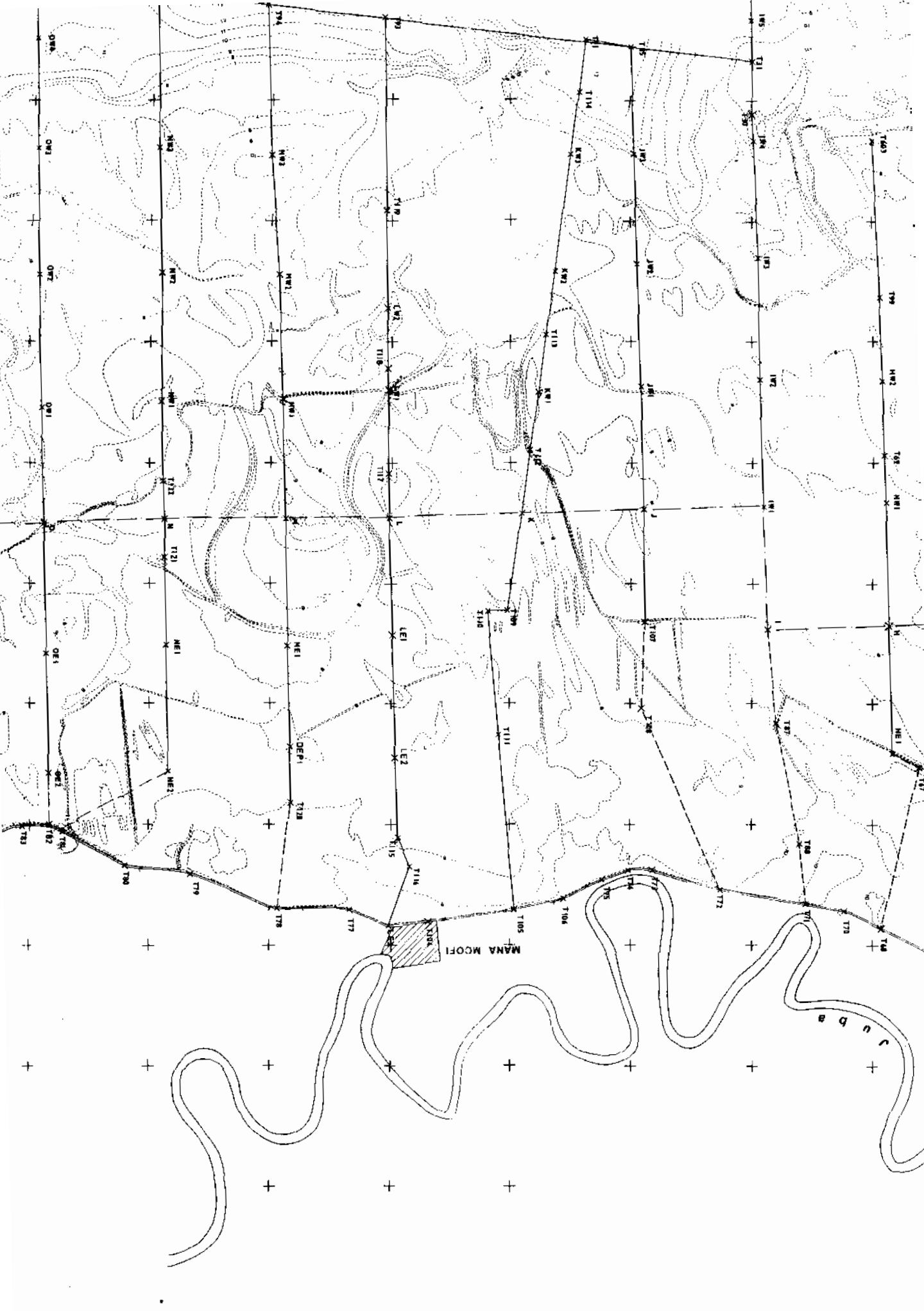
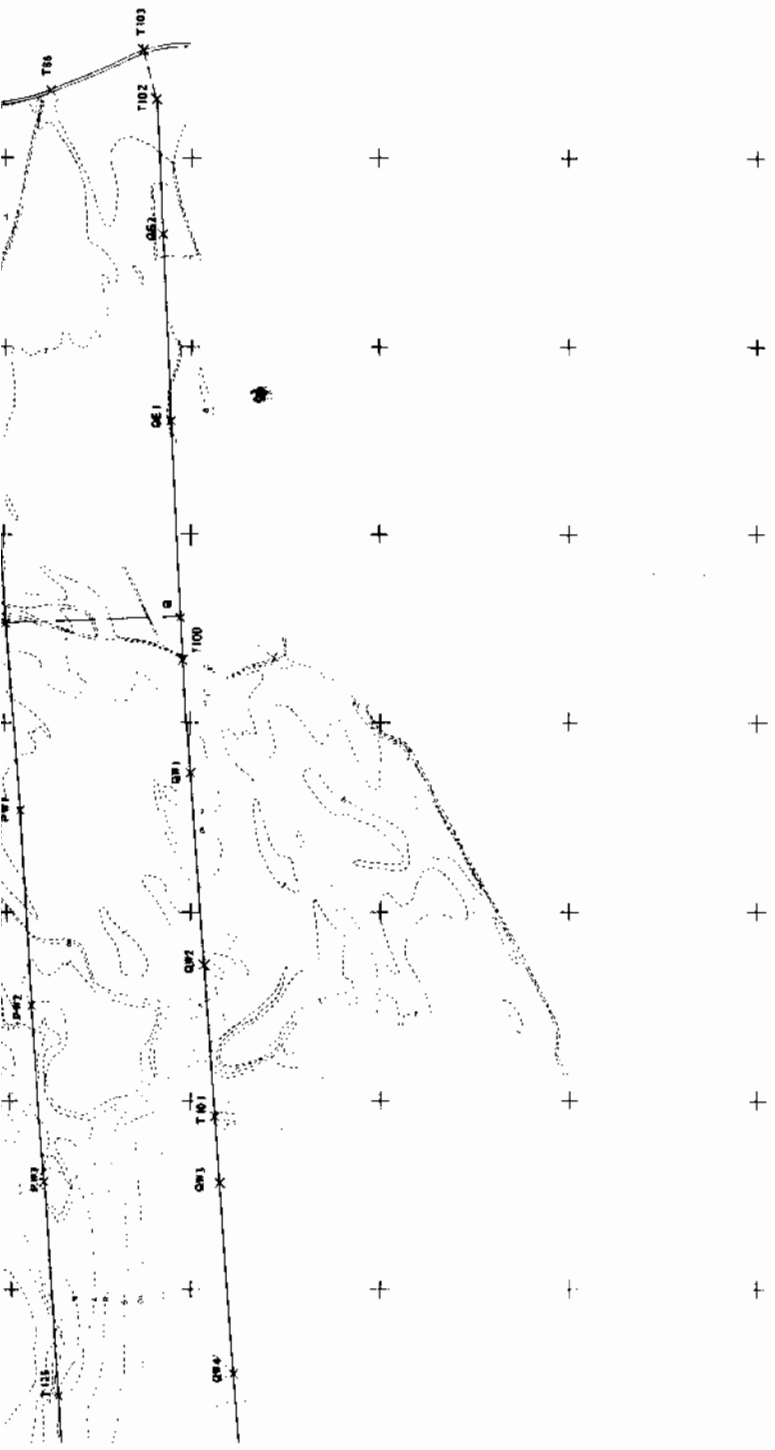

MANA MCOFI

FIGURE I.1



LEGEND

× BENCH MARK
SURVEY TRACE
MAIN N-S TRACE

NOTES

1. BENCH MARKS:- EW7, FW7, GW6, GW7, IW6, WN1, WN2, T32, T33, T34, T36, T37, T38, T95, T96, T97, T99, T129, T130 NOT SHOWN
2. FOR DETAILS OF BENCH MARKS SEE ANNEX 5 APPENDIX 1 TABLE I.1

km 0.5 0 0.5 1.0 1.5 2.0 km

MOGAMBO IRRIGATION PROJECT

LOCATION OF BENCH MARKS

JUNE 1979

SIR M MACDONALD & PARTNERS LTD

Horizon	Depth (cm)	Description
	59-123	Brown (10YR 4/3) clay, weak coarse prismatic structure, moist extremely firm; common fine vertical, very few fine horizontal cracks; few fine pores, common fine roots in cracks. Strongly developed slickensides. Common $CaCO_3$ and gypsum deposits. Gradual smooth boundary to:
	123-260 200 + augered	Very dark greyish brown (10YR 3/2) with few fine faint grey brown (10YR 5/2) mottles, clay, massive medium wedge structure, moist extremely firm, common fine diagonal cracks, few fine pores few fine roots. Few fine ferromanganese nodules, few broken shell fragments. Common fine 20 mm powdery pockets $CaCO_3$ with 15 mm patches gypsum crystals.
	260-420	Dark greyish brown (10YR 4/2) with few fine distinct grey brown (10YR 5/2) mottles, clay, slightly moist very firm. Common fine 15 to 20 mm carbonate and gypsum salts.
	420-460	Brown (10YR 4/3) with common medium faint grey brown (10YR 5/2) mottles, clay, slightly moist very firm. Very few fine crystals gypsum, abundant powdery carbonates. Few fine nodules managanese and ferromanganese coated $CaCO_3$ nodules.
	460-500	Brown (10YR 5/3), silt clay loam, moist loose, very few fine $CaCO_3$ nodules, occassionally coated with ferromanganese.

Profile Nr: D012

Classification: Jbl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-22	6	9	2	33	50	1.5	8.2	7.8	37.6
P2	22-50	6	9	1	19	65	4.8	8.4	8.1	33.8
P3	59-123	4	11	4	23	58	11.5	8.2	8.1	33.0

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
49.3	10.5	0.5	3.3	0.9	8.62	2.0	3.2	0.92
35.1	18.0	7.2	0.7	1.2	5.25	3.6	23.7	0.2
70.0	20.2	7.2	0.9	-	20.00	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
14.1	94.4	2.2	0.10	1.5	-	3.2	4.8	9.2
18.7	64.8	0.4	0.04	0.6	-	6.4	30.0	20.8
15.6	-	-	-	-	-	-	-	111.4

Extractable Zn	Cu	Total gypsum (%)	ESP
0.9	0.1	0.02	1.0
0.5	0.2	-	21.0
-	-	1.00	21.0

Pit Nr:	G052
Soil class:	Jb2-3
Land class:	U3s/R2g
Location:	Line G 0.7E
API legend:	Jb
Topography:	Broad flat plain between levee courses
Micro-relief:	marked gilgai (M2 - M3)
Vegetation:	F1
Surface:	Dry dark brown many irregular polygonal cracks especially on gilgai crests.
Profile drainage:	Imperfect
Depth to water table:	More than 5 m

Brief Description:

A heavy textured dark brown clay profile. Moderately structured surface horizons become more massive at depth with wedge shaped peds. Finely developed vertical cracks extend to 1.5 m and pores and roots to 2 m. Fine carbonate nodules occur throughout the profile and gypsum below 1.5 m.

Horizon	Depth (cm)	Description
A1	0-15	Very dark greyish brown (10YR 3/2) with fine ferromanganese stains, heavy clay loam, moderate fine subangular blocky breaking to fine granular or crumb structure, low organic matter content, dry slightly hard, few fine vertical cracks, common fine pores, many fine roots. Abundant fine to medium $CaCO_3$ nodules, few shell fragments. Clear wavy boundary to:
B1	15-44	Very dark greyish brown (10YR 3/2) clay, weak coarse prismatic structure, dry very hard, few medium vertical cracks, common fine pores, common fine roots. Many fine and medium $CaCO_3$ nodules, common fine shell fragments, few fine manganese nodules, occasional patches powdery secondary carbonates. Gradual wavy boundary to:

Horizon	Depth (cm)	Description
B2	44-108	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles clay, weak medium wedge structure, moist firm, few fine horizontal cracks, rare fine roots. Many fine $CaCO_3$ nodules occasionally stained with ferromanganese, common fine manganese nodules and lenses of ferromanganese carbonate nodules. Gradual smooth boudary to:
B3	108-150	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles; clay, weak medium wedge structure, moist firm, few fine horizontal cracks, few fine pores, rare fine roots. Many fine $CaCO_3$ nodules with some fine ferromanganese stains, common fine manganese nodules and lenses of fine carbonates. Gradual smooth boundary to:
B4	150-350 200 + augured	Dark brown (10YR 3/3) with common fine faint red brown (5YR 4/3) motles, clay, massive breaking to weak fine to medium angular blocky structure, moist slightly plastic, very few fine pores, rare fine roots. Common fine manganese and carbonate nodules, common powdery secondary $CaCO_3$ and fine gypsum crystals.
C1	350-400	Dark brown (10YR 3/3) with common medium distinct red brown (5YR 4/3) mottles, clay, wet slightly plastic, common fine $CaCO_3$ and manganese nodules. Abundant powdery secondary cabonates and gypsum crystals.
C2	400-450	Very dark greyish brown (10YR 3/2) with common medium distinct red brown (5YR 4/3) mottles, clay, wet slightly plastic, few fine $CaCO_3$ and manganese nodules, common patches powdery secondary carbonates and gypsum crystals.
C3	450-500	Very dark greyish brown/dark brown (10YR 3/2.5) with few fine faint red brown (5YR 4/3) mottles, clay, wet plastic, few fine $CaCo_3$ nodules, occasional 3 to 4 mm $CaCO_3$ nodules, common powdery secondary carbonates and gypsum crystals, few medium manganese nodules.

Profile Nr: GO52

Classification: Jb3

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/ cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/ 100 g soil
P1	0-15	9	27	5	19	50	1.1	8.1	7.6	35.6
P2	15-44	9	18	4	19	50	0.8	8.7	8.4	31.9
P3	44-108	6	16	6	14	58	1.4	8.4	7.9	32.6
P4	108-150	9	13	5	15	58	3.7	8.7	8.2	31.4

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
50.3	7.6	0.4	1.2	1.0	5.00	1.6	1.6	0.16
34.8	8.8	0.7	0.5	1.1	3.00	1.8	3.8	0.04
34.7	15.2	2.1	0.5	-	5.75	-	-	-
23.3	16.6	6.2	0.6	-	3.50	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
13.0	177.0	1.6	0.09	1.2	-	2.1	3.6	4.3
12.0	71.2	0.5	0.08	0.7	-	2.0	2.8	4.8
12.6	-	-	-	-	-	-	-	-
11.4	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.6	0.1	0.07	1.0
0.6	0.1	0.04	2.0
-	-	0.03	6.0
-	-	-	19.0

Pit Nr:	G054
Soil class:	Jb3
Land class:	U3s/R2g
Location:	Line F 1.05E
API legend:	Jub
Topography:	Flat level plain
Micro-relief:	Uneven (M2 occasionally M3)
Vegetation:	Grasses and sedges open plain
Surface:	Dry hard irregular surface cracks, deep redish brown in colour
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A dual profile with dark brown and dark reddish brown moderately well structured silt clay loams developed in recent alluvium, passing into very dark grey brown older alluvial clays with moderate prismatic and wedge structures. Medium vertical cracks occur throughout with many fine pores to 55 cm in the recent alluvium and roots to 2 m. Carbonates are confined to the older alluvium.

Horizon	Depth (cm)	Description
A1	0-15	Dark brown (7.5YR 3/4) silt clay loam, moderate fine subangular blocky structure, dry hard, common medium vertical cracks, many fine pores, abundant fine roots. Clear wavy boundary to:
B1	15-23	Dark reddish brown (5YR 3/3) with few fine faint red (10YR 4/6) mottles, silt clay loam, weak medium prismatic breaking to fine subangular blocky structure, slightly moist firm, common medium vertical cracks, many fine pores, common fine roots, few fine manganese nodules. Diffuse boundary to:
B2	33-55	Dark reddish brown (5YR 3/4) with few fine faint grey and yellow brown (10YR 5/1 and 5/4) mottles, clay loam, weak medium prismatic breaking to fine subangular blocky structure, slightly moist friable, common medium vertical cracks, many fine pores, few fine roots. Few fine $CaCO_3$ nodules, occasional shell fragments. Abrupt smooth boundary with many shells to:

Horizon	Depth (cm)	Description
C1	55-130	Very dark greyish brown (2.5YR 3/2) surface of horizon less than 10 cm thick very dark grey (10YR 3/1), clay, moderate coarse prismatic breaking to moderate medium wedge structure, slightly moist extremely firm, low organic matter content, few medium to coarse vertical and few fine horizontal cracks, few fine pores, few fine roots. Many shell fragments, well developed slickensides, abundant 1 to 3 mm $CaCO_3$ nodules increasing towards base of horizon many deposits powdery carbonates. Diffuse boundary to:
C2	130-200	Very dark greyish brown (2.5YR 4/2) clay, weak medium wedge breaking to fine angular blocky structure, slightly moist firm, low organic matter content, common fine vertical and horizontal cracks, few fine roots, well developed slickensides, common fine shell fragments, many fine $CaCO_3$ nodules.

Profile Nr: G054

Classification: Jb3

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-15	1	18	-	26	55	0.6	8.3	7.8	31.5
P2	15-33	-	11	1	30	58	0.5	8.2	8.0	29.3
P3	33-55	-	11	1	30	58	0.5	8.5	8.1	30.1
P4	55-130	9	17	5	11	58	0.7	8.7	7.8	31.7

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
34.7	6.9	0.2	1.8	1.0	3.75	0.9	1.4	0.21
37.9	6.9	0.2	1.4	0.9	2.75	0.6	1.4	0.16
35.3	6.1	0.2	1.1	-	2.75	-	-	-
41.0	11.0	0.6	1.2	-	3.75	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
19.2	70.8	3.0	0.10	1.1	-	2.6	2.0	1.4
20.2	73.4	2.8	0.09	0.8	-	2.2	1.6	2.7
20.0	-	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.5	0.1	0.05	-
0.5	0.4	0.05	-
-	-	0.06	-
-	-	0.04	1.0

Pit Nr:	G057
Soil class:	Jd
Location:	Line 0 3.4W
Land class:	U6d/R2dt
API legend:	Jd
Topography:	Slight depression between meander complex and marine plain
Micro-relief:	Uneven (M2)
Vegetation:	80% tree cover, **Acacia nilotica**
Surface:	Dark grey, thin litter layer
Profile drainage:	Poor
Depth to water table:	More than 2 m

Brief Description:

A moderately structured very dark grey brown clay Ap horizon passes into a dark olive grey weakly structured B horizon at 27 cm. The subsoil is composed of very dark greyish brown massive clays. Finely developed vertical cracks occur to 1 m and roots are developed to 2 m. Fine carbonates occur throughout the profile.

Horizon	Depth (cm)	Description
A1	0-27	Very dark greyish brown (10YR 3/2) clay, weak to moderate medium subangular blocky structure, low organic matter content, moist firm, few fine vertical cracks, common fine pores; many fine, few medium roots. Few fine $CaCO_3$ nodules, common lenses of very fine ferromanganese coated $CaCO_3$ nodules. Clear smooth boundary to :
B1t	27-102	Dark olive grey (5Y 3/2) clay, weak coarse prismatic structure, moist very firm, few medium vertical cracks, few fine pores; common fine, occasional large woody roots. Common fine $CaCO_3$ nodules, common lenses of very fine ferromanganese coated $CaCO_3$ nodules. Diffuse boundary to :
B21	102-145	Very dark greyish brown (10YR 3/2) clay, massive, moist extremely firm, occasional fine vertical cracks, few fine pores, few fine roots. Very compact. Few fine and medium $CaCO_3$ nodules. Clear smooth boundary to :

Horizon	Depth (cm)	Description
B22	145-190	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles, clay, massive to moderate medium wedge, moist firm, common fine pores, few fine roots. Well developed horizontal slickensides, very few very fine $CaCO_3$ nodules.

Profile Nr: G057

Classification: Jdl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-27	6	15	8	15	53	0.8	8.1	7.5	35.8
P2	27-102	5	19	6	15	55	0.8	8.3	7.0	34.9
P3	102-145	3	18	4	15	60	8.3	7.8	7.7	32.4

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
42.4	6.4	0.3	1.20	1.1	6.0	0.9	1.9	0.22
47.1	8.9	0.7	0.50	0.6	5.0	0.9	3.0	0.04
38.8	20.4	6.0	0.75	-	21.2	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
4.2	58.4	1.1	0.07	1.1	-	2.7	3.6	4.3
3.8	51.6	0.4	0.05	0.7	-	1.9	2.8	5.9
3.6	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.8	0.4	0.05	1.0
0.6	0.6	0.05	2.0
-	-	0.10	19.0

Pit Nr:	G059
Soil class:	Jb 2-3
Land class:	U3t/R3g
Location:	Line N 3.2W
API legend:	Jd
Topography:	Shallow depression alongside marine plain
Micro-relief:	Very uneven
Vegetation:	Sesame
Surface:	Slightly self mulching, dark grey, irregular cracks
Profile drainage:	Poor
Depth to water table:	More than 2 m

Brief Description:

Moderately structured very dark grey brown to grey brown clays overly dark greyish brown weakly structured clay loams at 77 cm. Finely developed vertical cracks occur in the surface horizons to 135 cm with well developed slickensides in the subsoil. Roots extent throughout, and carbonates occur as fine to medium sized nodules below the Ap horizon.

Horizon	Depth (cm)	Description
Ap	0-23	Very dark greyish brown (10YR 3/2) with few fine distinct root mottles, clay, moderate medium subangular blocky structure with a slightly platy surface, dry slightly hard, common fine vertical cracks, common fine pores; many fine, few medium roots. Occasional shell fragments, few fine $CaCO_3$ nodules and small lenses of ferromanganese carbonate nodules. Clear irregular boundary to:
Blt	23-77	Dark greyish brown (10YR 4/2) clay, weak to moderate medium wedge structure, slightly moist firm; common fine vertical, few fine horizontal cracks; few fine pores; many fine, few medium roots. Common fine to medium manganese nodules, well developed diagonal slickensides, abundant shell fragments, abundant fine to medium $CaCO_3$ nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
B21	77-135	Dark greyish brown (2.5Y 4/2) with few fine faint yellowish brown (10YR 5/4) mottles, heavy clay loam, weak fine to medium angular blocky structure, moist friable, few fine horizontal and vertical cracks, common fine pores, rare fine roots. Few medium manganese nodules, common fine and medium $CaCO_3$ nodules. Clear smooth boundary to:
B22	135-200	Dark greyish brown (2.5Y 4/2) with few faint red brown (5YR 4/3) mottles, clay loam, weak fine platy to wedge structure, moist firm, few fine horizontal cracks, few fine roots. Well developed slickensides, common shell fragments common fine $CaCO_3$ nodules often coated with ferromanganese; few fine manganese nodules.

Profile Nr: G059

Classification: JB2-3

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-23	5	20	2	8	65	1.3	7.5	7.3	38.2
P2	23-77	15	21	4	7	53	0.9	8.3	7.7	30.5
P3	77-135	15	19	4	9	53	3.1	8.1	7.7	30.2

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
51.9	8.7	0.3	2.00	1.6	13.3	2.4	1.8	0.39
45.7	11.0	0.8	0.82	1.2	5.5	1.4	3.8	0.07
40.6	11.5	1.7	0.40	-	18.7	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
1.2	53.4	1.0	0.10	1.5	-	2.0	2.0	12.6
9.5	29.4	0.1	0.03	0.4	-	1.9	2.4	7.4
9.3	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
1.6	1.0	0.06	-
0.7	0.3	0.04	2.0
	-	0.18	5.0

Pit Nr:	G137
Soil class:	Jmxd
Land class:	U3se/R2t
Location:	Line P 1.1W
API legend:	Jmx
Topography:	Broad flat depression between levees in meander complex
Micro-relief:	Even (M1)
Land use:	Sesame, beans, tomatoes
Surface:	Dry, slightly self mulching, dark grey, scattered shell fragments and carbonate nodules
Profile drainage:	Imperfect
Depth to water table:	250 cm

Brief Description:

Very dark greyish brown clay loams and clays pass into dark yellowish brown fine sandy clay loam at 190 cm. Structure is only weakly developed with medium to coarse vertical cracks. Mottling occurs throughout the profile, with common fine carbonates below 20 cm and gypsum below 70 cm. Roots extend to 70 cm. Below 190 cm there is an increasing content of coarse micaceous sand.

Horizon	Depth (cm)	Description
A1	0-20	Very dark grey brown (10 YR 3/2) with common coarse distinct red brown (5YR 4/3) mottles, clay loam, low organic matter content, weak medium prismatic breaking to moderate fine angular blocky structure, dry hard, common medium vertical cracks, common fine pores, few fine roots. Common fine shell fragments, few fine $CaCO_3$ nodules. Clear smooth boundary to:
B1	20-70	Very dark greyish brown to dark brown (10 YR 3/2.5) with few medium faint red brown (5YR 4/3) mottles, clay, weak coarse, prismatic structure, slightly moist very firm; few medium vertical, few fine horizontal cracks; few fine pores, few fine roots. Few fine manganese stains on ped faces. Common fine $CaCO_3$ nodules few shell fragments, occasional fine manganese nodules and 2 to 3 mm $CaCO_3$ nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	70-190	Dark brown (10YR 3/3) with common medium faint red brown (5YR 4/3) mottles, clay, weak medium wedge structure, moist firm, common medium vertical and horizontal cracks, few fine pores, rare fine roots. Common fine manganese nodules, few fine $CaCO_3$ nodules, weakly developed cutans, common fine gypsum crystals. Clear smooth boundary to:
C1	190-300 200 + augered	Dark yellowish brown (10YR 3/6) with common medium distinct red brown, grey and olive (5YR 4/3, 10YR 5/1 and 5YR 4/3) mottles, heavy sandy clay loam, massive structureless, moist to wet very sticky, few fine pores, few fine $CaCO_3$ and manganese nodules, occasional deposits secondary carbonates. Common fine ferromanganese staining and larger areas of manganese staining.
C2	300-350	Dark yellowish brown (10YR 3/6) with common fine distinct red brown and grey (5YR 4/3 and 10YR 5/1) mottles, coarse sandy loam, wet sticky, occasional lenses of sand and marl like material, common fine ferromanganese staining.
C3	350-400	Dark yellowish brown (10YR 4/4) with common fine distinct red brown (5YR 4/3) and common fine faint grey (10 YR 5/1) mottles loamy coarse sand, wet slightly sticky, common mica sand flakes and iron manganese staining.

Profile Nr: G137

Classification: Jmxd

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	4	18	5	18	55	1.4	7.9	7.5	34.3
P2	20-70	11	19	8	14	48	0.9	8.6	8.0	23.2
P3	70-190	8	18	8	21	45	5.7	8.4	8.2	21.6

Exchangeable cations meq/100 g soil

Ca	Mg	Na	K	B (ppm)
39.6	7.9	0.3	1.3	1.5
24.5	10.5	0.7	0.8	1.1
38.7	10.5	1.3	0.3	-

Soluble cations (meq/l)

Ca	Mg	Na	K
10.6	2.6	3.2	0.26
3.4	1.2	2.7	0.09
17.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
1.0	62.8	0.9	0.07	0.9
11.2	51.8	0.2	0.03	0.4
14.3	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	1.9	3.2	13.5
-	2.0	3.6	4.8
-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
2.8	1.6	0.06	-
0.7	0.3	0.02	3.0
-	-	1.30	6.0

Pit Nr:	G138
Soil class:	Jd1
Land class	U6d/R6d
Location:	Line P 3.4W
API legend:	Jd
Topography:	Depressional area between meander complex and marine plain.
Micro-relief:	Even (M1)
Land Use:	Tobacco
Surface:	Very slighlty self mulching, dark grey, shell fragments and irregular cracks.
Profile drainage:	Poor
Depth to water table:	More than 2 m

Brief Description:

Very dark grey to dark olive grey clays and heavy clay loams at the surface are weakly structured with finely developed vertical cracks. The subsoil is composed of more massive olive grey and brown clays. Roots extend to 1 m. Finely divided carbonates and gypsum occur throughout the profile.

Horizon	Depth (cm)	Description
A1	0-30	Very dark grey (5Y 3/1) with few fine faint red brown (5YR 4/3) mottles, clay, weak medium to coarse prismatic breaking to medium angular blocky structure, few medium vertical cracks, few fine pores, few fine roots. Few very fine $CaCO_3$ nodules, common gypsum crystals, few fine manganese nodules. Clear wavy boundary to :
B1	30-105	Dark olive grey to olive grey (5Y 3.5/2) with few medium faint red brown (5YR 4/3) mottles, heavy clay loam, weak fine platy to wedge structure, moist friable, few fine vertical and horizontal cracks, few fine pores, rare fine roots. Few fine gypsum crystals, common black manganese stains within peds, few fine, manganese nodules. Diffuse boundary to :

Horizon	Depth (cm)	Description
B2	105-210	Brown (10YR 4/3) with common medium prominent red brown (5YR 4/3) mottles, light fine sandy loam; massive single grain, structureless; moist friable, common fine pores. Very compact between 155 and 160 cm, few medium $CaCO_3$ nodules, common white 2 to 5 mm powdery secondary carbonate deposits, common gypsum crystals, common black manganese stains, common mica sand flakes.

Profile Nr: G138

Classification: Jd1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	5	23	6	8	58	0.8	7.8	7.0	30.7
P2	30-105	5	24	4	7	60	0.6	8.2	7.6	30.2
P3	105-155	4	25	5	11	55	2.8	7.9	7.7	32.7

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
44.8	7.3	0.3	1.6	1.4	3.7	0.9	2.2	0.42
44.3	8.9	0.6	1.1	1.5	3.7	0.5	2.5	0.12
50.0	11.7	1.9	0.7	-	2.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
3.2	39.0	1.2	0.02	1.0	-	2.0	4.0	3.4
1.2	35.8	0.5	0.04	0.5	-	2.0	1.6	3.2
2.0	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
2.5	2.4	0.04	1.0
1.8	1.6	0.02	2.0
-	-	0.08	6.0

Pit Nr:	G140
Soil class:	Jb1-2
Land class	U2s/R1
Location:	Line Q 1.7E
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	M1 after levelling
Vegetation:	**Acacia nilotica, Ac. zanzibaria,** in abandoned banana plantation
Surface:	Dry hard, dark grey, irregular surface cracks
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Very dark greyish brown clays, moderately well structured subangular blocky at the surface and prismatic to wedge structures in the subsoil. There are well developed vertical cracks to 63 cm and more strongly developed diagonal cracks and slickensides to 2 m. Roots and pores extend throughout the profile. Fine carbonate nodules occur from the surface, associated with fine manganese nodules and gypsum appears as fine crystals below 63 cm.

Horizon	Depth (cm)	Description
	0-15	Very dark greyish brown (10YR 3/2), clay, with low organic matter content moderate, medium subangular blocky structure, dry very hard; many fine and few medium to coarse vertical cracks, common fine pores, common fine and medium roots. Occasional shell fragments, abundant fine $CaCO_3$ nodules, few 1 to 3 mm nodules, few fine manganese nodules and fine stains. Clear wavy boundary to :
	15-35	Very dark greyish brown (10YR 3/2) clay, weak medium prismatic structure, slightly moist extremely firm, few medium vertical cracks, common fine pores, few fine roots. Few fine manganese nodules, many fine $CaCO_3$ nodules with ferromanganese staining, few medium $CaCO_3$ nodules and shell fragments. Gradual irregular boundary to :

Horizon	Depth (cm)	Description
	35-63	Very dark greyish brown to dark greyish brown (10YR 3/2 to 2.5 4.2) clay, moderate medium prismatic structure, slightly moist extremely firm, few medium vertical cracks, common fine pores, few fine roots. Abundant fine, and few medium $CaCO_3$ nodules, common fine ferromanganese stains and nodules. Occasional shell fragments. Gradual smooth boundary to :
	63-200	Dark brown (10YR 3/3) clay, moderate to strong coarse wedge structure, moist extremely firm; common fine and medium diagonal and common fine vertical cracks; few fine pores, few fine roots. Very strongly developed diagonal cracks, common fine $CaCO_3$ nodules, few fine manganese nodules, occasional shell fragments, common patches fine gypsum crystals near base of horizon.

Profile Nr: G140

Classification: Jb1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-15	9	14	5	23	49	1.1	8.3	7.9	35.7
P2	15-35	6	16	8	20	50	0.8	8.3	8.0	34.4
P3	35-63	9	15	6	17	53	1.3	8.2	8.0	33.9
P4	63-200	3	16	6	20	55	2.9	8.3	8.3	33.5

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
45.7	12.5	0.3	1.9	1.1	7.5	2.0	2.8	0.49
38.0	11.7	0.5	0.8	1.3	3.0	1.7	1.8	0.09
43.8	16.0	0.8	0.6	-	6.2	-	-	-
26.3	17.6	1.2	0.6	-	9.2	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
17.3	66.2	0.8	0.09	1.3	-	4.7	2.8	7.0
14.7	62.8	0.2	0.05	0.6	-	2.0	2.4	3.0
16.3	-	-	-	-	-	-	-	-
16.1	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.7	0.3	0.07	-
0.8	0.3	0.04	1.0
-	-	-	2.0
-	-	-	3.0

Pit Nr:	G141
Soil class:	Jb3
Land class:	Uβsg/R3g
Location:	Line E 1.4W
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Very uneven (M3)
Vegetation:	10% tree cover, grass plain with **Dobera glabra, Acacia zanzibaria**
Surface:	Light grey brown slightly capped, occasional shell fragments, fine cracks
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Moderately well structured dark brown silt clay to very fine sandy clay surface horizons with well developed cracks extending to 1 m. The subsoil is massive wedge structured dark yellowish brown clay. Roots extend to 1.5 m. Carbonates occur throughout the profile increasing at depth with occasional gypsum increasing below 27 cm and becoming abundant below 135 cm.

Horizon	Depth (cm)	Description
A1	0-27	Dark brown (10YR 3/3) silt clay, moderate fine to medium subangular blocky structure, dry hard, low organic matter content, common fine vertical and horizontal cracks, common fine pores, abundant fine and common medium roots. Common fine $CaCO_3$ nodules often ferromanganese stained, common fine manganese nodules. Clear wavy boundary to:
B/t	27-90	Dark brown (10YR 3/3), very fine sandy clay, weak coarse prismatic breaking to moderate fine subangular blocky structure, slightly moist very firm; common fine horizontal, few medium vertical cracks; few fine pores, common fine roots. Common fine $CaCO_3$ nodules often ferromanganese stained, few fine black manganese nodules, occasional shell fragments, occasional gypsum crystals. Clear wavy boundary to:

Horizon	Depth (cm)	Description
	90-135	Dark brown/dark yellowish brown (10YR 3/3.5) very fine sandy clay, weak medium wedge structure, moist very firm, few fine vertical and horizontal cracks, few fine pores, rare fine roots. Abundant fine $CaCO_3$ nodules occasionally ferromanganese coated, few fine manganese nodules, common 2 to 5 mm deposits, white powdery secondary carbonates, common gypsum crystals, very compact horizon. Diffuse boundary to:
	135-180	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, weak fine wedge structure, moist firm, few fine vertical and horizontal cracks, few fine pores, rare fine roots. Common fine $CaCO_3$ nodules some ferromanganese coated, few fine manganese nodules. Occasional patches 2 to 5 mm white powdery secondary carbonates, abundant gypsum crystals increasing towards base of horizon.
	180-330 180 + augered	Dark yellowish brown (10YR 3/6) with few medium distinct red brown (5YR 4/3) mottles, silt clay, moist firm, few fine $CaCO_3$ and manganese nodules. Common patches white powdery secondary carbonates up to 10 mm diameter. Common gypsum crystals. Occasional fine dark yellowish brown (10YR 4/4) sand lenses.
	330-410	Dark yellowish brown (10YR 4/4) with few fine faint strong brown (7.5YR 5/6) mottles, very fine sandy clay loam, moist friable, few fine $CaCO_3$ and manganese nodules, common black manganese stains. Common 2 to 5 mm patches powdery carbonates, abundant gypsum crystals.
	410-500	Dark yellowish brown (10YR 3/4) with few fine faint strong brown to red-brown (7.5YR 5/6 to 5YR 4/3) mottles, clay, moist firm. Common fine manganese nodules, common fine ferromanganese stains, occasional fine dark yellowish brown (10YR 4/4) sand lenses. Common 1 to 3 mm patches powdery carbonates. Abundant gypsum crystals especially below 470 cm.

Profile Nr: G141

Classification: Jb1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-27	6	28	11	22	33	1.0	8.2	7.8	24.7
P2	27-90	6	20	14	15	45	1.1	8.7	8.2	26.3
P3	90-135	3	20	6	53	18	0.6	8.2	7.9	21.0

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
34.6	6.8	0.4	1.4	0.9	4.0	1.5	2.9	0.36
26.2	10.6	2.9	0.8	1.3	1.8	0.3	8.5	0.11
94.6	11.8	4.0	0.7	-	33.7	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
11.4	83.0	0.9	0.07	0.8	-	2.1	3.6	4.4
11.0	62.8	0.3	0.06	0.5	-	2.9	4.8	2.8
7.9	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.8	0.5	-	1.0
0.8	0.4	-	1.1
-	-	-	19.0

Pit Nr:	T008
Soil class:	Jb1
Land class:	Uβse/R2st
Location:	Line A 1.7W
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Very gently undulating (M2)
Vegetation:	**Acacia nilotica, Dobera glabra,** scrub woodland
Surface:	Dry hard yellowish brown
Profile drainage:	Imperfect
Depth to water table:	More than 5 m

Brief Description:

A dark yellowish brown, fine textured soil. The surface horizons are moderatley structured becoming more massive below 120 cm where craking is less pronounced. Porosity is well developed with roots reaching to 200 cm. Calcium carbonate deposits occur throughout the profile.

Horizon	Depth (cm)	Description
Ap	0-11	Dark yellowish brown (10YR 3/4) clay loam. Moderate fine subangular blocky structure, dry slightly hard. Few fine vertical cracks. Abundant coarse inped pores, abundant fine, few medium roots. Few fine shell fragments, common very fine calcium carbonate nodules occasionally coated with ferromanganese. Clear smooth boundary to:
A1	11-24	Dark brown (10YR 3/3) heavy silt clay loam. Moderate medium subangular blocky structure, slightly moist firm, common fine vertical, fine horizontal cracks. Few fine pores, few fine roots. Common very fine calcium carbonate concretions and 1 to 5 mm nodules coated with ferromanganese, small pockets of manganese concretions. Gradual smooth boundary to:
B1	24-50	Dark brown (10YR 3/3) clay loam. Moderate coarse prismatic structure, slightly moist and extremely firm. Common medium vertical cracks, few fine pores, common fine and few medium roots. Common ferromanganese coated concretions and 1 to 5 mm nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	50-124	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay. Weak coarse prismatic structure, moist extremely firm, few medium vertical cracks, few fine pores, common fine roots. Occasional lenses of calcium carbonate, ferromanganese coated nodules; few shell fragments; cracks cease below 124 cm gradual smooth boundary to:
B2	124-183	Dark yellowish brown (10YR 3/4) clay, with very fine sand inclusions, weak subangular blocky structure, moist extremely firm, many fine pores; few fine roots. Occasional lenses of fine 1-5 mm nodular calcium carbonate with patches of secondary calcium carbonate up to 1 cm across.
B4	183-225 200 + augered	Dark yellowish brown (10YR 3/4) with common medium fine red brown (5YR 4/3) mottles, clay, weak medium subangular blocky structure, moist firm to friable. Common fine pores, few fine roots. Common fine 1 to 2 mm manganese concretions, many medium $CaCO_3$ nodules and powdery patches secondary carbonates.
	225-240	Dark yellowish brown (10YR 3/6) with common medium distinct red brown (5YR 4/3) mottles, silt clay loam, dry slightly hard. Many fine $CaCO_3$ nodules and powdery secondary carbonates.
	240-320	Dark yellow brown (10YR 4/4) with few fine faint yellowish brown (10YR 5/4) mottles towards the base. Loamy very fine sand, dry loose; common powdery deposits of secondary carbonates and common fine ferromanganese calcium carbonate nodules.
	320-350	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, moist firm. Abundant secondary carbonates and common fine $CaCO_3$ nodules.

Profile Nr: T008

Classification: Jb1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-11	8	14	1	27	48	1.8	8.1	7.9	35.0
P2	11-24	3	17	1	24	55	1.3	8.0	7.9	33.2
P3	24-50	6	6	3	25	60	7.3	8.2	8.1	31.4
P4	50-124	3	12	6	19	60	7.2	7.9	7.8	28.8
P5	124-183	3	14	5	23	55	8.6	7.9	8.0	24.5

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
51.0	6.9	0.3	2.1	0.5	8.6	1.4	3.2	0.77
49.6	8.9	0.5	0.9	0.1	6.7	2.5	2.5	0.13
24.1	18.2	5.1	1.0	-	15.1	-	-	-
31.2	12.4	1.8	0.8	-	27.5	-	-	-
80.3	13.5	0.8	0.5	-	35.0	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
12.8	104.6	2.8	0.10	1.3	-	2.8	10.0	7.4
14.5	92.0	0.8	0.08	0.9	-	1.6	6.0	6.7
22.0	-	-	-	-	-	-	-	16.0
12.0	-	-	-	-	-	-	-	48.3
10.1	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.6	0.1	0.04	-
0.6	0.3	0.02	1.0
-	-	-	16.0
-	-	0.9	6.0
-	-	1.2	3.0

Pit Nr: T009

Soil class: J1

Land class: U2s/R2s

Location: Line A 0.85E

API legend: J1

Topography: Old levee slightly undulating

Micro-relief: Slightly undulating

Vegetation: **Dobera glabra**, grass shrubland, small cropped areas

Surface: Uncracked, dry hard

Profile drainage: Imperfect, moderately well

Depth to water table: 450 cm

Brief Description:

Medium textured, brown, moderately well structured surface horizons pass into dark brown clays with more massive structures. Few vertical cracks confined to the surface horizons, very porous and well rooted to 2 m.

Horizon	Depth (cm)	Description
Ap	0-13	Dark brown (10YR 3/3) heavy silt clay loam, moderate medium subangular blocky structure, dry slightly hard, few fine vertical cracks, many fine pores, few coarse pores many fine roots, few medium roots. Clear wavy boundary to:
A1	13-40	Dark brown (7.5YR 4/3) heavy silt clay loam, moderate coarse prismatic structure breaking to moderate medium subangular blocky, slightly moist firm. Common fine vertical cracks, many fine tubular pores, few medium and common fine roots. Common fine soft powdery $CaCO_3$ increasing towards base with ferromanganese coatings. Gradual wavy boundary to:
B1t	40-116	Dark brown (7.5YR 4/3) silt clay to clay, moderate to strong medium fine subangular blocky structure, slightly moist firm, many medium pores, common fine and medium roots. Many soft powdery $CaCO_3$ concretions up to 2 cm across, weak clay skins and occasional shells. Gradual wavy boundary to:

Horizon	Depth (cm)	Description
B2	116-145	Dark brown (10YR 4/4) with few fine faint yellowish brown (10YR 5/4) mottles, clay loam with few fine sand inclusions. Moderate medium subangular blocky structure breaking to fine subangular blocky structure breaking to fine subangular blocky; moist firm, very many pores, common fine roots. Common fine $CaCO_3$ nodules occasionally ferromananganese coated. Gradual wavy boundary to:
B3	145-176	Dark brown (7.5YR 4/4) with common fine distinct yellow (10YR 7/6) mottles, clay, massive to weak fine subangular blocky structure, moist firm, common fine pores, few fine and medium roots. Common fine manganese stains, common to many 2 to 3 cm patches of powdery secondary $CaCO_3$, occasional fine gypsum crystals. Gradual smooth boundary to:
B4	176-280 200 + augered	Dark brown to reddish brown (7.5YR 4/4 to 5YR 4/4) with common medium distinct red brown and grey (5YR 4/3 and 10YR 5/1) mottles, clay; massive, moist very firm, many fine pores, few fine roots. Many fine manganese concretions few 1 to 2 cm $CaCO_3$ nodules and powdery carbonates.
C1	280-360	Reddish brown (5YR 4/4) with few fine faint red brown and grey (5YR 4/3 and 10YR 5/1) mottles, silt clay loam, moist firm to friable. Increase in secondary carbonates and $CaCO_3$ nodules, few fine nodules and concretions of manganese.
C2	360-380	Dark yellowish brown (10YR 4/4) with few fine faint red brown (5YR 4/3) mottles, fine sandy clay loam, moist firm. Very few fine manganese nodules. Abrupt boundary to:
C3	380-450	Yellowish brown (10YR 5/6) sand becoming wet and loose below 450 cm.

Profile Nr: T009

Classification: Jl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-13	10	20	13	27	30	1.8	8.1	7.9	27.4
P2	13-40	7	15	12	26	40	1.0	8.1	7.8	24.7
P3	40-116	4	11	15	30	40	1.6	8.1	7.9	24.3

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
19.7	4.8	0.02	2.8	1.3	9.5	2.5	3.0	1.3
26.6	6.1	0.08	1.5	0.8	8.8	1.9	2.2	0.5
23.1	9.1	0.20	1.8	-	8.8	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
13.7	171.8	13.1	0.10	1.0	-	2.3	4.8	13.8
14.3	140.2	0.8	0.08	0.6	-	2.5	4.0	6.5
15.7	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.7	0.3	0.02	-
0.7	0.2	-	-
-	-	0.02	-

Pit Nr:	T020
Soil class:	Jb1
Land class:	U2s/R1
Location:	Line C 0.2E
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Even very slight depresions
Vegetation:	Open shrub grassland
Surface:	Dry hard few shallow sink holes and irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Fine textured, moderately well structured, dark brown silty clay to clay surface horizons overly moderate wedge structured strong brown clays. Porosity and vertical cracks are well developed with roots extending to 200 cm.

Horizon	Depth (cm)	Description
Ap	0-15	Dark brown (10YR 3/3) light silt clay, moderate medium subangular blocky structure surface weak slightly platy dry slightly hard, low organic matter content, common fine vertical cracks, many fine tubular pores, abundant fine to medium roots. Few very fine powdery $CaCO_3$ concretions and few very fine shell fragments. Clear smooth boundary to:
A1	15-40	Brown (10YR 4/3) clay, moderate, coarse prismatic breaking to moderate medium subangular blocky structure, dry slightly hard, low organic matter content, common fine to medium vertical cracks, common fine tubular pores, common fine roots. Few shell fragments, common fine $CaCO_3$ and ferromanganese coated nodules. Clear smooth boundary to:
B1	40-80	Dark brown (7.5YR 4/4) clay, moderate, coarse angular blocky structure, slightly moist firm; common fine to medium vertical cracks, few fine horizontal cracks, few medium pores common fine roots, common fine powdery secondary $CaCO_3$ and common hard fine ferromanganese concretions.

Horizon	Depth (cm)	Description
B2	80-140	Dark brown (7.5YR 4/4) clay, moderate fine to medium wedge structure breaking to fine angular blocky; moist very firm, common fine vertical and diagonal cracks, few fine, few medium pores common fine roots. Common powdery secondary $CaCO_3$ deposits along crack faces with ferromanganese coated nodules. Common fine cutans on ped faces and slickensides developed near base of horizon. Gradual smooth boundary to:
B3	140-200	Dark greyish brown (10YR 4/2) clay, moderate to strong medium wedge breaking to fine subangular blocky structure, moist very firm, few diagonal cracks, few fine tubular pores, few fine roots, few fine shell fragments, well developed slickensides. Common fine $CaCO_3$ especially along old cracks. Well developed cutans and patches hard ferromanganese nodules.
	200-450 200 + augered	Dark yellowish brown (10YR 4/4) with few fine faint red-brown (5YR 4/3) mottles, clay, slightly moist extremely firm, common fine manganese nodules common fine nodules of $CaCO_3$ with ferromanganese staining, few medium pockets of $CaCO_3$ and few fine gypsum crystals. Well developed cutans on ped faces and fine pockets of sandy material.
	450-475	Brown (10YR 4/3) with common medium, faint red-brown (5YR 4/3) mottles, clay, slightly moist firm. Abundant fine gypsum crystals and many medium pockets of powdery $CaCO_3$, few fine manganese nodules, few fine sandy lenses.
	475-500	Dark yellowish brown (10YR 4/4.5) very fine sandy clay loam slightly moist and firm. Abundant powdery $CaCO_3$, few hard nodules $CaCO_3$ up to 1 cm diameter, very few fine manganese nodules.

Profile Nr: T020

Classification: Jb1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-15	7	13	10	35	35	2.1	8.7	8.0	27.8
P2	15-40	5	12	5	30	48	2.8	9.1	8.5	26.4
P3	40-80	5	12	7	26	50	16.3	8.5	8.5	28.3
P4	80-140	4	13	5	25	53	15.4	8.6	8.5	29.7
P5	140-200	3	12	6	24	55	15.8	8.5	8.4	24.8

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
21.7	6.5	2.5	0.8	0.5	6.2	1.1	22.5	0.19
14.0	9.9	11.5	0.4	0.5	1.7	0.4	31.8	0.05
32.9	9.0	13.0	0.6	-	23.7	-	-	-
44.0	9.4	10.8	0.5	-	25.0	-	-	-
83.4	10.2	15.2	0.5	-	22.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
16.3	88.0	1.4	0.10	1.0	-	4.0	12.6	9.2
20.9	86.4	0.6	0.05	0.6	-	5.6	20.0	12.5
17.8	-	-	-	-	-	-	-	-
13.6	-	-	-	-	-	-	-	-
9.7	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.6	0.3	-	8.0
0.5	0.2	0.01	43.0
-	-	0.40	45.0
-	-	0.60	36.0
-	-	1.00	61.0

Pit Nr:	T021
Soil class:	Jmxl
Land class	4s(U3st/R3t)
Location:	Line C 0.92W
API legend:	Jb
Topography:	Lower slope of levee into basin unit
Micro-relief:	Very gently undulating
Vegetation:	Moderately dense shrub grassland, **Acacia zanzibaria**
Surface:	Dry hard with few shallow sink holes
Profile drainage:	Imperfect
Depth to water table:	More than 5 m

Brief Description:

Fine textured, moderately well structured surface horizons overly brown mottled and manganese stained weakly structured clays. Vertical cracks are well developed to 1 m. There is well developed porosity and roots extend to 2 m. Secondary calcium carbonates occur in the lower horizons.

Horizon	Depth (cm)	Description
A1	0-21	Dark brown (10YR 3/3) heavy silt clay loam, moderate medium subangular blocky structure, dry slightly hard, low organic matter content, few fine vertical cracks, common fine, few medium pores, abundant fine and medium roots. Few fine shell fragments, few fine $CaCO_3$ concretions. Clear smooth boundary to :
B1	21-50	Dark brown (7.5YR 4/4) with common medium distinct grey brown (? topsoil stains) (10YR 5/2) mottles, light clay, moderate medium to coarse prismatic breaking to medium subangular blocky structure, dry slightly hard, common fine vertical cracks, common fine tubular pores, common fine, few medium roots. Few ferromanganese coated nodules, few fine shell fragments common very fine powdery secondary $CaCO_3$ deposits. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
B2	50-107	Dark brown (7.5YR 4/4) with common medium distinct manganese stains clay, slightly moist firm, strong fine prismatic breaking to strong very fine crumb structure. Many fine and very fine vertical cracks, many fine tubular pores, many fine few medium roots. Many fine powdery $CaCO_3$ concretions. Gradual smooth boundary to :
B3	107-137	Brown (10YR 4/3) with common fine faint strong brown (7.5YR 5/6) mottles, light clay, weak to moderate fine subangular blocky structure, slightly moist very firm; common fine pores, common fine, few medium roots; patches of 1 to 2 cm diam. $CaCO_3$. Gradual smooth boundary to :
B4	157-310 200 + augered	Dark brown (7.5YR 4/4) with manganese staining, heavy silt clay loam, weak medium subangular blocky structure, slightly moist very firm; common fine pores, common fine, few medium roots. Common fine 1 to 2 cm hard $CaCO_3$ nodules, many termite channels, becoming lighter textured towards base with increase in mica sand flakes on ped faces.
C1	310-325	Dark yellowish brown (10YR 4/4) with common medium faint red brown (5YR 4/3) mottles, very fine sand (? silt) clay, slightly moist firm, few fine nodules manganese, abrupt change to :
C2	325-500	Yellowish brown (10YR 5/6) sand, moist loose, grain size finer at depth.

Profile Nr: T021

Classification: Jmxl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-21	12	13	15	22	38	1.2	7.9	7.7	28.2
P2	21-50	10	20	12	13	45	1.3	8.3	7.9	21.3
P3	50-107	5	15	32	3	45	1.3	8.4	8.1	22.6
P4	107-137	7	15	13	27	38	0.8	8.6	8.1	18.0
P5	137-190	4	28	20	18	30	2.1	8.6	8.1	15.5

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
27.3	5.7	0.1	2.0	0.3	5.2	2.8	1.4	1.08
17.6	6.1	0.1	1.5	0.3	3.5	0.8	1.2	0.39
15.0	9.1	0.1	1.5	-	5.2	-	-	-
13.4	13.1	0.2	1.9	-	3.7	-	-	-
10.6	7.9	0.2	2.0	-	6.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
2.4	120.0	10.6	0.10	1.7	-	2.8	3.6	7.8
9.5	157.0	2.4	0.05	0.5	-	3.0	4.0	-
21.1	-	-	-	-	-	-	-	-
17.6	-	-	-	-	-	-	-	-
16.3	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.5	0.6	0.02	-
0.4	0.3	0.01	-
-	-	-	-
-	-	-	1.0
-	-	-	1.0

Pit Nr:	T024
Soil class:	Jmxl
Land class:	4s (U2st/R3st)
Location:	Line D 2.5W
API legend:	Jmx
Topography:	Site between levees of old meander complex, weakly undulating
Micro-relief:	Uneven, common large termitaria
Vegetation:	Heavy riverine forest
Surface:	Dry hard, dark grey, thin litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Weakly structured very dark grey brown and dark brown fine sandy loam to fine sandy clay loam surface horizons pass into more massive to structureless sands below 60 cm. Cracks are poorly developed and there are well developed pores, roots extend to 2 m. Carbonates are found in a thin band at 60 cm.

Horizon	Depth (cm)	Description
A1	0-10	Very dark greyish brown (10YR 3/2), heavy, fine sandy loam, moderate organic matter content, weak fine subangular blocky to single grain structure, dry slightly hard abundant fine pores; many fine, few medium roots. Gradual smooth boundary to:
IB1	10-60	Dark brown (10YR 3/3) fine sandy clay loam, weak fine subangular blocky to fine crumb structure, low organic matter content, dry slightly hard, few very fine vertical cracks especially at top of horizon. Abundant fine, common medium pores; abundant fine, common medium roots. Considerable faunal activity, few fine pockets powdery $CaCO_3$ especially at base of horizon. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
IIC1	60-110	Dark yellowish brown (10YR 4/4), heavy fine sandy loam to fine sandy loam, low organic matter content, massive to weak fine subangular blocky structure, dry slightly hard, very few fine vertical cracks at top of horizon, abundant fine tubular pores, common fine roots, considerable faunal activity, accumulations of powdery $CaCO_3$ at top of horizon associated with 1 cm manganese nodules, common mica sand flakes and sandy pockets. Clear smooth boundary to:
IIIC2	110-140	Dark yellowish brown (10YR 4/4) fine loamy sand, massive structureless, dry slightly hard, abundant fine pores, few fine roots. Few fine pockets of powdery carbonates and 1 to 3 cm ferromanganese coated nodules, ped faces coated with mica sand flakes, 5 cm band of coarse sand at 125 cm. Gradual smooth boundary to:
IIC3	140-500 200 + augered	Dark yellowish brown (10YR 4/4) fine sand, structureless single grain, dry loose abundant fine pores; few fine, few medium roots. Considerable faunal activity. Lense of loamy fine sand 230 to 280 cm; sand becomes coarser at depth especially below 400 cm.

Profile No: T024

Classification: Jmxl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-10	7	15	1	59	18	12.6	8.2	8.2	22.3
P2	10-60	17	30	15	10	28	1.6	8.1	7.8	19.4
P3	60-110	9	36	25	7	23	1.5	8.7	8.3	13.7
P4	110-140	-	-	-	-	-	-	-	-	-
P5	140-210	44	50	1	-	5	1.8	8.8	8.4	3.8

Exchangeable cations meq/100 g soil

Ca	Mg	Na	K	B (ppm)
75.0	10.4	-	0.2	3.1
16.7	4.1	0.06	1.5	0.4
10.8	5.7	0.09	4.0	-
-	-	-	-	-
6.5	2.8	0.04	0.8	-

Soluble cations (meq/l)

Ca	Mg	Na	K
36.2	31.1	159.3	0.1
9.2	3.8	3.1	1.3
5.0	-	-	-
-	-	-	-
5.0	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
9.4	51.2	0.1	0.01	0.2
3.5	112.2	10.3	0.08	1.0
9.9	-	-	-	-
-	-	-	-	-
3.1	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	1.4	80.0	-
-	2.1	9.3	5.8
-	-	-	-
-	-	-	-
-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.3	0.1	0.9	-
0.5	0.1	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Pit Nr:	T027
Soil class:	J1
Land class:	U3s/R1
Location:	Line H 0.6E
API legend:	J1
Topography:	Very low levee formation
Micro-relief:	Flat few low hollows
Vegetation:	Tree cover 10%, **Acacia nilotica, Ac. zanzibaria,** grassland
Surface:	Dry hard brownish grey, thin grass litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Dark brown, clay loam and heavy silt clay loam surface horizons are moderately well structured with many fine to medium vertical cracks, and common fine pores. The subsoil below 35 cm contains increasing amounts of carbonates in a clay matrix with more weakly developed structures; roots are well developed throughout.

Horizon	Depth (cm)	Description
A1	0-15	Dark brown (10YR 3/3) clay loam, with pale yellowish brown (10YR 5/4) sand inclusions, moderate medium subangular blocky structure with slightly platy surface, low organic matter content, dry slightly hard, common fine and few medium vertical cracks, common fine pores, common fine roots. Many very fine $CaCO_3$ nodules, common fine shell fragments. Clear wavy boundary to:
B1	15-35	Very dark grey brown/dark brown (10YR 3/2 to 2/3), heavy silt clay loam, moderate medium to coarse subangular blocky structure, dry hard, common fine and few medium 1 to 2 cm vertical cracks, few fine horizontal cracks, common fine pores, common fine roots. Common very fine powdery $CaCO_3$ and ferromanganese nodules, few shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B21	35-130	Dark brown (10YR 3/3) with fine manganese stains, clay, weak coarse prismatic breaking to medium angular blocky structure, dry hard, few medium vertical and 1 to 2 cm diagonal cracks, few fine pores, common fine roots. Moderately well developed slickensides, common fine ferromanganese concretions, few fine $CaCO_3$ nodules and shell fragments. Gradual smooth boundary to:
B22	130-350 200+ augered	Dark brown to dark yellowish brown (10YR 3/3 to 3/4) with few faint brown (10YR 4/3) mottles, clay, moderate medium subangular blocky structure, moist extremely firm, few fine vertical cracks near top of horizon, common pores, common fine roots. May fine to very fine $CaCO_3$ nodules, common fine balck rounded ferromanganese nodules, occasional patches powdery $CaCO_3$ and gypsum, few shell fragments, patchy weak cutans on ped faces.
C1	350-400	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, moist slightly plastic, few fine $CaCO_3$ and ferromanganese nodules, occasional patches powdery $CaCO_3$ and gypsum.
C2	400-500	Very dark greyish brown (2.5YR 3/2) with few fine faint red brown (5YR 4/3) mottles, clay, moist firm, few fine $CaCO_3$ and ferromanganese nodules, occasional patches powdery $CaCO_3$ and gypsum increasing towards base.

Profile Nr: T027

Classification: J1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-15	3	12	2	41	42	1.9	8.1	7.8	33.4
P2	15-35	3	15	2	34	46	1.1	8.2	7.9	32.1
P3	35-130	3	15	-	31	51	1.8	8.3	8.0	10.3
P4	130-200	2	21	-	31	46	12.0	7.9	7.9	6.1

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
35.5	9.6	0.3	1.0	0.06	13.3	3.8	5.8	0.15
29.1	10.9	0.6	0.6	1.06	6.7	1.7	5.57	0.07
26.1	14.5	2.0	0.6	-	5.5	-	-	-
17.1	14.2	-	0.5	-	68.1	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
18.5	60.2	0.8	0.06	0.9	-	1.8	7.6	10.5
19.6	60.8	0.3	0.05	0.7	-	2.0	5.6	5.25
21.6	-	-	-	-	-	-	-	-
18.3	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.5	0.2	-	-
0.5	0.3	0.03	1.0
-	-	-	19.0
-	-	0.09	-

Pit Nr:	T028
Soil class:	MP
Land class	U3es/R3t
Location:	Line G 4.7W
API legend:	Jt
Topography:	Terrace on marine plain
Micro-relief:	Weakly undulating
Vegetation:	Tree cover 90%; **Dobera glabra, Acacia zanzibaria, Thespesia sp.**
Surface:	Fine dry yellowish brown slight mulch occasional shell fragments.
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A very dark grey brown very fine sandy clay loam, moderately structured surface horizon passes into a dark brown moderate to strongly structured silt clay below 18 cm, with yellowish brown sandy clay to 73 cm. The subsoil is composed of olive brown silt clays to clays with moderate subangular blocky structures. These marine clays contain moderate to strong brown, red brown and greenish grey mottles with abundant carbonates and gypsum. Roots are well developed throughout.

Horizon	Depth (cm)	Description
A1	0-18	Very dark greyish brown (10YR 3/2), very fine sandy clay loam, moderate medium subangular and fine crumb structure; low organic matter content, dry slightly hard, few fine cracks common fine pores; many fine, few medium roots. Common fine sand inclusions. Gradual smooth boundary to :
B1	18-42	Dark brown (10YR 4/3) silt clay, moderate to strong fine to medium angular blocky and weak coarse prismatic structure, dry slightly hard, common fine vertical cracks, few fine pores; common fine, few medium roots. Common very fine ferromanganese nodules, few fine $CaCO_3$ nodules, common fine sand inclusions. Gradual smooth boundary to :
B2	42-73	Yellowish brown (10YR 5/4) sandy clay, weak medium prismatic to fine vertical cracks, few fine pores; common fine, few medium roots. Many very fine soft $CaCO_3$ nodules, few fine ferromanganese nodules, few shell fragments. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
C1	73-100	Olive brown (2.5Y 4/4) with few fine faint brown and strong brown (10YR 5/3 and 7.5YR 5/6) mottles. Light clay, moderate medium subangular blocky structure, moist very firm, few fine pores, many fine roots. Common medium patches of $CaCO_3$, occasional 2 to 3 cm patches $CaCO_3$ and gypsum, increase in gypsum towards base, few fine ferromanganese nodules, few weak slickensides and cutans. Gradual smooth boundary to :
C2	100-300 200 + augered	Olive brown (2.5Y 4/4) with common fine distinct strong brown and greenish grey (7.5YR 5/6 and 5G 4/2) mottles. Silty clay, moderate fine to medium subangular blocky structure, moist firm, few fine pores, common fine roots. Well developed cutans, common, large 10 cm patches powdery $CaCO_3$ and gypsum often with hard 3 to 5 cm central nodules of ferromanganese coated $CaCO_3$; many fine powdery $CaCO_3$ and gypsum crystals.
C3	300-350	Yellowish brown (10YR 5/4) with common fine distinct strong brown (7.5YR 5/6) mottles, light sandy clay loam, slightly moist firm, common 2 to 4 mm deposits of soft white $CaCO_3$ nodules, few fine manganese nodules, common gypsum crystals in sand lenses.
C4	350-400	Strong brown (7.5YR 5/6) with common medium distinct yellowish red (5YR 4/6) mottles, coarse sandy loam, moist friable, few deposits white secondary carbonates 2 to 5 mm across, common grey/black manganese staining, common gypsum.
C5	400-500	Red (2.5YR 4/8) with dark iron/manganese stains and patches strong brown (7.5YR 5/6), heavy coarse sandy loam, moist friable, many 1 to 2 mm $CaCO_3$ nodules, and patches 5 to 10 mm powdery $CaCO_3$ with hard fine nodules, abundant gypsum crystals.

Profile Nr: T028

Classification: Jt/MP

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-18	24	28	4	13	31	1.0	8.2	7.8	26.8
P2	18-42	-	-	-	-	-	-	-	-	-
P3	42-73	-	-	-	-	-	-	-	-	-
P4	73-100	9	18	-	27	46	17.0	8.4	8.4	21.2
P5	100-200	6	24	7	7	56	3.0	8.4	8.3	24.1

Exchangeable cations (meq/100 g soil)

Ca	Mg	Na	K	B (ppm)
20.1	6.1	0.08	2.1	0.7
-	-	-	-	-
-	-	-	-	-
96.5	19.2	10.50	0.7	-
34.4	12.5	5.30	0.5	-

Soluble cations (meq/l)

Ca	Mg	Na	K
8.6	2.4	1.9	0.6
-	-	-	-
-	-	-	-
41.8	-	-	-
60.6	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
5.3	70.8	2.6	0.1	2.0
-	-	-	-	-
-	-	-	-	-
10.3	-	-	-	-
12.2	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	4.0	2.6	5.67
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.5	0.3	0.003	-
-	-	-	-
-	-	-	-
-	-	0.700	49.0
-	-	-	21.0

Pit Nr:	T029
Soil class:	Jb1
Land class	U3st/R3t
Location:	Line G 1.7W
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Weakly undulating (M1)
Vegetation:	Grassland plain, small fields maize
Surface:	Few medium cracks, fine surface mulch
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A heavy textured clay profile. Surface horizons are very dark brown to very dark greyish brown moderate to strongly structured with prismatic and wedge shaped peds and a decrease in porosity. The soil is dark brown in colour becoming yellowish brown on drying. There are well developed slickensides below 80 cm with many carbonates and fine gypsum. Roots are well developed throughout.

Horizon	Depth (cm)	Description
	0-20	Very dark brown (10YR 2/2), light clay, moderate to strong fine to medium subangular blocky structure, low organic matter content, dry slightly hard; common fine pores; abundant fine and many medium roots. Common very fine $CaCO_3$ concretions. Clear wavy boundary to :
	20-45	Very dark greyish brown (10YR 3/2) clay, moderate, medium subangular blocky structure; dry hard, common fine vertical and horizontal cracks, common fine, few medium to coarse pores; common fine roots. Many very fine soft $CaCO_3$ concretions, common fine shells and shell fragments, weak patchy cutans, few fine to medium lenses of $CaCO_3$ nodules. Clear wavy boundary to :
	45-82	Very dark greyish brown (10YR 3/2) clay, weak to moderate coarse prismatic to moderate medium subangular blocky structure, dry hard, common medium 3 to 4 cm vertical cracks, common fine pores, many fine roots. Occasional lenses of very fine $CaCO_3$ nodules, many very fine ferromanganese and $CaCO_3$ nodules, common fine shell fragments, weak cutans developed on ped faces; occasional very fine sand lenses. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
	82-147	Dark brown (10YR 3/3) clay, weak to moderate medium to coarse angular blocky structure, slightly moist extremely firm, few fine vertical cracks, few fine pores, common fine roots. Abundant very fine $CaCO_3$ and ferromanganese nodules, patchy vertical cutans, few shell fragments, very few very fine gypsum crystals. Gradual smooth boundary to :
	147-300 190 + augered	Dark brown (10YR 3/3) clay, weak to moderate medium wedge to fine angular blocky structure; slightly moist extremely firm, common vertical and diagonal cracks, few fine pores, rare fine roots. Abundant very fine hard and soft $CaCO_3$ nodules and gypsum crystals, many fine ferromanganese nodules, well developed slickensides.
	300-430	Dark yellowish brown (10YR 3/4) with common fine faint red-brown (5YR 4/3) mottles clay, moist firm, common fine $CaCO_3$ nodules, few fine ferromanganese nodules, some patches of powdery secondary carbonates.
	430-450	Dark brown (10YR 3/3) with few fine faint yellow brown (10YR 5/4) mottles, clay loam, moist firm, common fine $CaCO_3$ and ferromanganese nodules, occasional patches powdery carbonates and gypsum crystals.
	450-470	Dark brown (10YR 3/3) with common fine faint red brown (5YR 4/3) mottles, loamy coarse sand, dry loose, abundant gypsum crystals and fine mica sand flakes.
	470-500	Dark brown (10YR 3/3) with common fine faint red-brown (5YR 4/3) mottles, clay loam, moist firm, few fine $CaCO_3$ and manganese nodules, few patches powdery secondary carbonates and gypsum.

Profile Nr: T029

Classification: Jb1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	3	17	2	30	48	1.1	8.1	7.8	28.8
P2	20-45	7	13	2	20	58	0.6	8.3	7.9	16.6
P3	45-82	8	12	2	17	61	1.4	-	-	7.2
P4	82-147	-	-	-	-	-	-	-	-	-
P5	147-190	8	12	2	21	57	5.9	8.1	7.9	14.4

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
31.5	6.1	0.7	1.0	0.1	8.8	1.5	3.7	0.20
45.0	11.1	0.8	0.9	0.2	5.0	0.7	3.0	0.04
35.3	15.3	2.0	0.7	-	6.5	-	-	-
-	-	-	-	-	-	-	-	-
75.6	15.6	2.5	0.8	-	15.0	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
3.9	139.4	1.9	0.10	2.1	-	2.4	4.4	4.1
10.1	95.2	0.7	0.04	1.1	-	2.3	2.6	3.3
11.1	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
11.3	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.7	0.3	-	2.0
0.6	0.1	-	4.0
-	-	0.01	27.0
-	-	-	-
-	-	0.8	17.0

Pit Nr:	T031
Soil class:	Jmxl
Land class:	4s(U3st/R3t)
Location:	Line F 1.9W
API legend:	Jmx
Topography:	Depressional site in meander complex
Micro-relief:	Weakly undulating
Land Use:	Fl fallow cropped
Surface:	Dry hard, moderately cracked
Profile drainage:	Moderately well
Depth to water table:	More than 2 m (very moist at base of pit)

Brief Description:

Very dark grey brown surface clays exhibit weak prismatic structures, cracking is moderately well developed to 134 cm and roots extend to 2 m. Fine carbonate nodules are distributed throughout the profile with gypsum below 134 cm. The subsoil below 175 cm is a dark yellowish brown very fine sandy loam becoming very moist at 200 cm.

Horizon	Depth (cm)	Description
A1	0-30	Very dark grey brown (10YR 3/2) common fine red brown (5YR 4/3) root mottles, heavy silt clay loam, low organic matter content, weak coarse angular blocky to prismatic structure, dry hard, few fine vertical cracks, few fine pores; abundant fine, few medium roots. Few fine calcium carbonate nodules, few fine sand inclusions. Diffuse boundary to:
B1	30-94	Very dark grey brown/dark brown (10YR 3/3.5) clay, weak very coarse prismatic to moderate medium wedge structure, slightly moist extremely firm, common medium vertical, few fine horizontal and diagonal cracks, few fine pores, many fine roots. Abundant fine 1 to 5 mm calcium carbonate concretions, common fine shells, patchy slickensides, common fine manganese nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
B21	94-134	Dark brown/dark yellowish brown (10YR 3/3.5) with common medium distinct red brown (5YR 4/3) root mottles. Clay, moderate medium wedge structure, moist extremely firm, many medium vertical, common fine horizontal cracks; few fine, few medium pores; many fine roots. Common fine manganese nodules, patchy slickensides, few fine shell fragments, common fine $CaCO_3$ nodules. Diffuse boundary to:
B22	134-175	Dark brown (7.5YR 3/2) with common medium distinct grey and strong brown (10YR 5/1 and 7.5YR 5/6) mottles. Clay loam, weak, medium subangular blocky structure, moist friable, common fine pores, common fine roots. Many fine gypsum crystals, common fine powdery $CaCO_3$, common fine manganese nodules. Diffuse boundary to:
C1	175-200	Dark yellowish brown (10YR 3/6, oxidising to 10YR 4/4), very fine sandy loam, single grain massive, structureless, wet and slightly sticky, abundant fine pores, few fine pores,few fine roots. Abundant fine mica sand flakes, few fine manganese stains.

Profile Nr: T031

Classification: Jmxl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	6	19	-	22	53	1.9	8.0	7.8	30.2
P2	30-94	2	11	4	30	53	6.7	7.9	7.8	23.1
P3	94-134	3	15	7	57	18	6.9	8.0	7.9	22.5

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
26.7	7.9	1.1	1.2	0.3	14.5	3.3	7.2	0.25
32.1	17.0	1.5	0.4	0.6	44.3	-	-	-
96.8	18.7	1.5	0.3	-	23.7	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
10.1	83.4	1.1	0.05	0.7	-	1.7	8.6	-
10.0	-	-	-	-	-	-	-	-
11.3	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.7	0.4	-	3.0
-	-	0.03	6.0
-	-	1.30	6.0

Pit Nr:	T032
Soil class:	BM
Land class:	U6est/R6est
Location:	Line I 4.6W
API legend:	BM
Topography:	Weakly undulating degraded aeolian dune field
Micro-relief:	Weakly undulating
Vegetation:	Large baobab **(Adansonia digitata)**, 30% tree cover in grass shrubland **Dobera glabra**
Surface:	Sandy surface tilth, thin leaf litter layer, dry and hard, red brown
Profile drainage:	Moderately well
Depth to water table:	More than 475 cm

Brief Description:

Surface horizons are severely leached coarse sands and sandy loams with a dark yellowish brown very porous surface overlying a red B1. Structure is very poorly developed throughout the profile. Increasing clay content occurs with depth especially below 130 cm where there is a yellowish red fine sandy clay loam. Carbonates are found in sigificant quantities only in the lower horizons.

Horizon	Depth (cm)	Description
Ale	0-30	Dark yellowish brown (10YR 3/6), coarse sand, weak fine subangular blocky structure, dry loose, few fine vertical cracks, abundant fine pores; many fine, few medium roots. Few very fine $CaCO_3$ nodules. Diffuse boundary to:
B1	30-80	Yellowish red to red (5YR 4/6 to 2.5YR 4/6), heavy sandy loam, massive, dry very hard, few fine vertical cracks, abundant fine few medium pores, many fine, few medium roots. Very compact horizon, occasional fine to medium inclusions of yellow brown (10YR 5/4) sand inclusions, very few, very fine powdery $CaCO_3$ nodules, Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	80-130	Red (2.5YR 4/6), with common fine faint yellow brown (10YR 5/4) mottles fine sandy loam, massive to medium subangular blocky structure, slightly moist friable, abundant fine pores; common fine, few medium roots. Some faunal activity, common fine powdery $CaCO_3$, common manganese stains, few fine yellow brown (10YR 5/4) sand inclusions. Gradual smooth boundary to:
B3	130-200 200 + augered	Yellowish red (5YR 4/8) with common fine distinct red (5YR 4/3) mottles, fine sandy clay loam, massive to weak fine subangular blocky structure, slightly moist firm, many fine pores, common fine roots. Common fanual activity, many fine powdery calcium carbonate deposits and fine manganese stains.
C1	200-250	Yellowish red (5YR 4/8) with few fine faint red brown (5YR 4/3) mottles and fine iron manganese stains. Heavy sandy loam, dry loose to slightly moist friable. Common fine manganese nodules, common secondary carbonates and gypsum crystals, common 3 to 5 mm white nodular gravelly fragments towards base.
C2	250-300	Strong brown (7.5YR 4/6) light gravelly sandy loam, dry loose. Abundant 3 to 20 mm white coated nodular carbonaceous gravels.
C3	300-475	Strong brown (7.5YR 4/6) gravelly loamy sand, dry loose. Abundant 3 to 20 mm nodular horizon white coated carbonaceous gravels psssing into indurated horizon (? limestone) at 475 cm.

Profile Nr: T032

Classification: BM

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	76	16	2	-	6	1.3	6.9	6.6	4.9
P2	30-80	58	19	-	2	21	7.3	8.2	7.9	11.3
P3	80-130	44	23	2	3	28	12.6	8.7	8.5	13.0
P4	130-200	37	28	-	7	28	9.6	9.2	8.9	18.2

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
3.0	2.3	0.06	0.2	0.6	6.5	2.9	3.9	0.95
6.1	4.8	5.30	0.9	1.7	6.2	4.1	72.2	0.86
15.5	5.2	6.00	1.1	-	14.5	-	-	-
-	-	-	-	-	7.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
0.8	17.8	2.7	0.03	0.4	-	1.4	3.6	10.8
0.5	21.2	0.8	0.03	0.2	-	2.4	64.0	25.0
0.6	-	-	-	-	-	-	-	-
3.5	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
2.2	1.8	-	1.0
13.2	6.2	-	46.0
-	-	-	46.0
-	-	-	-

Pit Nr:	T075
Soil class:	Jb2-3
Land class:	U3s/R2g
Location:	Line L 2.4W
API legend:	Jmx
Topography:	Flat depression in meander complex
Micro-relief:	Very gently undulating (M2)
Land Use:	Small cleared areas sesame and maize
Surface:	Dry hard, not cracked, thin litter layer
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Very dark grey to dark grey clay loam surface horizons are moderately well structured, below 36 cm there are brown or dark brown prismatic structured silt clays and clays. Cracks are well developed to 80 cm with many fine pores, roots extend to 130 cm. Fine calcium carbonate and manganese nodules occur throughout the profile with significant increase in carbonates and gypsum below 130 cm.

Horizon	Depth (cm)	Description
A1	0-10	Very dark greyish brown (10YR 3/2), clay loam, moderate medium subangular blocky structure, dry hard, low organic matter content, few fine vertical cracks; abundant fine, few medium pores; many fine roots. Many shell fragments, few very fine $CaCO_3$ nodules, few very fine sand inclusions. Clear wavy boundary to:
B1	10-36	Dark brown (10YR 3/3), light silt clay, weak medium prismatic breaking to moderate fine subangular blocky structure; dry slightly hard, common fine vertical, few fine horizontal cracks; many fine tubular pores, common fine roots. Few fine shell fragments, 1 cm wide band of slightly mottled iron rich $CaCO_3$ nodules at top of horizon, few sand inclusions towards base. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B21	36-80	Brown (10YR 4/3) with few fine faint strong brown (7.5YR 5/6) mottles and common medium distinct black manganese stains. Silt clay, weak coarse prismatic to moderate medium angular blocky structure; dry slightly hard, common fine vertical cracks, common fine pores; common fine, few medium roots, few fine shell fragments, common pockets of very fine sand inclusions. Gradual smooth boundary to:
B22	80-130	Dark brown (10YR 3/3), with common fine faint red brown (5YR 4/3) mottles, silt clay, weak medium prismatic structure, dry very hard, few medium vertical cracks, common fine pores, common fine roots. Very weak clay skins, shallow bands of manganese staining near top of horizon, few fine filaments of secondary $CaCO_3$. Gradual smooth boundary to:
B3	130-200	Dark greyish brown (10YR 4/2) clay, moderate medium wedge structure, slightly moist extremely firm; few fine vertical, common fine horizontal cracks; very few, very fine pores; common fine roots. Abundarnt fine to medium nodular $CaCO_3$, large patches of secondary $CaCO_3$ towards top of horizon, well developed slickensides, common sand wedges and pockets of shell fragments.

Profile No: T075

Classification: Jb2-3

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-10	2	18	9	41	32	1.3	8.2	7.8	34.0
P2	10-36	2	18	12	34	34	0.8	8.4	7.9	25.8
P3	36-80	1	22	17	24	36	0.7	8.4	8.0	25.5
P4	80-130	1	29	7	22	41	1.3	8.5	8.0	27.4
P5	130-200	4	20	4	9	63	2.5	8.3	7.9	36.0

Exchangeable cations meq/100 g soil

Ca	Mg	Na	K	B (ppm)
33.9	6.0	0.4	0.3	0.9
16.0	4.4	0.3	0.5	1.5
21.0	7.5	0.3	0.2	-
25.9	9.2	0.7	0.5	-
47.1	13.4	2.6	0.7	-

Soluble cations (meq/l)

Ca	Mg	Na	K
7.8	2.3	2.1	0.95
7.8	1.5	2.5	0.15
6.5	-	-	-
6.7	-	-	-
8.6	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
8.8	103.4	4.10	0.1	1.9
15.4	59.6	0.6	0.04	0.5
12.3	-	-	-	-
10.8	-	-	-	-
8.3	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	2.4	4.4	1.9
-	1.6	3.0	3.9
-	-	-	-
-	-	-	-
-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.7	0.4	0.07	1.0
0.8	0.3	-	1.0
-	-	0.05	2.0
-	-	-	2.0
-	-	-	7.0

Pit Nr:	T076
Soil class:	Jb3
Land class:	U3sg/R3g
Location:	Line F 1.7/W
API legend:	Jb
Topography:	Very weakly undulating, depressional site
Micro-relief:	Very uneven, strong gilgai (M3)
Vegetation:	F1, **Convolvulacea sp.**, grasses and sedges
Surface:	Dry hard, very dark grey brown, irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A heavy textured moderately well structured soil. Very dark grey brown to brown silt clays and clays at the surface exhibit finely developed vertical cracks. Below 80 cm the cracks are predominantly diagonal. There is a concentration of calcium at depth with gypsum below 150 cm. Roots extend to 2m.

Horizon	Depth (cm)	Description
A1	0-30	Very dark greyish brown (10YR 3/2), heavy silt clay, weak fine subangular blocky structure; dry fard, few fine vertical and horizontal cracks; common fine, few medium roots. Few very weak slickensides, common fine $CaCO_3$ nodules, few fine manganese nodules, common broken shell fragments. Clear very wavy boundary to:
B1	30-80	Brown/dark yellowish brown (10YR 4/3.5), clay, weak medium prismatic, breaking to weak to moderate medium subangular blocky structure, slightly moist very firm; common medium vertical, few fine horizontal and diagonal cracks, common fine pores, common fine roots. Few manganese nodules and ferromanganese coated $CaCO_3$ nodules, well developed cutans, few shell fragments. Distinct band of powdery $CaCO_3$ and hard nodules from 30 to 35 cm. Diffuse boundary to:
B21	80-150	Dark yellowish brown (10YR 4/4), heavy silt clay, weak to moderate, medium prismatic breaking to moderate medium subangular blocky structure slighty moist extremely firm, common medium vertical, few fine horizontal and diagonal cracks, few fine pores, few fine roots. Common manganese nodules, very few fine sand inclusions, common well developed cutans, few fine $CaCO_3$ nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B22	150-275 200 + augered	Dark yellowish brown (10YR 3/4), with few fine faint red brown (5YR 4/3) mottles, silt clay loam to silt clay, weak medium subangular blocky structure, moist extremely firm common fine vertical and horizontal cracks, few fine pores, few fine roots. Few shells and shell fragments, well developed slickensides, few fine manganese and hard $CaCO_3$ nodules, few fine crystals gypsum. Colour becomes lighter at depth.
C1	275-310	Yellowish brown (10YR 5/4) with very few fine faint red brown (5YR 4/3) mottles increasing in intensity with depth. Very fine sandy clay loam, moist firm, common mica sand coats to ped faces, few fine powdery carbonates.
C2	310-380	Brown (10YR 4/3) with few fine faint red brown (5YR 4/3) mottles, heavy silt clay loam, moist firm, common mica sand coats to ped faces few hard $CaCO_3$ and manganese nodules. Sandy lense at 325 cm.
C31	380-420	Dark greyish brown (10YR 4/2) with few fine faint red brown (5YR 4/3) mottles, clay, slightly moist extremely firm, few hard manganese and $CaCO_3$ nodules, abundant powdery $CaCO_3$ few fine gypsum crystals. Abrupt boundary to:
C32	420-500	Very dark grey (5YR 3/1), heavy clay, slightly moist extremely firm, few fine 1 to 3 mm gypsum crystals.

Profile Nr: T076

Classification: Jb3

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	4	21	2	15	58	0.8	8.2	7.7	37.7
P2	30-80	3	16	4	24	53	0.7	8.4	7.8	29.5
P3	80-150	2	18	4	25	51	0.7	8.5	7.9	28.7
P4	150-200	1	19	4	21	55	0.4	8.2	8.0	28.8

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
51.3	9.2	0.3	1.8	0.8	5.0	1.1	1.7	0.28
22.7	8.3	0.4	0.7	0.5	5.0	1.6	2.8	0.05
31.9	15.7	0.8	0.7	-	2.7	-	-	-
26.8	16.9	1.7	0.7	-	27.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
4.3	97.0	4.8	0.10	1.8	-	1.8	2.6	3.2
21.3	58.6	0.8	0.04	0.6	-	1.6	2.0	3.6
20.9	-	-	-	-	-	-	-	-
12.2	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
1.3	0.5	0.04	-
0.7	0.2	0.03	1.0
-	-	0.03	2.0
-	-	0.14	5.0

Pit Nr:	T077
Soil class:	J1
Land class:	U2set/R2st3st
Location:	Line L 1.05W
API legend:	J1
Topography:	Levee on western edge of meander complex
Micro-relief:	Flat to very gently undulating several large termitaria
Vegetation:	F1
Surface:	Dry hard, slightly capped, pale yellowish brown, few sink holes
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A moderately well structured dark brown to dark yellowish brown clay loam profile with well developed cracks and pores at the surface and roots to two metres. Calcuim carbonate and ferromanganese nodules occur below 20 cm increasing with depth; gypsum occurs below 130 cm.

Horizon	Depth (cm)	Description
A1	0.20	Dark brown (10YR 3/3), light clay loam, moderate fine crumb structure; dry slightly hard, very low organic matter content, common very fine vertical cracks; abundant fine, common medium pores; few fine, few medium roots. Few very fine manganese nodules; very few, very fine $CaCO_3$ nodules. Gradual smooth boundary to:
IB1	20-76	Brown (10YR 4/3), heavy clay loam, strong fine subangular blocky structure, dry slightly hard, few very fien vertical and horizontal cracks, many fine pores, common fine few medium roots. Few fine shells, and shell fragments, common mica sand flakes, common very fine manganese nodules, few fine termite chambers, slight increase in $CaCO_3$ content towards base. Gradual smooth boundary to:
IIB2	76-130	Dark yellowish brown (10YR 4/4), with few medium, faint strong brown (7.5YR 5/6) mottles, light, very fine sandy clay loam; weak medium subangular blocky structure, dry hard, abundant fine pores, common medium roots. Common fine manganese stains, common faunal activity, common fine $CaCO_3$ nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
IIIB3	130-200	Dark brown (10YR 3/3) with common medium distinct strong brown (7.5YR 5/6) mottles, and manganese stains, silt clay, moderate medium angular blocky to medium prismatic structure, slightly moist extremely firm, common fine vertical and horizontal cracks, few fine pores, few fine and medium roots. Abundant calcium carbonate and gypsum deposits, common fine manganese nodules, patchy slickensides.
IVC1	200-280 200+ augered	Dark yellowish brown (10YR 4/4) with common fine faint red brown (5YR 4/3) mottles, silt clay, slightly moist firm, common fine $CaCO_3$ and manganese nodules, common fine 1 to 2 mm gypsum crystals.
VC2	280-320	Brown (10YR 4/3) with few fine faint red brown (5YR 4/3) mottles, silt clay loam, slightly moist firm, few fine ferromanganese nodules, abundant fine $CaCO_3$ nodules and powdery carbonates, common fine gypsum crystals.
VIC3	320-475	Yellowish brown (10YR 5/4), with few fine faint red brown (5YR 4/3) mottles between 390 and 450 cm. Very fine sandy clay loam, slightly moist firm. Few broken shell fragments, few medium manganese nodules increasing at depth, few ferromanganese coated $CaCO_3$ nodules, mica sand coats to peds.
VIIC4	475-500	Brown (10YR 4/3) very fine loamy sand, very moist and loose, abundant mica sand flakes, few manganese and $CaCO_3$ nodules at top of horizon.

Profile No: T077

Classification: Jl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	6	31	15	28	20	0.4	8.3	7.9	26.0
P2	20-76	2	33	13	19	31	0.9	8.5	8.0	22.4
P3	76-130	2	38	19	17	24	1.5	8.6	8.1	17.5
P4	130-200	3	22	8	22	45	7.1	8.1	8.0	24.6

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
29.2	6.3	0.1	3.8	1.5	15.5	2.8	2.1	2.2
27.5	6.9	0.2	1.8	1.0	5.7	1.1	2.7	1.1
10.8	5.2	0.1	1.3	-	4.7	-	-	-
65.0	10.8	1.4	1.2	-	21.2	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
4.3	161.8	15.6	0.10	1.5	-	6.0	4.4	6.7
8.2	68.2	2.6	0.03	0.4	-	2.6	3.6	2.8
10.7	-	-	-	-	-	-	-	-
8.9	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.8	0.3	0.01	-
0.8	0.2	0.01	-
-	-	-	-
-	-	1.2	5.0

Pit Nr: T078

Soil class: Jl

Land class: U2est/R2st

Location: Line L 0.2E

API legend: Jl

Topography: Low levee area, nearly flat, sloping to north

Micro-relief: Smooth, even

Vegetation: Open savanna woodland, **Dobera glabra, Acacia nilotica,** shrubby understorey

Surface: Dry hard yellowish brown slightly capped

Profile drainage: Moderately well

Depth to water table: More than 5 m

Brief Description:

Dark yellowish brown very fine sandy clay loam surface horizons with finely developed structure overly heavier textured horizons below 70 cm with more massive structure. Finely developed vertical cracks extend to 2 m, there are abundant pores in the surface horizons, roots extend to 2 m. Calcium carbonate nodules occur throughout the profile with an increase in secondary deposits in the subsoil accompanied by the appearance of gypsum.

Horizon	Depth (cm)	Description
A1	0-25	Dark yellowish brown (10YR 4/4), very fine sandy loam, weak fine subangular blocky structure, breaking to fine granular/crumb, dry slightly hard; very few fine and very fine vertical cracks abundant fine and common tubular pores, abundant fine, few medium roots. Common mica sand coats to ped faces, few fine manganese nodules, very few fine powdery $CaCO_3$ nodules. Gradual smooth boundary to:
B1	25-70	Dark yellowish brown (10YR 4/4) light, very fine sandy clay loam, weak, fine subangular blocky structure; dry slightly hard, few fine vertical, very few fine diagonal cracks, abundant fine tubular pores; abundant fine, few medium roots. Common mica sand coats to ped faces, few fine manganese nodules, very few patches powdery $CaCO_3$, few broken shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	70-135	Brown/dark yellowish brown (10YR 4/3.5), silt clay to clay, moderate medium subangular blocky to fine subangular blocky structure; dry hard; few medium vertical cracks, common fine pores, few medium, abundant fine roots. Common mica sand coats to ped faces, common fine manganese and $CaCO_3$ nodules occasionally ferromanganese coated, increase in powdery $CaCO_3$ towards base of horizon. Diffuse boundary to:
B3	135-310 200 + augered	Dark yellowish brown (10YR 4/4), clay, massive, weak fine subangular blocky structure; slightly moist extremely firm, few medium vertical and few very fine diagonal cracks; few medium, few fine roots. Abundant $CaCO_3$ nodules, abundant gypsum crystals between ped faces, common fine manganese nodules, common pockets of powdery $CaCO_3$, common mica sand flakes on ped faces and a few very fine sand inclusions.
C1	310-380	Dark yellowish brown (10YR 4/4), with common fine faint red brown (5YR 4/3) mottles, silt clay; slightly moist extremely firm; few pockets of very fine gypsum crystals; few fine manganese nodules.
C2	380-500	Dark grey (5YR 4/1), with very few fine faint red brown (5YR 4/3) mottles, clay, slightly moist extremely firm; common medium nodules of calcium carbonate and manganese; few ferro-manganese coated $CaCO_3$ nodules, few fine and medium gypsum crystals.

Profile Nr: T078

Classification: J1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-25	2	48	15	22	13	0.4	8.3	7.8	17.3
P2	25-70	2	42	15	18	23	0.6	8.6	7.9	18.6
P3	70-135	3	24	8	20	45	2.7	9.1	8.0	26.9
P4	135-190	3	19	10	20	48	9.7	8.3	8.1	26.6

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
13.0	3.4	0.1	1.3	2.1	3.0	0.5	1.2	0.20
19.8	5.3	0.5	0.4	1.4	2.1	0.5	2.1	0.04
-	-	-	-	-	2.2	-	-	-
31.8	14.0	4.7	0.5	-	32.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
5.1	89.0	2.2	0.05	0.5	-	5.2	1.6	0.5
8.2	60.2	0.5	0.02	0.3	-	2.6	2.0	0.9
13.3	-	-	-	-	-	-	-	-
12.7	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.8	0.2	0.05	-
0.8	0.2	0.03	2.0
-	-	-	-
-	-	0.90	17.0

Pit Nr:	T079
Soil class:	Jb1
Land class:	U3se/R1
Location:	Line M 2.0W
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Smooth even
Vegetation:	Open savanna woodland, **Acacia zanzibaria, Acacia nilotica, Dobera glabra**
Surface:	Dry hard, pale yellowish brown, uncracked
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Dark yellowish brown, very fine sandy clay, moderately well structured surface horizons overly more massive brown clays below 60 cm. Vertical cracks extend throughout the porfile and porosity is well developed, roots extend to 150 cm. Calcuim carbonate occurs as fine nodules from the surface downwards.

Horizon	Depth (cm)	Description
	0-20	Dark yellowish brown (10YR 4/4), heavy, very fine sandy clay loam; weak fine subangular blocky breaking to fine granular or crumb structure; dry slightly hard, very low organic matter content, few fine vertical and horizontal cracks, abundant fine pores; abundant fine, few medium roots. Considerable faunal activity, abundant $CaCO_3$ nodules few complete shells and shell fragments. Clear wavy boundary to:
	20-60	Brown to dark yellowish brown (10YR 4/5) heavy, very fine sandy clay loam; moderate, fine subangular blocky structure, dry very hard, few fine vertical and horizontal cracks, abundant fine pores; common fine, few medium roots. Common fine manganese and $CaCO_3$ nodules, few shell fragments, common mica sand coats to ped faces. Gradual smooth boundary to:
	60-90	Dark yellowish brown (10YR 4/4), clay, massive to weak medium subangular blocky structure; dry extremely hard, very few fine vertical cracks, very few fine, few medium roots. Abundant fine, few medium manganese nodules, common fine $CaCO_3$ concretions, common mica sand coats to ped faces. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
	90-150	Brown (10YR 4/3) clay, massive breaking to weak fine subangular blocky structure, dry extremely hard, very few fine vertical cracks, common fine pores; few fine roots. Common fine and few medium manganese nodules, common fine nodules of $CaCO_3$. Gradual smooth boundary to:
	150-310 200 + augered	Brown (10YR 4/3), with few fine faint red brown (5YR 4/3) mottles, clay, massive; slightly moist extremely firm, few fine vertical cracks, abundant fine pores, few fine roots. Common fine manganese and ferromanganese coated $CaCO_3$ nodules, few pockets fine gypsum crystals, few mica sand inclusions and sand coats to ped faces, well developed cutans.
	310-460	Brown/dark yellowish brown (10YR 4/3.5), with few fine faint red-brown (5YR 4/3) mottles, clay, slightly moist extremely firm, common fine manganese nodules, few fine $CaCO_3$ nodules, few well developed cutans, abundant fine crystals and filaments of powdery gypsum.
	460-500	Olive (5YR 5/3), with few fine faint yellow brown (10YR 5/4) mottles, clay; slightly moist extremely firm; common medium crystals of gypsum, few fine nodules of manganese, common fine sand inclusions.

Profile Nr: T079

Classification: Jbl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	5	22	15	28	30	0.9	8.3	7.7	27.2
P2	20-60	7	30	13	15	35	0.5	8.6	8.2	21.9
P3	60-90	7	33	13	12	35	1.9	8.7	8.2	23.6
P4	90-150	5	32	10	13	40	6.4	8.6	8.2	23.3

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
20.8	2.2	0.4	0.7	2.3	5.5	1.2	2.5	0.28
17.7	4.8	0.6	0.3	0.2	2.0	0.5	3.3	0.08
21.3	10.6	3.0	0.5	-	3.1	-	-	-
10.9	8.0	2.5	0.4	-	5.7	-	-	-

Total carbonate (%)	Total P mq/100 g soil	Avail-able P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
10.7	56.2	1.7	0.08	1.0	-	3.3	3.6	1.7
12.4	45.0	0.4	0.02	0.3	-	2.6	1.6	1.4
11.5	-	-	-	-	-	-	-	-
10.9	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.6	0.2	0.03	1.0
0.7	0.3	0.02	2.0
-	-	-	12.0
-	-	-	10.0

Pit Nr: T080

Soil class: Jt

Land class: U6es/R2es

Location: Line M 2.8W

API legend: Jt

Topography: Alluvial terrace on marine plain outlier

Micro-relief: Gently undulating gilgai (M1 - M2)

Vegetation: Non thorny scrub **Dobera glabra, Salvadore** sp.

Surface: Dry hard, thin litter layer, few small cracks

Profile drainage: Imperfect

Depth to water table: More than 5 m

Brief Description:

An older alluvial soil predominantly olive in colour with a heavy, very fine sandy clay loam surface passing into silt clay. Moderately well developed structure at the surface becoming more massive below 60 cm, roots penetrate to 2 m. Calcium carbonate and gypsum well distributed below 30 cm.

Horizon	Depth (cm)	Description
A1	0.30	Olive brown (2.5YR 4/4), heavy very fine sandy clay loam, moderate fine subangular blocky breaking to fine granular or crumb structure: dry slightly hard, common fine vertical cracks, abundant fine, common medium pores, common fine, few medium roots. Common fine 2 mm sized ferromanganese coated $CaCO_3$ modules. Clear smooth boundary to:
B11	30-60	Light olive brown (2.5Y 5/4), silt clay, moderate medium prismatic to moderate fine angular blocky structure; dry hard, common fine vertical cracks, few fine pores; common fine, few medium roots; many fine ferromanganese coated $CaCO_3$ nodules, common weak cutans. $CaCO_3$ and gypsum crystals developing on ped faces. Gradual smooth boundary to:
B12	60-110	Olive brown (2.5Y 4/4), silt clay, massive breaking to medium subangular blocky; slightly moist extremely firm; few fine few medium vertical cracks, common fine pores, few medium roots. Common fine gypsum crystals along old crack faces. Diffuse boundary to:

Horizon	Depth (cm)	Description
B3	110-410 200 + augured	Olive brown to light olive brown (2.5Y 4/4 to 5/4) with few fine faint red brown (5YR 4/3) mottles. Silt clay, weak fine to medium subangular blocky structure, moist extremely firm, very few fine pores, few fine roots. Patchy clay skins, few fine sand lenses, few fine manganese nodules, few 1 cm circular patches of secondary $CaCO_3$ and gypsum, distinct accumulation of powdery secondary $CaCO_3$ at 325 and 355 cm. Abrupt boundary to:
C1	410-460	Greyish brown (2.5Y 5/3), very fine sandy clay loam, moist friable, abundant mica on ped faces, abundant powdery $CaCO_3$, few hard fine nodules of $CaCO_3$.
C2	460-500	Greyish brown to yellowish brown (2.5Y 5/3 to 10YR 5/4) silt clay to very fine sandy clay loam, slightly moist firm, clay is rich in powdery secondary $CaCO_3$.

Profile Nr: T080

Classification: Jt

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	16	31	5	10	38	1.8	8.2	8.0	21.0
P2	30-60	14	23	5	13	45	8.0	8.8	8.3	24.9
P3	60-110	12	25	5	13	45	13.9	8.6	8.4	22.1
P4	110-200	6	21	5	13	55	13.5	8.6	8.4	24.5

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
25.8	4.4	0.5	2.1	2.3	6.7	0.1	4.5	0.59
17.1	13.8	12.2	1.7	7.0	9.2	0.5	52.8	0.72
63.1	8.5	7.9	1.2	-	32.5	-	-	-
18.4	10.9	2.2	0.9	-	18.7	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
12.6	52.8	1.9	0.06	0.8	-	2.8	13.5	2.6
15.9	38.2	0.5	0.03	0.3	-	3.2	69.2	26.2
12.4	-	-	-	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-

Extractable		Total gypsum (%)	ESP
Zn	Cu		
0.7	0.3	0.03	2.0
0.7	0.2	-	48.0
-	-	1.00	35.0
-	-	0.10	8.0

Pit Nr:	T081
Soil class:	Jd
Land class:	U6sd/RSdg
Location:	Line M 3.6W
API legend:	Jd
Topography:	Broad flat depression at foot of marine plain
Micro-relief:	Uneven, well developed gilgai (M2)
Land use:	Maize and sesame
Surface:	Dry crumbly, dark grey, common shell fragments
Profile drainage:	Poor
Depth to water table:	More than 5 m; surface water adjacent to pit

Brief Description:

A heavy textured gleyed profile subject to periodic flooding, poorly developed structure and no cracking. Gypsum and calcium carbonate increase below 145 cm.

Horizon	Depth (cm)	Description
A1	0-20	Very dark grey (10YR 3/1), clay, weak, fine subangular blocky breaking to fine granular/crumb structure; slightly moist, firm common very fine pores, few fine, few medium roots. Few shell fragments, few fine $CaCO_3$ nodules. Diffuse boundary to:
B1	20-50	Dark grey (5Y 4/1), with abundant medium distinct dark red brown (5YR 3/2) mottles, clay, massive, slightly moist firm, few fine pores, few fine, few medium roots. Few shell fragments, common medium $CaCO_3$ nodules up to 10 mm in diameter. Diffuse boundary to:
B21t	50-145	Dark greyish brown (10YR 4/2), with very few medium distinct red brown (5YR 4/3) mottles near surface; light clay, massive, slightly moist firm, few very fine pores, very few fine and medium roots. Common well developed cutans, occasional very large complete shells and fine shell fragments, occasional 1 to 2 cm $CaCO_3$ nodules, common fine randomly distributed sand lenses. Common medium $CaCO_3$ and manganese nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
B22t	145-260 200+ augured	Dark grey (5Y4/1), with common medium distinct red brown and yellow brown (5YR 4/3 and 10YR 5/4) mottles; clay, massive, slightly moist firm, very few fine pores, few fine roots. Well developed cutans, few fine shell fragments, very few fine manganese nodules, few fine $CaCO_3$ nodules abundant fine crystals of gypsum.
C1	260-320	Olive grey (5Y 5/2), with common medium faint red brown (5YR 4/3) mottles; clay, slightly moist firm, few fine manganese nodules, common fine gypsum crystals, few fine secondary carbonates, occasional mica sand flakes on ped faces.
C2	320-390	Grey (5Y 5/1 to 6/1), with few fine faint red brown (5YR 4/3) mottles, silt clay, slightly moist firm. Abundant powdery $CaCO_3$ and common fine gypsum crystals up to 4 mm in size.
C3	390-450	Olive grey (5Y 5/2), with few fine faint red brown (5YR 4/3) mottles, sandy clay, slightly moist firm, few pockets powdery $CaCO_3$.
C4	450-500	Olive brown (2.5Y 4/3), with few fine faint red brown (5YR 4/3) mottles; very fine sandy clay loam, slightly moist firm, few pockets of powdery $CaCO_3$.

Profile Nr: T081

Classification: Jdl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	13	17	0	7	63	1.5	7.8	7.4	38.0
P2	20-50	21	16	3	2	58	1.7	7.9	7.5	29.6
P3	50-145	27	18	5	-	50	2.0	8.1	8.0	25.3
P4	145-200	19	18	3	2	58	6.2	8.0	7.8	29.2

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
43.7	6.0	0.6	1.4	2.6	12.1	2.2	3.2	0.48
37.6	7.5	1.1	0.9	2.8	9.5	2.8	3.7	0.16
24.6	5.7	1.4	0.4	-	6.5	-	-	-
15.3	1.5	-	0.3	-	17.0	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
2.0	45.4	1.5	0.10	1.2	-	4.2	5.0	11.6
2.4	30.4	0.5	0.05	0.5	-	4.8	4.4	13.2
2.0	-	-	-	-	-	-	-	-
1.4	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
2.6	1.2	0.01	2.0
1.3	0.5	0.02	4.0
-	-	-	6.0
-	-	1.10	-

Pit Nr: T135

Soil class: Jmxl

Land class: 4s (U2s/R2s)

Location: Line K 0.8W

API legend: J1

Topography: Levee site within meander complex, weakly undulating

Micro-relief: Slightly undulating few termitaria

Vegetation: F1 regrowth scattered **Dobera glabra**

Surface: Dry powdery, occasional large cracks

Profile drainage: Moderately well

Depth to water table: More than 5 m

Brief Description:

A layered profile with medium to finely structured surface horizons of dark brown very fine sandy clay loam over heavy clay loam and silt clay loam passing into a more massive dark brown very fine sandy loam below 115 cm. Calcium carbonate is abundant below the surface horizon with well developed porosity throughout and roots extending to 2 m.

Horizon	Depth (cm)	Description
A1	0-30	Dark brown (10YR 3/3), very fine sandy clay loam, moderate medium subangular blocky structure, dry hard; common fine few medium vertical and few fine horizontal cracks, common fine pores, common fine, few medium roots. Surface marked by laminar banding. Common fine shell fragments, few whole shells, few fine $CaCO_3$ nodules. Clear smooth boundary to:
B1	30-65	Dark brown (10YR 3/3), heavy clay loam, weak medium subangular blocky structure, dry hard; common fine and medium vertical cracks, few fine pores, common fine, few medium roots. Common sand coats to ped faces, few fine nodules of manganese, abundant $CaCO_3$ nodules. Diffuse boundary to:
B2	65-115	Brown/dark yellowish brown (10YR 4/3) mottles, silt clay loam, moderate to strong fine to medium crumb to granular structure, slightly moist extremely firm; few fine vertical cracks, many fine pores, common fine, few medium roots. Common sand coats to ped faces. Abundant 1 to 3 mm sized $CaCO_3$ nodules, few fine secondary $CaCO_3$ filaments, few ferromanganese coated nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
C1	115-250 200 + augered	Dark brown (7.5YR 4/4) with few medium faint strong brown (7.5YR 5/6) mottles, very fine sandy loam, massive, dry hard; many fine pores, rare fine roots. Abundant fine mica sand flakes on ped faces, many 1 to 3 mm sized $CaCO_3$ concretions, few fine powdery secondary $CaCO_3$ concretions; pockets of upper horizons mixed in relic termite channels 2 to 5 cm in diameter
C2	250-290	Dark yellowish brown (10YR 4/4), light, very fine sandy clay loam, slightly moist firm. Abundant fine and medium nodules $CaCO_3$, few fine powdery concretions $CaCO_3$, abundant mica sand coats to ped faces.
C3	290-480	Dark yellowish brown (10YR 4/4), with very few fine faint red brown (5YR 4/3) mottles, very fine sandy clay loam, slightly moist very firm. Few very small powdery $CaCO_3$ concretions, fine manganese staining, abundant mica sand coats to peds. Occasional lenses finer textured material containing many $CaCO_3$ and few manganese nodules. Abrupt boundary to:
C4	480-500	Dark yellowish brown (10YR 4/6) very fine sand, slightly moist.

Profile Nr: T135

Classification: Jmxl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	5	35	18	17	25	1.1	8.4	7.7	27.4
P2	30-65	2	35	10	18	35	0.8	8.4	8.0	21.9
P3	65-115	2	25	15	23	35	0.6	8.3	8.1	22.3
P4	115-190	1	31	20	20	28	0.6	8.6	8.2	19.7

Exchangeable cations meq/100 g soil

Ca	Mg	Na	K	B (ppm)
15.5	2.7	0.06	1.8	3.3
28.8	2.9	0.10	1.3	2.4
31.8	3.3	0.10	1.0	-
53.0	5.0	0.10	0.2	-

Soluble cations (meq/l)

Ca	Mg	Na	K
6.2	0.7	1.7	1.10
5.2	1.1	1.5	0.28
4.5	-	-	-
3.6	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
3.4	114.4	16.7	0.10	2.3
6.5	94.0	1.9	0.04	0.4
12.5	-	-	-	-
11.0	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	3.0	2.0	3.6
-	1.8	2.8	3.2
-	-	-	-
-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.7	0.3	0.08	-
0.8	0.2	0.04	-
-	-	0.03	-
-	-	0.05	-

Pit Nr:	T136
Soil class:	Jmxd
Land class:	U2s/R3s
Location:	Line J 1.8W
API legend:	Jmx
Topography:	On margin of depressional area in meander complex
Micro-relief:	Smooth even
Vegetation:	F1 regrowth
Surface:	Dry hard, many large active termitaria to north
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Dark brown medium textured surface horizons with a weakly developed crumb structure pass into lighter textured sandy horizons below 60 cm with poorly developed structures. Extremely porous profile, well rooted 2 m, calcium carbonate nodules present in the sandy horizons.

Horizon	Depth (cm)	Description
A1	0-30	Dark brown (10YR 3/3), silt clay, weak fine crumb to granular structure, dry slightly hard, low organic matter content, common fine vertical and horizontal cracks, abundant fine pores, common fine, few medium roots. Abundant mica sand flakes on ped faces, few fine manganese nodules, few very fine $CaCO_3$ nodules, very few fine shell fragments. Clear smooth boundary to:
B1	30-60	Brown (10YR 4/3), light very fine sandy clay loam, weak fine subangular blocky breaking to granular or single grain structure; dry slightly hard, few vertical and horizontal cracks, abundant fine and few very fine tubular pores; common fine, few medium roots. Common fine shells and shell fragments, abundant mica sand coats to ped faces, few fine nodules at $CaCO_3$. Gradual smooth boundary to:
B2	60-155	Dark brown (7.5YR 4/4), very fine sandy loam, massive, dry slightly hard; abundant fine pores few fine and medium roots. Abundant mica sand flakes, abundant $CaCO_3$ nodules up to 4 mm in diameter occasionally coated with ferromanganese deposits, few pockets secondary carbonates, few nodules fine manganese. Approximately 10 cm thick bank of 1 to 4 mm diameter $CaCO_3$ nodules at base of horizon. Abrupt smooth boundary to:

Horizon	Depth (cm)	Description
C1	155-255 200+ augered	Dark brown (7.5YR 4/4), very fine sand, massive, dry loose; abundant fine pores, few fine, common medium roots, very compact with abundant mica sand flakes. Few medium, hard nodules of $CaCO_3$.
C2	225-345	Dark yellowish brown (10YR 4/4) with few fine faint red brown increasing to common fine-faint red brown (5YR 4/3) mottles, clay, slightly moist extremely firm. Few fine ferromanganese nodules, few small 1 to 2 mm powdery concretions $CaCO_3$ increasing at depth. Very fine sand lense 280 to 320 cm.
C31	345-395	Dark grey (5Y 4/1) with few fine distinct red brown (5YR 4/3) mottles, heavy clay, slightly moist extremely firm, few very fine gypsum crystals.
C32	395-445	Dark yellowish brown (10YR 4/4) with few faint red brown (5YR 4/3) mottles, clay, slightly moist extremely firm. Mica sand flakes on ped faces. Abrupt boundary to:
C4	445-500	Yellowish brown (10YR 5/4) very fine sand/fine sand, wet with abundant mica flakes.

Profile Nr: T136

Classification: Jmxd

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-30	3	24	5	30	38	0.7	8.4	7.6	36.5
P2	30-60	3	42	8	12	25	1.8	8.6	7.8	18.6
P3	60-155	2	50	18	10	20	0.5	8.4	8.2	13.9

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
31.5	2.6	0.1	2.3	2.0	5.7	0.7	0.6	0.55
17.4	4.7	0.1	0.8	2.2	5.2	1.6	3.5	0.25
11.2	3.1	0.2	0.4	-	2.7	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
3.9	101.4	4.2	0.10	1.5	-	3.1	2.4	1.3
4.7	80.4	1.2	0.02	0.3	-	2.2	4.4	4.7
9.8	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.6	0.3	0.05	-
0.7	0.2	0.04	-
-	-	0.04	1.0

Pit Nr:	T137
Soil class:	Jb1-2
Land class:	U2s/R3g
Location:	Line J 2.8W
API legend:	Jb
Topography:	Levee terrace between meander complex and marine plain
Micro-relief:	Flat few very gentle undulations (M2)
Vegetation:	Moderately dense scrub woodland, 70% tree cover, **Dobera glabra, Acacia nilotica, Thespesia daria**
Surface:	Yellowish brown surface wash, abundant leaf litter and few shell fragments
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A moderately well structured medium to fine textured profile with dark brown very fine sandy loam and silt clay surface horizons passing into dark yellowish brown clay at depth. Finely developed vertical cracks and roots exend to 2 m, there is well developed porosity. Calcium carbonate increases with depth and gypsum occurs below 65 cm.

Horizon	Depth (cm)	Description
	0-18	Very dark greyish brown (10YR 3/2) very fine sandy clay loam, moderate medium subangular blocky structure, slightly moist firm, dry slightly hard; low organic matter content, few fine vertical cracks, abundant fine pores, common fine, few medium roots. Common fine sand inclusions, common fine shell fragments, few very fine manganese stains close to base of horizon. Clear smooth boundary to:
	18-65	Dark brown (10YR 3/3) silt clay, moderate fine subangular blocky structure, dry hard, common fine vertical and horizontal cracks, few fine pores, many fine, few medium roots. Many fine black manganese concretions, many fine shell fragments, common mica sand coats to ped faces. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
	65-142	Dark brown/dark yellowish brown (10YR 3/3.5) very fine sandy clay/clay, moderate coarse prismatic to medium subangular blocky structure, slightly moist extremely firm, common fine and medium vertical cracks, few fine pores, common fine few medium roots. Common fine sand inclusions, many fine black manganese stains and fine nodules, common fine to meidum vertical slickensides, occasional calcium carbonate and gypsum crystals. Gradual smooth boundary to:
	142-190	Dark yellowish brown (10YR 4/4) with common medium distinct yellowish brown (10YR 5/4) mottles, clay, moderate medium subangular blocky structure, moist very firm, few fine and medium vertical cracks, few fine pores, common fine roots. Abundant black manganese stains and mottles abundant secondary deposits of gypsum and calcium carbonate, weak slickensides.

Profile Nr: T137

Classification: Jbl-2

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-18	3	47	18	12	20	1.4	8.2	7.6	22.5
P2	18-65	4	36	15	12	33	1.0	8.4	7.7	21.1
P3	65-142	4	36	9	16	35	1.8	9.0	8.6	24.4
P4	142-190	8	19	5	15	53	3.0	8.3	7.8	31.5

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
24.1	4.7	0.08	2.1	3.0	6.5	1.7	3.1	0.78
17.9	4.7	0.40	0.5	2.2	6.2	2.0	3.2	0.11
16.0	7.7	2.30	0.3	-	2.3	-	-	-
25.7	8.3	1.20	0.4	-	10.3	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
17.6	56.2	2.5	0.10	1.3	-	2.8	4.8	7.1
8.8	48.8	0.4	0.02	0.3	-	2.2	2.8	6.0
8.1	-	-	-	-	-	-	-	-
11.4	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
4.8	1.8	0.04	-
0.9	0.3	0.04	1.0
-	-	-	9.0
-	-	-	3.0

Pit Nr:	T138
Soil class:	Jmxd
Land class	U3se/R2ge
Location:	Line B 2.0E
API legend:	Jmx
Topography:	Depression within meander complex
Micro-relief:	Flat to very weakly undulating
Vegetation:	Maize
Surface:	Extremely large surface cracks up to 8 cm across, dry hard, pale grey brown.
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A dark brown to grey brown, silt clay loam to silt clay soil with moderately developed coarse surface structures and deep vertical cracks; well rooted with well developed porosity. Calcium carbonate nodules increase with depth and gypsum occurs below 80 cm.

Horizon	Depth (cm)	Description
Alp	0-10	Dark brown (10YR 3/3) silt clay loam, moderate medium subangular blocky to moderate fine platy structure, dry slightly hard, common fine vertical cracks, abundant fine pores, common fine roots. Common fine shell fragments. Clear smooth boundary to :
B11	10-40	Brown (10YR 4/3) heavy silt clay loam, weak coarse prismatic to subangular blocky structure, common coarse vertical cracks, infilled with platy surface material, few fine pores, common fine and few medium roots. Common very fine powdery secondary $CaCO_3$, common very fine ferromanganese nodules, very weak cutans. Diffuse boundary to :
B12	40-80	Dark greyish brown/dark brown (10YR 4/2.5) silt clay, weak coarse prismatic to moderate fine/medium wedge structure, dry very hard, common medium and vertical cracks, common fine horizontal and diagonal cracks, few fine pores, common fine and medium roots, weak cutans, common very fine $CaCO_3$ nodules, few fine shell fragments. Clear smooth boundary to :

Horizon	Depth (cm)	Description
B21	80-140	Dark greyish brown (10YR 4/2) heavy silt clay, weak fine wedge structure, dry very hard, few medium vertical and diagonal cracks, common fine pores, common fine, few medium roots. Patchy calcium carbonate and gypsum deposits along crack faces, few fine shell fragments. Clear smooth boundary to :
B22	140-210	Brown (10YR 5/3) heavy silt clay loam, strong fine to medium crumb to granular structure, dry hard, few medium vertical cracks, many fine pores, common fine, few medium roots. Abundant 1 to 5 mm powdery $CaCO_3$ concretions, few shell fragments.

Profile Nr: T138

Classification: Jmxd (Jd)

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-10	4	21	8	32	35	1.1	8.4	8.2	31.2
P2	10-40	3	11	6	32	48	2.8	8.3	7.9	28.4
P3	40-80	2	11	6	38	53	5.7	8.4	8.2	28.5
P4	80-140	7	12	6	65	10	10.2	8.3	8.1	18.1
P5	140-210	2	11	14	35	38	18.3	8.6	8.6	23.0

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
35.0	6.0	0.2	3.2	3.0	9.20	2.1	2.6	0.60
29.0	7.5	0.6	1.4	3.0	22.50	5.8	8.2	0.41
24.3	9.9	2.4	1.2	-	20.00	-	-	-
75.0	6.2	-	0.6	-	15.00	-	-	-
11.6	4.2	0.7	0.8	-	14.75	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
16.1	163.0	5.6	0.10	1.6	-	2.2	3.2	6.3
23.7	93.6	0.8	0.04	0.5	-	2.8	5.6	30.8
23.1	-	-	-	-	-	-	-	-
19.4	-	-	-	-	-	-	-	-
26.1	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.7	0.2	0.04	-
0.8	0.3	-	2.0
-	-	0.01	8.0
-	-	1.20	-
-	-	0.40	3.0

Pit Nr:	T139
Soil class:	Jb1
Land class:	U2s/R1
Location:	Line D 1.0E
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Smooth even
Land use:	Maize/sesame
Surface:	Dry hard dark grey brown, irregular 40 cm deep surface cracks
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

A very dark greyish brown to dark brown silt clay to clay profile. Well developed vertical cracks in the surface horizons become more diagonal at depth with strong slickensides in the subsoil horizons. Rooted to 1 m. Calcium carbonate nodules occur throughout the profile with abundant gypsum below 140 cm.

Horizon	Depth (cm)	Description
	0-15	Very dark greyish brown (10YR 3/2) silt clay, weak very fine granular to single grain structure, dry slightly hard, few very fine vertical and horizontal cracks, abundant fine tubular pores, abundant fine roots, abundant fine $CaCO_3$ nodules, few fine powdery $CaCO_3$ deposits. Gradual smooth boundary to:
	15-40	Dark brown (10YR 3/3) clay, slightly laminar to weak fine subangular blocky becoming granular structure, dry slightly hard, few fine vertical and horizontal cracks, abundant fine pores, common fine roots, few broken shell fragments, abundant fine $CaCO_3$ nodules, few fine powdery $CaCO_3$ concretions, few very fine manganese nodules. Gradual diffuse boundary to:

Horizon	Depth (cm)	Description
	40-100	Very dark greyish brown/dark brown (10YR 3/2.5) clay, weak medium subangular blocky structure, moist extremely firm, few fine horizontal and vertical cracks, common fine diagonal cracks, few fine pores, common fine roots, few very fine nodules of $CaCO_3$, well developed cutans, abundant broken shell fragments, common fine manganes nodules, few patches of powdery secondary $CaCO_3$ especially on ped faces. Gradual smooth boundary to:
	100-140	Dark brown (10YR 3/3) clay, massive to moderate medium sub-angular blocky structure slightly moist extremely firm, few fine vertical, diagonal, and horizontal cracks, few very fine pores. Common very fine manganese nodules, common broken shell fragments, few very fine nodules $CaCO_3$, well developed cutans and slickensides. Gradual smooth boundary to:
	140-270 200 + augered	Dark brown (10YR 3/3) with few fine faint red-brown (5YR 4/3) mottles clay, weak medium prismatic to medium subangular blocky structure, slightly moist extremely firm, few fine vertical and diagonal cracks, very few fine pores. Very well developed slickensides, abundant fine gypsum crystals, abundant broken shell fragments, abundant medium nodules of $CaCO_3$
	270-340	Brown (10YR 4/3) with few fine faint red/grey brown (2.5 YR 4/6/10YR 5/2) mottles clay slighty moist extremely firm very few fine gypsum crystals common fine nodules manganese, few fine nodules $CaCO_3$, few very small pockets powdery $CaCO_3$.
	340-480	Dark brown (10YR 3/3) with very few fine faint red-brown (5YR 4/3) mottles, clay slightly moist firm, very few fine nodules ferro-manganese, very few fine nodules $CaCO_3$, few fine gypsum crystals increasing with depth.
	480-500	Dark greyish brown (25YR 4/2) with few fine distinct red-brown mottles (5YR 4/3) clay, slightly moist extremely firm; few fine gypsum crystals, few fine $CaCO_3$ and ferromanganese nodules.

Profile Nr: T139

Classification: Jbl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-15	5	11	4	30	50	0.7	8.5	7.8	-
P2	15-40	3	13	4	29	51	0.8	8.6	7.9	34.7
P3	40-100	3	13	4	26	54	0.9	8.7	7.9	33.9
P4	100-140	2	12	6	20	60	3.9	8.6	8.0	35.7
P5	140-200	4	12	6	65	13	3.8	8.1	7.8	30.2

Exchangeable cations meq/100 g soil					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
17.1	4.4	0.7	0.8	2.4	3.0	1.3	2.7	0.19
34.1	10.1	0.8	1.2	1.7	3.2	1.4	3.0	0.20
20.9	11.8	2.7	1.1	-	2.7	-	-	-
19.4	14.8	4.4	1.0	-	11.0	-	-	-
168.5	20.1	5.2	1.0	-	10.6	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4
17.4	85.4	1.3	0.09	1.0	-	2.4	2.4	1.9
18.2	85.4	0.9	0.06	1.0	-	3.6	2.4	4.2
17.6	-	-	-	-	-	-	-	-
18.6	-	-	-	-	-	-	-	-
17.6	-	-	-	-	-	-	-	-

Extractable Zn	Cu	Total gypsum (%)	ESP
0.8	0.3	0.06	-
1.0	0.3	0.02	2.0
-	-	0.02	7.0
-	-	-	12.0
-	-	1.20	17.0

Pit Nr:	T191
Soil class:	J1
Land class	U3se/R2s
Location:	Line Q 2.7W
API legend:	J1
Topography:	Levee adjacent to marine plain
Micro-relief:	Flat
Vegetation:	F1
Surface:	Capped surface, yellow brown, very fine cracking, few shell fragments
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Well structured brown very fine sandy loams to clay loams pass into silt clays below 60 cm with an increase in calcium carbonate content and a tendency towards wedge shaped structures. Cracks are well developed at the surface, roots occur to 2 m.

Horizon	Depth (cm)	Description
A1	0-20	Brown (10YR 4/3) heavy very fine sandy loam, moderate medium subangular blocky structure, dry slightly hard, very few fine vertical cracks, many fine pores, common fine roots. Few fine manganese nodules, secondary carbonates deposited on ped faces, few shell fragments. Gradual smooth boundary to :
B1	20-60	Dark brown (10YR 3/3) very fine sandy clay loam, moderate to strong medium subangular blocky structure, slightly moist extremely firm, common very fine vertical and horizontal cracks, common fine, few medium pores, common fine roots. Common very fine manganese and $CaCO_3$ nodules, sand coats to ped faces, coatings of secondary carbonate on ped faces. Gradual smooth boundary to :
B21	60-90	Dark brown (10YR 3/3) silt clay, weak to moderate medium angular blocky structure, slightly moist very firm, few fine vertical cracks, few fine pores, common fine roots, many fine ferromanganese and $CaCO_3$ nodules, few fine red sand inclusions, few fine shell fragments, common secondary carbonates on ped faces. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
B22	90-200	Dark brown (10YR 3/3) silt clay, weak to massive wedge structure, slightly moist extremely firm, few fine pores, few fine roots, many fine ferromanganese and $CaCO_3$ nodules, common fine shell fragments, occasional fine gypsum crystals increasing towards base of horizon. Occasional 1 to 6 mm nodules of ferromanganese coated $CaCO_3$.

Profile Nr: T191

Classification: Jl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	5	36	16	25	18	1.2	8.4	7.9	20.6
P2	20-60	5	23	9	25	38	1.0	8.6	8.2	23.5
P3	60-90	4	27	9	22	38	1.8	8.5	7.8	25.4
P4	90-200	7	24	9	20	40	7.3	8.0	7.8	25.0

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
31.1	4.5	0.2	1.3	-	9.7	1.6	3.2	0.46
29.5	7.2	0.5	0.5	-	4.2	1.5	3.9	0.16
28.3	8.9	1.7	0.4	-	4.2	-	-	-
34.1	10.1	4.8	0.4	-	32.5	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
10.9	-	-	-	-	-	3.0	5.0	3.4
13.1	-	-	-	-	-	3.0	5.0	2.3
9.2	-	-	-	-	-	-	-	-
12.1	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
-	-	0.02	-
-	-	0.04	2.0
-	-	0.01	6.0
-	-	0.50	19.0

Pit Nr:	T252
Soil class:	J1
Land class	U3s/R2t
Location:	Line D 1.5E
API legend:	J1
Topography:	Recent levee formation
Micro-relief:	Slightly uneven
Vegetation:	Fallow
Surface:	Ploughed
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A dual profile with recent yellowish red and brown very fine sandy clay loams overlying dark brown older clays. Well developed subangular blocky surface structures pass into strongly developed prismatic and wedge structures in the older alluvium. Cracks are will developed thoughout the profile; there are many pores and roots are well developed to 2 m. Sand inclusions occur throughout the profile.

Horizon	Depth (cm)	Description
A1	0-20	Dark brown (7.5YR 4/4) with few fine faint red brown (5YR 4/3) mottles, very fine sandy clay loam, strong medium subangular blocky structure, dry slightly hard, low organic matter content, few fine vertical cracks, many fine tubular pores, common fine roots, occasional very fine spheroidal clay nodules, possibly brought to the surface by ploughing, few fine shell fragments. Clear wavy boundary to :
B1	20-36	Mixture of yellowish red (5YR 5/6) rounded spheriods of dry hard clay, in a matrix of brown (10YR 4/3), very fine sandy loam, dry slightly hard. Moderate medium subangular blocky structure, few fine vertical cracks abundant fine pores, common fine roots. Clear wavy boundary to :

Horizon	Depth (cm)	Description
B2	36-57	Yellowish red (5YR 4/6) clay loam, moderate to strong medium subangular blocky structure, breaking to moderate to strong fine crumb; few fine vertical cracks, abundant fine pores, common fine roots, extensive laminar banding in upper part of horizon; soft spheroidal clay nodules present, common black manganese stains, sand coats on ped faces. Clear wavy boundary to :
C1	57-110	Dark brown/dark greyish brown (10YR/7.5YR 4/2) clay, moderate to strong medium prismatic structure, moist extremely firm, common fine vertical and horizontal cracks, many fine tubular pores, common fine roots. Common very fine sand inclusions and coatings to ped faces, few line $CaCO_3$ nodules, few fine shell fragments. Gradual smooth boundary to :
C2	110-190	Dark brown/dark greyish brown (10YR/7.5YR 4/2) clay, moderate to strong fine to medium wedge structure, moist extremely firm, common fine vertical, horizontal and diagonal cracks, common fine pores, few fine roots. Common dark red (2.5YR 3/6) linear inclusions, common fine powdery gypsum and $CaCO_3$, strongly developed slickensides, common fine $CaCO_3$ nodules.

Profile Nr: T252

Classification: Jl

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-20	-	24	9	37	30	0.6	8.4	7.8	24.7
P2	20-36	-	49	11	15	25	0.7	8.4	7.8	16.9
P3	36-57	-	23	14	35	28	0.7	8.5	8.0	22.4
P4	57-80	2	11	4	25	58	1.0	8.6	7.9	32.1
P5	80-190	6	14	4	18	58	5.0	8.3	8.0	31.0

Exchangeable cations (meq/100 g soil)					Soluble cations (meq/l)			
Ca	Mg	Na	K	B (ppm)	Ca	Mg	Na	K
31.3	4.4	0.2	1.1	2.3	4.2	2.1	3.0	0.95
23.0	3.7	0.1	0.6	2.4	3.5	1.1	1.8	0.09
27.4	4.8	0.5	0.5	-	3.7	-	-	-
30.4	8.1	0.9	0.8	-	2.7	-	-	-
59.3	12.0	1.8	0.8	-	18.0	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Avail-able P (ppm)	Total N (%)	Organic C (%)	Soluble anions (meq/l)			
					CO_3	HCO_3	Cl	SO_4
16.8	48.0	3.6	0.08	0.8	-	2.1	2.6	2.2
13.3	45.8	2.1	0.02	0.4	-	2.0	2.8	2.3
16.6	-	-	-	-	-	-	-	-
11.6	-	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.7	0.2	0.08	-
0.6	0.1	0.04	-
-	-	0.04	2.0
-	-	0.02	2.0
-	-	1.20	5.0

Pit Nr:	T255
Soil class:	Jb1
Land class	U3st/R3t
Location:	Line H 0.0
API legend:	Jb
Topography:	Upper part of old levee slope
Micro-relief:	Weakly undulating
Vegetation:	Grass plain
Surface:	Slightly capped light brown, few shell fragments
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A dual profile with moderately structured medium textured surface horizons overlying fine textured wedge structure very dark grey brown clays. No significant cracks on the surface. Pores well developed at the surface, roots penetrate to 2 m. Sand lenses occur between the upper and lower horizons.

Horizon	Depth (cm)	Description
A1	0-27	Dark yellowish brown (10YR 4/4) with few fine faint strong brown (7.5YR 5/6) mottles, light very fine sandy clay loam, weak fine subangular blocky to single grain structure, dry slightly hard, many fine pores, common fine roots. Very few fine $CaCO_3$ nodules, few fine manganese nodules, few fine shell fragments, abundant mica sand flakes. Gradual smooth boundary to :
B1	27-60	Dark yellowish brown (10YR 3/4) with few medium faint strong brown (7.5YR 5/6) mottles, very fine sandy clay loam, moderate to strong fine to medium angular blocky structure, dry slightly hard, abundant fine pores, common fine roots. Common fine manganese stains, abundant fine mica sand flakes, common old termite chambers. Common laminar structure at base, lenses of clay 4 to 7 cm across, with abundant fine carbonates and small shells below which is a loamy very fine sand band less than 10 cm wide. Clear wavy boundary to :

Horizon	Depth (cm)	Description
B21	60-130	Very dark greyish brown (10YR 3/2) clay, massive to weak coarse prismatic structure, slightly moist extremely firm, common fine to medium vertical cracks, few fine pores, common fine roots. Patchy cutans, abundant fine 1 to 3 mm $CaCO_3$ nodules many fine shells and shell fragments, common fine black manganese stains and nodules, abundant sand inclusions. Gradual smooth boundary to :
B22	130-190	Dark brown (10YR 3/3) clay, weak medium wedge structure, moist very firm, common fine to medium vertical and common medium diagonal cracks, few fine pores, common fine roots. Well developed diagonal slickensides, many fine $CaCO_3$ and ferromanganese concretions, common fine shell fragments, common gypsum crystals.

Profile Nr: T255

Classification: J1

Soil particles %

Sample Nr	Depth (cm)	Coarse sand	Fine sand	Co. silt	Silt	Clay	EC_e (mmhos/cm)	pH soil/water 1:2.5 susp	pH KCl	CEC meq/100 g soil
P1	0-27	1	39	26	21	13	0.8	8.7	8.0	15.8
P2	27-60	1	43	20	13	23	1.0	8.7	8.3	16.3
P3	60-130	7	19	5	19	50	0.4	9.0	8.3	29.9

Exchangeable cations (meq/100 g soil)

Ca	Mg	Na	K	B (ppm)
23.3	2.9	0.2	0.6	0.9
20.3	4.8	0.3	0.4	1.0
27.8	11.8	2.4	0.5	-

Soluble cations (meq/l)

Ca	Mg	Na	K
3.70	1.0	2.8	0.15
4.50	1.3	2.7	0.05
1.25	-	-	-

Total carbonate (%)	Total P mg/100 g soil	Available P (ppm)	Total N (%)	Organic C (%)
10.4	47.4	1.3	0.04	0.6
10.2	46.2	0.7	0.01	0.3
15.5	-	-	-	-

Soluble anions (meq/l)

CO_3	HCO_3	Cl	SO_4
-	2.8	4.0	2.5
-	2.0	5.6	3.2
-	-	-	-

Extractable Zn	Extractable Cu	Total gypsum (%)	ESP
0.5	0.2	0.07	1.0
0.8	0.3	0.03	1.0
-	-	0.01	8.0

Pit Nr:	D004
Soil class:	Jmxl
Land class:	4s(U2s/R2t)
Location:	Line A 0.2W
API legend:	Jmx
Topography:	Low levee in old meander channel
Micro-relief:	Uneven
Vegetation:	(F2) **Dobera glabra** and **Thespesia daria** open woodland
Surface:	Dry hard, irregular surface cracks, pale yellowish brown
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Surface horizons are moderately well structured subangular blocky, brown, silt clay loams to clays with medium vertical cracks common pores and many fine roots. Below 40 cm structure to become weaker and prismatic with fairly massive subsoil horizons below one metre. At 150 cm the clays pass into a massive dark brown very fine sandy loam. Fine carbonates occur below 40 cms and gypsum below 1 m.

Horizon	Depth (cm)	Description
A1	0-11	Dark brown (10YR 3/3) heavy silt clay loam, moderate medium subangular blocky breaking to fine crumb structure, dry slightly hard, few medium vertical cracks, common fine in ped pores, common fine roots, Very few fine shell fragments. Clear smooth boundary to:
B1	11-40	Dark brown (10YR 3/3) clay, moderate medium subangular blocky structure, dry very hard, common medium vertical cracks, many fine inped pores, many fine roots. Few ferromanganese coated carbonate nodules, few very fine soft $CaCO_3$ concretions increasing towards base of horizon, very few shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B21	40-100	Dark brown (10YR 3/3) clay, weak medium prismatic structure, slightly moist very firm, common medium vertical, few fine horizontal cracks, few fine horizontal cracks, few fine inped pores, common fine, few medium roots. Few very fine shell fragments, may soft white $CaCO_3$ concretions at top of horizon decreasing with depth, few fine ferromanganese coated nodules, weak cutans, few fine sandy nodules and powdery secondary carbonate deposits. Gradual smooth boundary to:
B22	100-250	Dark brown/dark yellowish brown (10YR 3/3.5) with few fine faint yellow brown (10YR 5/4) mottles, clay, massive to weak medium angular blocky structure, slightly moist extremely firm, few fine vertical and horizontal cracks, very few fine pores, common fine roots. Very weak small cutans on ped faces, and clay coatings along cracks, few fine $CaCO_3$ concretions, few shell fragments and complete shells, fine gypsum crystals at base. Gradual smooth boundary to:
B3	150-200	Dark brown (7.5YR 4/4) with few fine faint red brown (5YR 4/3) mottles, very fine sandy loam, massive to weak medium angular blocky structure, slightly moist firm, common fine pores, few fine roots. Common fine, mainly soft manganese nodules increasing with depth, few fine hard $CaCO_3$ nodules, common mica sand flakes on ped faces.

Pit Nr: D009

Soil class: Jmxl

Land class: 4s(U3s/R2t)

Location: Line B 2.2W

API legend: Jmx

Topography: Low levee in meander complex

Micro-relief: Very slightly undulating

Vegetation: **Acacia nilotica, Thespesia darii** scrub woodland

Surface: Dry slightly hard, reddish brown

Profile drainage: Imperfect

Depth to water table: More than 2m

Brief Description:

Surface horizons are dark brown weak to moderately structured silt clay loams to clays with common fine vertical cracks and roots. Prismatic and wedge structures are moderately well developed in the subsoil below 55 cm in brown and dark greyish brown clays. Fine carbonate nodules and secondary carbonates occur throughout the profile.

Horizon	Depth (cm)	Description
A1	0-12	Brown (7.5YR 4/4) with common medium faint strong brown (7.5YR 5/6) mottles, silt clay loam, moderate medium subangular blocky structure, dry slightly hard, common fine cracks, common fine pores, common fine roots. Common very fine $CaCO_3$ nodules, few fine shell fragments. Clear smooth boundary to:
B1	12-55	Brown (7.5YR 4/4) with few fine faint grey brown (10YR 5/2) mottles, clay, weak coarse prismatic to medium subangular blocky structure, slightly moist very firm, common medium and vertical cracks, common very fine tubular pores, common fine, few medium roots. Gradual smooth boundary to:
B21	55-110	Brown (7.5YR 4/4) with common fine faint grey brown (10YR 5/2) mottles, clay, strong very coarse prismatic to coarse wedge, structure, slightly moist extremely firm, common 2 cm vertical and fine horizontal cracks, very few fine pores, common fine roots. Many well developed slickensides, common shell fragments, common fine $CaCO_3$ nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B22	110-175	Very dark greyish brown to dark greyish brown (10YR 3/2 to 4/2) with common medium faint brown (10YR 4/3) mottles clay, weak to moderate medium wedge structure, moist very firm, few medium at top and fine vertical cracks at base, rare, very fine pores, few roots. Common fine $CaCO_3$ nodules, abundant shell fragments, many well developed slickensides. Gradual smooth boundary to:
B3	175-200	Brown (10YR 4/3) with many medium fine brownish and common medium grey (10YR 3/2 and 10YR 5/1) mottles, clay, massive, moist extremely firm, few fine roots. Many fine $CaCO_3$ and manganese nodules.

Pit Nr:	D010
Soil class:	Jb3
Land class	U3sg/R3g
Location:	Line A 4.0E
API legend:	Jb
Topography:	Weakly undulating old flood plain
Micro-relief:	Strongly developed gilgai (M3)
Vegetation:	**Acacia nilotica** scrub woodland and grassland
Surface:	Dark grey, very strong vertical cracking
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Dark grey to dark greyish brown clays with moderate to strongly developed structure, well developed vertical cracks and many roots pass into grey moderately structured clays at 70 cm. There are well developed slickensides in the subsoil which becomes more massive below 140 cm. Finely developed carbonates and gypsum salts precipitate on pit face.

Horizon	Depth (cm)	Description
A1	0-30	Dark greyish brown (2.5YR 4/2) clay, strong fine to medium subangular blocky structure, low organic matter content, dry extremely hard, many fine vertical and few fine horizontal cracks, common fine pores, many fine roots. Common fine $CaCO_3$ nodules and fine shell fragments, slight root mottling. Clear wavy boundary to:
B1	30-70	Dark grey (2.5YR 4/1) clay, moderate medium prismatic breaking to medium subangular blocky structure, dry extremely hard, common fine vertical, few fine horizontal cracks, few fine pores, many fine, few medium roots. Many shell fragments, common gypsum and carbonate salts precipitated on ped faces. Clear wavy boundary to:
B2	70-140	Dark grey (5YR 4/1) clay moderate coarse prismatic structure slightly moist extremely hard, common fine vertical, few fine horizontal cracks, very few fine pores, few intra-ped fine fibrous roots. Well developed slickensides, carbonates and fine gypsum crystals precipitated on ped faces, few shell fragments. Clear smooth boundary to:

Horizon	Depth (cm)	Description
B3	140-200	Dark grey (5YR 4/1) clay, massive structureless, slightly moist extremely firm, few fine vertical cracks, few fine pores, common fibrous roots along slickensides. Manganese stains along root channels, few fine ferromanganese stains few shell fragments. Common fine carbonate and gypsum crystals precipitated on ped faces.

Pit Nr:	D011
Soil class:	J1
Land class	U2s/R2st
Location:	Line A 3.4E
API legend:	J1
Topography:	Levee in old meander complex
Micro-relief:	Uneven, slight rill erosion, scattered low termitaria
Land Use:	Maize
Surface:	Dry powdery, pale reddish brown, scattered shell fragments
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Dark brown and strong brown silt clay loam surface horizons are weakly structured and porous with few roots. Between 62 and 130 cm there is a moderately well structured dark brownish grey silt clay horizon. The strong brown coloured subsoil varies in texture from very fine sandy clay loam to silt clay with weak to moderately developed structures. Powdery carbonates and fine nodules are confined mainly to the subsoil below 130 cm.

Horizon	Depth (cm)	Description
A1	0-28	Dark brown (7.5YR 3/2) silt clay loam, low organic matter, weak to moderate subangular blocky at surface to fine crumb and single grain structure below dry slightly hard, abundant very fine pores, common fine roots. Few large shell fragments. Abrupt smooth boundary to :
IB1	28-62	Strong brown (7.5YR 4/6) heavy clay loam, weak medium subangular blocky structure, dry very hard, few very fine vertical cracks, many very fine pores, few fine roots. Few broken shell fragments, isolated pockets manganese and patches powdery secondary carbonates, much faunal activity. Clear smooth boundary to :
IIB21	62-130	Dark greyish brown (10YR 4/2) with common medium distinct red brown and grey (5YR 4/3 and 10YR 5/1) mottles, silt clay, moderate medium subangular blocky structure, common fine vertical, few very fine horizontal cracks many fine pores, very few fine roots. Common powdery $CaCO_3$ and fine nodules especially at base of horizon, occasional broken shells and few whole shell fragments. Clear wavy boundary to :

Horizon	Depth (cm)	Description
IIIB22	130-160	Strong brown (7.5YR 4/6) with abundant medium distinct grey (10YR 5/1) mottles, very fine sandy clay loam, weak medium subangular blocky structure, dry slightly hard, few fine vertical cracks, many fine pores. Abundant powdery secondary carbonates, patches of very fine mica sand flakes. Clear smooth boundary to :
IVB3	160-180	Strong brown (7.5YR 4/6) silt clay, moderate fine subangular blocky structure, dry very firm, few medium vertical, common fine horizontal cracks, common fine pores. Abundant powdery secondary carbonates, few fine manganese nodules. Clear smooth boundary to :
VC1	180-200	Strong brown (7.5YR 4/6) with few fine faint grey (10YR 5/1) mottles, very fine sandy clay loam, massive structureless, dry very firm, very few fine vertical cracks, common fine pores. Common fine patches mica sand flakes.

Pit Nr:	G050
Soil class:	Jb2
Land class:	U3s/R2g
Location:	Line H 2.4W
API legend:	Jb
Topography:	Slight depression on lower part of levee slope
Micro-relief:	Uneven, weak gilgai (M2)
Land Use:	Maize, sesame in small clearings
Surface:	Slightly self mulching, dark grey brown
Profile drainage:	Imperfect
Depth to water table:	More than 2m

Brief Description:

A weakly structured very dark grey brown to dark yellowish brown silt clay to clay profile. Surface horizons are weak prismatic to medium angular blocky in structure with finely developed vertical cracks to 97 cm. The subsoil has strongly developed slickensides with wedge shaped peds. Fine pores are developed throughout and roots extend to 97 cm. Fine manganese and carbonate nodules are distributed throughout the profile.

Horizon	Depth (cm)	Description
A1	0-24	Very dark greyish brown (10YR 3/2), heavy clay loam, low organic matter content, weak coarse prismatic breaking to medium subangular blocky structure, dry hard, few fine 1 to 2 mm vertical cracks, few fine pores, common fine roots. Abundant fine to medium $CaCO_3$ nodules, common shell fragments. Clear wavy boundary to:
B1	24-97	Dark brown to dark yellowish brown (10YR 3/3 to 3/4) with few fine faint red brown (5YR 4/3) mottles. Silt clay, massive breaking to weak medium angular blocky structure slightly moist extremely firm, few fine vertical and diagonal cracks few fine roots. Few fine to medium manganese nodules, common shell fragments, common fine $CaCO_3$ nodules, well developed diagonal slickensides. Gradual smooth boundary to:

B2	97-145	Dark brown/dark yellowish brown (10YR 3/3.5) with few fine faint red brown (5YR 4/3) mottles, silt clay, weak medium prismatic breaking to weak to moderate medium subangular blocky structure, moist extremely firm, few fine diagonal cracks, few fine pores, rare fine roots. Few shell fragments, few medium manganese nodules, common fine $CaCO_3$ nodules, large diagonal slickensides. Clear smooth boundary to:
B3	145-200	Very dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, massive breaking to weak to moderate fine subangular blocky structure, moist firm, few fine pores. Few fine manganese nodules, common fine $CaCO_3$ nodules and fine gypsum crystals.

Pit Nr: G051

Soil class: BM

Land class U2s/R3s

Location: Line G 4.1W

API legend: BM

Topography: Weakly undulating, old dune field

Micro-relief: Uneven

Vegetation: Open scrub woodland, **Withania sp.** baobab (**Adansonia digitata**)

Surface: Dry hard, red brown, few low termitaria

Profile drainage: Moderately well to well

Depth to water table: More than 2 m

Brief Description:

Dark brown massive structureless sandy loam surface horizons pass into yellow red massive sandy clay loams at 80 cm. Porosity is well developed throughout the profile. Secondary carbonates and fine gypsum crystals occur below 22 cm.

Horizon	Depth (cm)	Description
Ale	0-22	Dark brown (7.5YR 3/4) with common fine manganese stains. Heavy sandy loam, single grain structureless, dry hard, many fine, few large tubular pores, common fine roots. Gradual smooth boundary to:
A2	22-80	Dark brown (7.5YR 3/4) heavy sandy loam, massive single grain structureless, dry hard, many fine tubular pores, common fine, few, medium roots. Few fine manganese concretions and fine gypsum crystals. Very compact horizon. Gradual smooth boundary to:
B1	80-125	Yellowish red (5YR 4/6) sandy clay loam, massive single grain structureless, dry hard, abundant fine pores, few fine, few medium roots. Common fine $CaCO_3$ nodules and 1 to 5 mm patches powdery secondary carbonates, many gypsum crystals. Gradual smooth boundary to:
B2	125-190	Yellowish red (5YR 4/6) with few faint yellow brown (10YR 5/4) mottles, sandy clay loam, massive structureless, dry hard, many fine pores, few fine roots. Common manganese concretions, abundant secondary carbonates and fine gypsum crystals. Very compact horizon.

Pit Nr:	G053
Soil class:	Jmx1
Land class	U2s/R3st
Location:	Line F 3.3W
API legend:	Jmx
Topography:	Depression in old meander complex, uneven with old channel scars.
Micro-relief:	Uneven (M1)
Vegetation:	Grassland species, and some riverine forest species
Surface:	Dark grey brown, dry hard, shallow irregular cracks
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A very dark greyish brown clay loam surface passes into a dark yellowish brown silt clay at 20 cm. Structures are weak to moderate fine to medium subangular blocky with fine vertical cracking, well developed porosity and roots. At 62 cm there is a moderately well structured dark yellowish brown very fine sandy clay loam which becomes more massive below 122 cm. Fine manganese and carbonate nodules occur throughout the profile with secondary carbonates and gypsum below the surface horizon.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) with few fine faint brown (10YR 4/3) mottles, clay loam, moderate fine to medium sub-angular blocky structure, low organic matter content, dry hard, common fine vertical, few fine horizontal cracks, many fine pores, many fine, common medium roots. Few fine $CaCO_3$ nodules and fine shell fragments. Clear wavy boundary to:
B1	20-62	Dark yelowish brown (10YR 4/4) with common medium faint red brown (5YR 4/3) mottles, silt clay, weak medium subangular blocky structure slightly moist, extremely firm, few fine to medium vertical and horizontal cracks, few fine pores, few fine and medium roots. Few fine manganese concretions, few powdery secondary $CaCO_3$ concretions and fine gypsum crystals. A very compact horizon. Clear smooth boundary to:

B2	62-122	Dark yellowish brown (10YR 4/4) with common fine ferro-manganese stains on ped faces, very fine sandy clay loam, moderate fine subangular blocky structure, moist very firm, few fine horizontal cracks, common fine pores, few fine and medium roots. Many fine to medium $CaCO_3$ nodules and powdery deposits secondary carbonates. 3 cms wide band of powdery secondary carbonates and 3 to 5 mm nodules at base of horizon. Clear smooth boundary to:
C1	122-210	Dark yellowish brown (10YR 4/4) with common medium distinct red brown and yellow brown (5YR 4/3 and 10YR 5/4) mottles, very fine sandy clay loam, massive breaking to weak fine to medium subangular blocky to crumb structure, moist friable, common fine pores, few fine and medium roots. Few fine manganese nodules, common powdery secondary carbonates and fine gypsum crystals. Diffuse boundary to:
C2	210-220	Dark yellowish brown (10YR 3/4) with few fine distinct red brown (5YR 4/3) mottles, heavy coarse sandy loam, moderate fine crumb structure, moist very friable, common fine, few medium pores, common fine, few medium roots. Few fine $CaCO_3$ nodules, common ferromanganese stains, few fine gypsum crystals.

Pit Nr:	G055
Soil class:	Jmxl
Land class	4S (U2s/R3s)
Location:	Line I 3.2W
API legend:	Jmx
Topography:	Very weakly undulating, low levee in old meander complex
Micro-relief:	Uneven, many large termitaria
Vegetation:	Riverine forest
Surface:	Dry hard, pale grey brown, thin litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A shallow very dark greyish brown silt clay loam surface horizon passes into dark brown to dark yellowish brown very fine and fine sandy clay loams. Structures are weakly developed to 1 m with fine vertical cracks, few pores and few roots. Below 1 m the soil is more massive becoming sandy loam in texture to 173 cm where it passes into dark brown heavy silt clay loam. Fine carbonates are developed throughout the profile becoming hard and ferromanganese coated below 1 m.

Horizon	Depth (cm)	Description
A1	0-16	Very dark greyish brown (10YR 3/2) silt clay loam, low organic matter content, moderate fine to medium subangular blocky structure, dry hard, few fine vertical cracks, few fine pores, few fine, few medium roots. Occasional fine shell fragments, few fine $CaCO_3$ nodules. Gradual wavy boundary to:
IB11	16-36	Very dark greyish brown (10YR 3/2.5) very fine sandy clay loam, weak medium subangular blocky structure, dry hard, few fine vertical cracks, few fine pores, common fine, few medium to coarse roots. Occasional shell fragments, few fine $CaCO_3$ nodules. Gradual wavy boundary to:

Horizon	Depth (cm)	Description
IIB12	36-102	Dark brown (10YR 3/3) fine sandy clay loam, weak fine prismatic to weak fine angular blocky structure, dry very hard, few fine vertical and horizontal cracks, rare fine roots, few fine, few medium roots. Fine yellowish brown (10YR 5/4) sand coats to ped faces. Many fine to medium $CaCO_3$ nodules and ferromanganese stains. Increasing carbonates towards base of horizon. Gradual smooth boundary to:
IIIB13	102-147	Dark yellowish brown (10YR 4/4) fine sandy clay loam, massive weak medium angular blocky structure, dry hard, few fine pores, few fine and medium roots. Common fine sand inclusions up to 20 cm in diameter. Common fine to medium $CaCO_3$ nodules and fine manganese nodules, abundant deposits of powdery carbonates increasing towards base of horizon. Gradual smooth boundary to:
IV	147-173	Dark yellowish brown (10YR 4/4) sandy loam massive breaking to weak fine subangular blocky structure, slightly moist friable, few fine pores, few fine and medium roots. Common fine, few medium $CaCO_3$ nodules and common fine ferromanganese coated nodules. Gradual smooth boundary to:
VC2	173-210	Dark brown (10YR 3/3) heavy silt clay loam, massive weak fine angular blocky structure, slightly moist very firm, few fine pores, rare medium and fine roots. Common 1 to 2 cm hard ferromanganese coated carbonate nodules.

Pit Nr:	G056
Soil class:	Jb3
Land class:	U3sg/R3g
Location:	Line I 0.6W
API legend:	Jb
Topography:	Flat plain at foot of levee
Micro-relief:	Very uneven (M3)
Vegetation:	F1
Surface:	Dry hard, irregular surface cracks
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A very dark grey brown to dark brown clay soil. Well rooted moderately well developed angular blocky to prismatic surface horizons with fine vertical cracks give way to wedge shaped peds below 1 m with diagonal crack and slickensides and rare fine roots. Fine ferromanganese coated carbonate nodules occur throughout the profile with gypsum below 1 m.

Horizon	Depth (cm)	Description
A1	0-30	Very dark greyish brown/dark brown (10YR 3/2.5), heavy clay loam, low organic matter content, moderate medium to coarse subangular blocky structure, dry hard, common fine vertical cracks common fine pores, common fine roots. Common fine ferromanganese coated $CaCO_3$ nodules, common shell fragments. Gradual wavy boundary to:
B1	15-100	Very dark greyish brown/dark brown (10YR 3/2.5) clay, moderate coarse prismatic breaking to moderate medium angular blocky structure, dry very hard, few coarse (3 cm) and common fine vertical cracks, few fine pores, few fine roots. Few shell fragments, few fine manganese nodules, common fine $CaCO_3$ nodules, occasionally ferromanganese stained. Gradual very wavy irregular boundary to:

Horizon	Depth (cm)	Description
B2t	100-160	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles, clay, massive breaking to weak to moderate medium wedge structure, moist very firm, few fine vertical and horizontal cracks rare fine roots. Weak cutans on ped faces, common fine $CaCO_3$ nodules, few fine manganese nodules, common fine gypsum crystals, few shell fragments well developed diagonal slickensides. Gradual smooth boundary to:
B3	160-200	Very dark greyish brown/dark brown (10YR 3/2.5) with few fine faint red brown (5YR 4/3) mottles, clay, weak fine wedge structure, moist friable, rare fine pores. Common fine ferromanganese stains and fine nodules, common fine $CaCO_3$ nodules, occasional shell fragments weakly developed cutans on ped faces, common ferromanganese stained carbonate nodules.

Pit Nr:	G058
Soil class:	Jmxd
Land class:	U3s/R2g
Location:	Line O 1.8W
API legend:	Jmx
Topography:	Flat depression within meander complex
Micro-relief:	Even (M1)
Land Use:	Sesame
Surface:	Dry hard, dark brown
Profile drainage:	Imperfect to poor
Depth to water table:	More than 2 m

Brief Description:

Very dark grey brown to dark brown very fine sandy clays and silt clays pass into dark yellowish brown silt clays and very fine sandy clay loams below 78 cm. Surface horizons are weak to moderately well structured angular to subangular blocky with few vertical cracks. Fine pores and roots extend to 78 cm. The subsoil is more massive with medium red brown and grey mottles. Fine carbonate and ferromanganese nodules occur throughout the profile with gypsum below 142 cm.

Horizon	Depth (cm)	Description
A1	0-30	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles along root channels, very fine sandy clay, low organic matter content, moderate medium subangular blocky structure, slightly moist very firm, common fine to medium vertical cracks, few fine pores, common fine, few medium roots. Abundant medium $CaCO_3$ nodules and lenses of fine 1 to 5 mm ferromanganese coated carbonates. Gradual irregular boundary to:
B1	30-78	Dark brown (10YR 3/3) with few fine distinct red brown (5YR 4/3) mottles, silt clay, weak coarse angular blocky structure, moist firm to friable, rare medium cracks, common fine pores few fine roots. Occasional deposits powdery secondary carbonates, few fine $CaCO_3$ nodules and lenses of fine to medium $CaCO_3$ nodules few fine manganese nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	78-142	Dark yellowish brown (10YR 3/4) with abundant faint distinct red brown (5YR 4/3) mottles increasing with depth. Silt clay massive, moist firm, common fine pores, rare fine roots. Weakly developed cutans, few fine $CaCO_3$ nodules and fine gypsum crystals, few fine manganese nodules and ferromanganese coated carbonates. Clear smooth boundary to:
C1	142-210	Dark yellowish brown (10YR 3/4) with common medium distinct red brown (5YR 4/3) and common coarse distinct grey (10YR 5/1) mottles. Very fine sandy clay loam, massive breaking to weak fine subangular blocky structure, moist friable, few fine pores, rare fine roots. Few medium angular carbonate nodules and common fine $CaCO_3$ nodules, many fine gypsum crystals, occasional deposits powdery secondary carbonates especially at base of horizon.

Pit Nr:	G060
Soil class:	Jmxl
Land class	4s (U3s/R2t)
Location:	Line N 1.25W
API legend:	Jmxl
Topography:	Very old, nearly flat levee area in meander complex
Micro-relief:	Occasional sink holes (M1)
Vegetation:	Scrub woodland **Acacia nilotica, Ac. zanzibaria**
Surface:	Moist firm, scattered shall fragments, slight surface sand wash
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A moderately structured very dark grey, heavy clay loam Ap horizon overlies weakly structured dark brown clays, which pass into brown sand at 135 cm. Finely developed cracks appear in the surface horizons, with few fine pores and roots to 2 m. Common fine carbonate nodules associated with manganese occur below the Ap horizon.

Horizon	Depth (cm)	Description
Ap	0-18	Very dark grey (10YR 3/1) heavy clay loam, low organic matter content, moderate medium subangular blocky structure, moist firm to friable, few very fine vertical cracks, few fine pores, many fine roots. Few fine $CaCO_3$ and manganese nodules, few shell fragments, occasional ferromanganese stained $CaCO_3$ nodules. Clear smooth boundary to:
B1	18-52	Dark brown (10YR 3/3), clay, weak fine prismatic structure, slightly moist very firm, few fine vertical cracks, few fine pores, common fine, few medium roots. Few patches fine secondary carbonates, common shell fragments, common fine manganese nodules, common fine few medium $CaCO_3$ nodules. Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	52-135	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, weak medium platy to wedge structure, slightly moist extremely firm, few fine vertical cracks, very few fine pores, few fine, few medium roots. Occasional patches powdery carbonates common fine $CaCO_3$ nodules with ferromanganese coatings, few fine manganese nodules, weak cutans. Clear smooth boundary to:
B3	135-210	Dark brown (10YR 3/3 to 4/3) sand, massive single grain, slightly moist firm, many fine and medium pores, few fine roots. Many medium $CaCO_3$ nodules, common patches of 3 to 5 mm powdery carbonates especially near top of horizon.

Pit Nr:	G136
Soil class:	Jb3
Land class	U2sg/R3g
Location:	Line P 0.85E
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Very uneven marked gilgai formations (M3)
Vegetation:	**Acacia nilotica**
Surface:	Dry hard, dark grey brown, irregular cracks over gilgai formations
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A heavy textured dark brown clay profile. Moderately well structured medium subangular blocky to prismatic to 45 cm passing into weak wedge structured subsoils. Well cracked throughout with few fine pores and roots. Well developed slickensides in the subsoil. Fine carbonates occur as fine nodules at the surface and powdery secondary deposits below 45 cm.

Horizon	Depth (cm)	Description
A1	0-15	Dark brown (10YR 3/3) clay, low organic matter, moderate medium subangular blocky structure, dry hard, common fine vertical cracks, few fine pores, abundant fine, common medium roots. Few medium $CaCO_3$ nodules, common fine $CaCO_3$ nodules, occasionally ferromanganese coated, occasional shell fragments. Clear irregular boundary to:
B1	15-45	Dark brown (10YR 3/3) clay weak medium prismatic structure, slightly moist firm, few medium vertical, few fine, horizontal cracks, few fine pores, many fine, few medium roots. Few fine manganese nodules, common fine, few medium $CaCO_3$ nodules, Occasional 2 to 4 mm deposits powdery carbonates, occasional shell fragments. Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	45-100	Dark brown (10YR 3/3) clay, structureless to weak medium wedge, slightly moist very firm, few medium vertical cracks, few fine pores, few fine roots. Few fine hard manganese nodules, common fine $CaCO_3$ nodules, occasional 2 to 4 mm deposits powdery carbonates. Occasional shell fragments. Gradual smooth boundary to:
B3	100-200	Dark brown (10YR 3/3) clay, weak medium wedge structure moist extremely firm, few medium vertical and few fine horizontal cracks, few fine pores, few fine roots. Well developed diagonal slickensides, common fine ferromanganese coated $CaCO_3$ nodules, common shell fragments.

Pit Nr:	G139
Soil class:	Jmxd
Land class	U3s/R2a
Location:	Line Q 1.9W
API legend:	Jmx
Topography:	Low levee formation in meander complex
Micro-relief:	Weak gilgai uneven (M2)
Land use:	Sesame, maize, cowpeas
Surface:	Dry slightly crusted, grey brown, shallow cracks
Profile drainage:	Imperfect
Depth to water table:	270 cm

Brief Description:

Dark brown surface horizons of weakly structured fine sandy clays loams to fine sandy loams have few fine pores and roots. Below 140 cm there is a brown medium sand which contains a water table at 270 cm. Fine carbonate nodules and secondary deposits occur to 140 cm with fine manganese stains in the sands.

Horizon	Depth (cm)	Description
A1P	0-15	Very dark greyish brown (10YR 3/2) with fine root mottles, fine sandy clay loam, weak medium subangular blocky structure, dry very hard, few fine vertical cracks, few fine pores, common fine roots. Common very fine $CaCO_3$ nodules, few very fine gypsum crystals, occasional small shell fragments and pockets of powdery secondary carbonates. Clear smooth boundary to :
B1	15-40	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles fine sandy loam, weak fine prismatic to medium angular blocky structure, moist friable, few fine pores, few fine roots. Few fine manganese concretions, very few fine $CaCO_3$ nodules, occasional shell fragments, common 1 to 3 mm deposits powdery secondary carbonates increasing towards base. Diffuse boundary to :

Horizon	Depth (cm)	Description
B2	40-140	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, very fine sandy clay loam weak medium angular blocky structure, moist friable, common fine pores, few fine roots. Few fine manganese stains, few fine manganese nodules, few fine 2 to 4 mm deposits white secondary carbonates, common mica sand flakes. Clear smooth boundary to :
C11	140-250	Brown (10YR 4/3) with few medium faint red brown (5YR 4/3) mottles medium sand, structureless, moist loose to wet non sticky abundant fine pores, abundant mica sand flakes, common fine manganese stains.
C12	250-270	Brown (10YR 4/3) with common fine faint red brown (5YR 4/3) mottles, medium to coarse sand, wet nonsticky abundant, mica sand flakes and common fine ferromanganese stains.

Pit Nr:	G142
Soil class:	Jb3
Land class	U3sg/R3g
Location:	Line H 1.0W
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Very uneven (M3)
Land use:	Maize
Surface:	Moist firm, dark grey brown, irregular cracks, slightly self mulching
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Dark brown clay loams and clays with weak fine prismatic and platy structures well developed vertical cracks few pores and roots extend to 54 cm. The subsoil is composed of more weakly wedge structured dark yellowish brown clays with horizontal cracks and slickensides and rare fine roots. Fine and medium carbonate and manganese nodules occur throughout the profile with gypsum below 54 cm.

Horizon	Depth (cm)	Description
A1P	0-28	Very dark greyish brown/dark brown (10YR 3/2.5) with few fine faint red brown (5YR 4/3) mottles, heavy clay loam, low organic matter content, weak fine prismatic structure, dry extremely hard, few medium vertical cracks, few fine pores, few fine roots. Common fine and medium $CaCO_3$ and fine manganese nodules, common large 1 to 2 cm powdery secondary carbonate deposits, occasional shell fragments. Clear smooth boundary to :
B1	28-54	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles clay, moderate fine platy structure, moist firm, common fine horizontal few fine vertical cracks, few fine pores, few fine roots. Few fine shell fragments, common fine black manganese and fine $CaCO_3$ nodules. Clear smooth boundary to :

Horizon	Depth (cm)	Description
B2	54-100	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, weak fine wedge structure, moist firm, horizontal and vertical cracks, few fine pores, rare fine roots. Occasional fine shell fragments, common fine black manganese and fine $CaCO_3$ nodules, occasional, fine 1 to 2 mm manganese nodules and stains, few fine gypsum crystals. Clear smooth boundary to :
B3	100-190	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay weak medium wedge structure, moist firm, few fine horizontal cracks, very few fine pores, rare fine roots. Weakly developed slickensides, common less than 5 mm black manganese and fine $CaCO_3$ nodules. Common very fine gypsum crystals, occasional shell fragments and fine ferromanganese stains.

Pit Nr:	G143
Soil class:	Jmxl
Land class	4s (U3s/R2s)
Location:	Line G 0.1W
API legend:	Jl
Topography:	Low levee just inside meander complex
Micro-relief:	Smooth even
Vegetation:	**Thespesia sp, Dobera glabra,** palms
Surface:	Dry hard, very few fine irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark yellowish brown very fine sandy loam to sandy clay loam surface horizons are weak to moderately well structured angular blocky to prismatic. There are well developed pores to 75 cm with fine roots. Below 75 cm there are more massive clays with coarse prismatic structures and well developed vertical cracks. These break down to fine crumbs on exposure. Fine manganese and carbonate nodules occur throughout the profile with gypsum below 75 cm.

Horizon	Depth (cm)	Description
A1	0-23	Dark yellowish brown (10YR 3/4) very fine sandy clay loam, moderate medium to fine subangular blocky structure, dry slightly hard, common fine pores, common fine, few medium roots. Few fine $CaCO_3$ nodules, occasional fine manganese nodules and shell fragments. Clear smooth boundary to :
IB11	23-45	Dark yellowish brown (10YR 4/4) with fine black manganese stains, very fine sandy loam, weak fine prismatic structure, dry hard, abundant fine pores, common fine, few medium roots. Few mica sand flakes, few fine and common medium $CaCO_3$ nodules common to 1 to 3 mm patches powdery secondary carbonates, common termite channels. Clear smooth boundary to :
IIB12	45-75	Dark yellowish brown (10YR 3/6), very fine sandy (silt) loam, structureless to weak fine prismatic breaking to fine angular blocky, dry hard, abundant fine pores, few fine and medium roots, common faunal channels, few fine manganese nodules and common fine manganese stains more compact horizon than above. Abrupt smooth boundary to :

Horizon	Depth (cm)	Description
IIIB21	75-134	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, massive to weak coarse prismatic structure, slightly moist extremely firm, one large vertical crack, few fine pores, rare fine roots. Few fine shell fragments, few fine gypsum crystals, few fine ferromanganese stained carbonate nodules, common fine $CaCO_3$ nodules. Gradual smooth boundary to :
IVB22	134-200	Dark brown (10YR 3/3) with few fine faint red brown and few distinct red brown mottles (5YR 4/3) clay, massive to weak coarse prismatic structure slightly moist extremely firm, few fine vertical cracks, very few fine pores, rare fine roots. Common patches 1 to 10 mm powdery carbonates, abundant fine ferromanganese stains, few fine and medium $CaCO_3$ nodules, common fine manganese nodules.

Pit Nr:	G144
Soil class:	Jb3
Land class	U3sg/R3g
Location:	Line F 0.0
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Uneven strong gilgai (M3)
Land Use:	Sesame
Surface:	Slightly mulching, dark grey brown, coarse irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark grey brown to dark brown clays with moderately well structured surface horizons pass into brown clays with moderate wedge structure below 40 cm. There are strongly developed slickensides in the subsoil with well developed cracks throughout. Fine pores and roots extend to two metres. Fine carbonate nodules increase with depth becoming ferromanganese coated, with gypsum below 142 cm.

Horizon	Depth (cm)	Description
A1	0-18	Very dark greyish brown (10YR 3/2) clay, low organic matter content, moderate medium subangular blocky structure, dry extremely hard, few medium vertical, few fine vertical cracks rare fine pores, abundant fine, few medium roots. Abundant fine and medium $CaCO_3$ with ferromanganese staining, few fine manganese nodules, common shell fragments. Clear smooth boundary to:
B1	18-40	Very dark greyish brown (10YR 3/2) clay, moderate medium to coarse prismatic structure, dry extremely hard, few medium and fine vertical cracks, few fine pores, common fine roots. Weakly developed slickensides, common fine and medium $CaCO_3$ nodules, common fine manganese nodules, common fine ferromanganese stains on ped faces and carbonate concretions, occasional gypsum crystals. Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	40-142	Very dark greyish brown dark brown (10YR 3/2.5) clay, weak fine to medium wedge structure slightly moist extremely firm, common fine diagonal and vertical cracks, very few fine pores, few fine roots. Well developed slickensides, abundant fine ferromanganese coated carbonates nodules, common fine manganese stains, common fine shell fragments, few medium $CaCO_3$ and fine manganese nodules. Diffuse boundary to:
B3	142-210	Dark brown (10YR 3/3) clay, moderate fine to medium wedge structure, moist extremely firm, common fine horizontal cracks, few fine pores, few fine, occasional medium roots. Extremely well developed slickensides, common shell fragments and fine manganese nodules, few fine ferromanganese coated and medium carbonate nodules, occasional fine manganese stains and very fine gypsum crystals.

Pit Nr:	G145
Soil class:	Jb2
Land class	U3s/R2g
Location:	Line E 0.5E
API legend:	Jb
Topography:	Flat level plain mid-slope between meander complex levee and low rise
Micro-relief:	Uneven (M2)
Land use:	Sesame
Surface:	Moist sticky, dark grey brown, irregular coarse surface cracks, scattered shell fragments
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Very dark greyish brown weak to moderate structured clays. Surface horizons are medium to coarse prismatic with many vertical cracks, the subsoil below 80 cm has medium wedge structures with diagonal cracks and well developed slickensides. Roots and pores are best developed above 80 cm. Fine carbonate nodules occur at the surface increasing in size and intensity with depth. Fine gypsum occurs in the subsoil.

Horizon	Depth (cm)	Description
A1	0-25	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles, clay, moderate medium prismatic structure, low organic matter content, dry extremely hard, common medium and fine vertical cracks, few fine pores, common fine, occasional medium roots. Common fine $CaCO_3$ and manganese nodules, extremely abundant black manganese staining on ped faces. Clear smooth boundary to:
B1t	25-82	Very dark greyish brown (10YR 3/2) with few fine red brown (5YR 4/3) mottles, clay weak coarse prismatic structure, dry extremely hard, few medium vertical and fine horizontal cracks, few fine pores, rare fine roots. Abundant fine, common 2 to 3 mm $CaCO_3$ nodules, common fine manganese nodules and fine manganese stains on ped faces weakly developed cutans. Clear smooth boundary to:

Horizon	Depth (cm)	Description
B2	82-200	Very dark greyish brown (10YR 3/2) with common medium faint red brown (5YR 4/3) mottles, clay, moderate medium wedge structure, slightly moist extremely firm, common fine horizontal and vertical, occasional medium diagonal cracks, very few fine pores, extremely rare fine roots. Weakly developed slickensides at top of horizon increasing at depth in horizon, abundant fine, common 2 to 4 mm $CaCO_3$ nodules, common fine manganese stains on ped faces, common fine 1 mm manganese nodules, few fine shell fragments, few fine gypsum crystals.

Pit Nr: T022

Soil class: Jmxl

Land class: U2s/R1

Location: Line C 2.4W

API legend: Jb

Topography: Mid slope to levee in meander complex

Micro-relief: Occasional low termitaria

Vegetation: **Withinia** sp., **Thespesia darii**, thick scrub woodland

Surface: Dry hard grey brown occasional small sink holes

Profile drainage: Moderately well

Depth to water table: More than 2 m

Brief Description:

Surface horizons are weak to moderately structured dark brown to dark yellowish brown silt clay loams to silt clays. There are well developed vertical cracks, common fine pores and roots. Below 75 cm there are more massive weakly structured dark yellowish brown clays with few fine pores and roots. Powdery secondary carbonates and fine nodules occur below 15 cm becoming ferromanganese coated in the deeper subsoil with fine gypsum crystals.

Horizon	Depth (cm)	Description
A1	0-15	Dark brown (10YR 3/3) silt clay loam, low organic matter content, weak fine subangular blocky structure, dry slightly hard, few fine vertical cracks, common fine pores, many fine, few medium roots. Clear smooth boundary to:
B1	15-75	Dark yellowish brown (10YR 4/4) silt clay, low organic matter content, moderate medium prismatic breaking to medium subangular blocky structure, slightly moist very firm, common medium vertical, few fine horizontal cracks, common fine pores, common fine, few medium roots. Few fine patches powdery $CaCO_3$ and fine ferromanganese coated carbonate nodules, few weak cutans on ped faces. Gradual smooth boundary to:
B2	75-140	Dark yellowish brown (10YR 4/4) with few fine faint grey brown (10YR 5/2) mottles, clay, massive to weak medium subangular blocky structure, slightly moist very firm, few medium vertical and fine horizontal cracks, few fine pores, few fine roots. Few broken shell fragments, common fine pockets powdery $CaCO_3$ and occasional hard $CaCO_3$ nodules, few very fine manganese stains and fine gypsum crystals. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B3	140-190	Dark yellowish brown (10YR 4/4) with few faint red brown (5YR 4/3) mottles, clay, massive structureless, slightly moist very firm, few fine pores, few very fine roots. Common fine ferromanganese coated carbonate nodules, common fine gypsum crystals, isolated patches of ferromanganese rich matrix material, occasional lenses of powdery carbonate deposits concentrated along cracks between ped faces.

Pit Nr:	T023
Soil class:	Jmxl
Land class:	4s (U2s/R3st)
Location:	Line D 3.85W
API legend:	Jmx
Topography:	Low levee in meander complex, very weakly undulating
Micro-relief:	Weakly undulating, few termitaria
Vegetation:	Low scrub woodland **Tamarindus** sp **Acacia** sp
Surface:	Dry hard thin leaf litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A weakly structured very porous and well rooted sandy profile. The surface is a very dark greyish brown very fine sandy loam passing into brown and dark brown fine sandy clay loams below 26 cm. The subsoil below 120 cm is composed of dark brown sandy loams and loamy sands. Powdery secondary carbonates are found below the surface horizon.

Horizon	Depth (cm)	Description
A1	0-26	Very dark greyish brown (10YR 3/2) with few medium yellowish brown (10YR 5/4) sand lenses, very fine sandy clay loam, moderate organic matter content, weak to moderate medium subangular blocky structure, dry slightly hard, many fine and medium tubular pores, many fine, common medium and few large roots. Few fine shell fragments, common faunal activity. Gradual smooth boundary to:
B1	26-51	Dark brown (10YR 4/3) fine sandy clay loam, low organic matter content, dry slightly hard, weak medium subangular blocky stucture, many fine pores, many fine, common medium and few large roots. Common fine powdery $CaCO_3$ nodules, common mica sand flakes. Gradual smooth boundary to:
B2	51-120	Dark brown (7.5YR 4/4) heavy fine sandy clay loam massive to weak medium subangular blocky structure, dry hard, few fine pores, many fine, common medium and few large roots. Common mica sand flakes, many fine $CaCO_3$ nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B22	120-150	Dark brown (7.5YR 4/4) heavy sand loam massive to weak medium subangular blocky structure, dry slightly hard, common fine pores, many fine, common medium and few large roots. Few fine manganese stains, few patches of powdery secondary carbonates. Gradual smooth boundary to:
C1	150-200	Dark brown (7.5YR 4/4) loamy sand, massive to single grain, moist soft, few fine pores, many fine, common medium and few large roots.

Pit Nr:	T025
Soil class:	Jb1
Land class:	U3dt/R3dt
Location:	Line E 4.1W
API legend:	Jb
Topography:	Levee backslope between meander complex and marine plain
Micro-relief:	Slightly undulating surface (M1)
Vegetation:	Grassland with patches dense woodland, **Acacia nilotica** and **Dobera glabra**
Surface:	Dry hard, irregular surface cracking
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Very dark greyish brown moderately well, medium structured silt clay loams and clays with finely developed vertical cracks many pores and roots, pass into more compact coarsely structured dark greyish brown clays below 45 cm. The subsoil contains fine manganese and carbonate nodules and common patches of powdery carbonates and gypsum crystals.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) silt clay loam, low organic matter content, moderate medium subangular blocky structure, dry very hard, few fine vertical cracks, many very fine pores, many fine roots. Common fine $CaCO_3$ nodules, clear wavy boundary to:
B1	20-45	Very dark greyish brown (10YR 2.5Y 3/2) clay, low organic matter content, moderate medium prismatic breaking to fine to medium subangular blocky structure, slightly moist very hard, few fine and coarse 3 cm vertical cracks, many fine pores, common fine, few medium roots. Few shell fragments and hard 1 cm $CaCO_3$ nodules. Diffuse boundary to:
B2	45-97	Very dark greyish brown (2.5Y 4/2) clay, weak coarse prismatic structure, moist extremely firm, few medium and coarse 3 cm vertical cracks, few fine pores, common fine, few medium roots. Common fine, few medium $CaCO_3$ nodules, few fine gypsum crystals and fine shell fragments. Clear wavy boundary to:

Horizon	Depth (cm)	Description
B3	97-200	Dark greyish brown (10YR 4/2) with few faint strong brown (7.5YR 5/6) manganese stains on ped faces, clay, weak medium wedge structure, moist extremely firm, few fine vertical and horizontal cracks, few fine pores, rare fine roots. Common patches powdery carbonates and 1 to 3 mm gypsum crystals.

Pit Nr:	T026
Soil class:	Jb1
Land class:	U2st/Rst
Location:	Line E 3.0W
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Very gentle undulations and gilgai (M1)
Land Use:	60% tree cover, **Dobera glabra** grassland
Surface:	Thin mulch, few irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark brown moderately well, medium structured clays with fine vertical cracks, fine pores and roots extend to 60 cm. The subsoil is composed of brown weak coarse prismatic and wedge structured clays with few roots and fine pores. Fine carbonate nodules and powdery carbonates occur throughout the profile with fine gypsum below 120 cm.

Horizon	Depth (cm)	Description
A1	0-15	Dark brown (10YR 3/3) light clay, low organic matter content, moderate medium subangular blocky to fine crumb structure, dry slightly hard, common fine pores, abundant fine roots. Common very fine $CaCO_3$ nodules, few ferromanganese coated, few shell fragments. Gradual smooth boundary to:
B1	15-34	Dark brown (10YR 3/3) clay, moderate fine to medium subangular blocky structure, dry hard, common fine vertical cracks, few fine pores, common fine, few medium roots. Common soft powdery $CaCO_3$ concretions occasionally ferromanganese coated. Clear smooth boundary to:

Horizon	Depth (cm)	Description
B2	34-60	Brown (10YR 4/3) clay, weak to moderate medium subangular blocky structure, slightly moist very firm, common medium 2 to 3 cm vertical cracks, few fine pores, common fine roots. Abundant hard fine 1 to 5 mm $CaCO_3$ concretions, few fine shell fragments and patches powdery secondary carbonates, few very weak cutans. Gradual smooth boundary to:
B3	60-120	Brown (10YR 4/3) clay, weak coarse prismatic and medium sub-angular blocky structure, moist extremely firm, few fine vertical and diagonal cracks, few fine pores, few fine roots. Few vertical slickensides, common fine $CaCO_3$ nodules, few patches powdery carbonates. Gradual smooth boundary to:
B4	120-200	Brown (10YR 4/3) clay, weak medium wedge structure, moist extremely firm, few fine diagonal cracks, few fine pores, few fine roots. Common vertical and diagonal slickensides, common fine $CaCO_3$ nodules, few shells and shell fragments, few fine gypsum crystals.

Pit Nr:	T030
Soil class:	Jmxl
Land class:	4S(U3st/R3t)
Location:	Line F 4.2W
API legend:	Jt
Topography:	Very weakly undulating terrace sloping 1 to 2 degrees to the south-east
Micro-relief:	Weakly undulating (M2)
Vegetation:	80% tree cover, **Dobera glabra, Thespesia daria, Acacia** spp.
Surface:	Fine surface mulch, thin litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Moderately well structured brown to dark brown silt clay loams to clays with well developed vertical cracks, fine pores and roots extend to 65 cm. Structures become prismatic at depth especially below 65 cm where there are olive brown clays with wedge shaped peds below 1 m, and fine vertical and diagonal cracks. Fine carbonates are found throughout the profile with fine gypsum below one metre.

Horizon	Depth (cm)	Description
A1	0-30	Dark brown (10YR 3/3) silt clay loam, low organic matter content, moderate medium subangular blocky structure, dry very hard, few medium vertical and common fine horizontal cracks, many fine pores, many fine and few medium roots. Few fine shell fragments, few very fine $CaCO_3$ and manganese nodules, increasing towards base,occasional 1 to 5 mm patches powdery carbonates. Clear wavy boundary to:
B1	30-65	Brown (10YR 4/3) clay, weak coarse prismatic to moderate medium angular blocky structure, slightly moist extremely firm, common medium vertical, few fine horizontal cracks, few fine pores, common fine, few medium roots. Few shell fragments, few weak slickensides, many very fine $CaCO_3$ and manganese nodules, common patches powdery secondary carbonates. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B21t	65-100	Olive brown (2.5Y 4/4) clay, weak coarse prismatic structure, slightly moist very firm, common 1 to 2 cm vertical, few fine horizontal cracks, common fine pores, common fine roots. Weakly developed slicknesides, 1 to 3 mm hard ferro-manganese coated $CaCO_3$ nodules, common very fine manganese nodules, patchy cutans. Diffuse boundary to:
B22t	110-200	Olive brown (2.5Y 4/4) with few fine faint brown (10YR 4/3) mottles, clay, weak fine to medium wedge to angular blocky structure, moist extremely firm, common fine diagonal and vertical cracks, common fine pores, few fine roots. Common fine black manganese nodules, abundant very fine hard $CaCO_3$ nodules, occasional lenses 1 to 3 cm $CaCO_3$ and manganese concretions and secondary carbonates, occasional patches fine gypsum crystals, well developed cutans.

Pit Nr:	T033
Soil class:	Jmxd
Land class	U3sg/R3g
Location:	Line I 2.0W
API legend:	Jmx
Topography:	Depression in meander complex
Micro-relief:	Strongly undulating (M3)
Vegetation:	Site on edge of riverine forest in grass plain
Surface:	Dry hard, dark grey brown, thin grass litter layer
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Very dark greyish brown moderately well structured clays with finely developed vertical cracks, common pores and roots extend to 40 cm. The subsoil clays are weakly structured medium wedges and dark brown in colour, with well developed slickensides and few cracks to 150 cm. Fine roots and pores extend throughout the profile. Fine carbonate nodules and secondary carbonates occur below 20 cm with fine gypsum below 75 cm.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) clay, low organic matter content, moderate to strong medium subangular blocky structure dry hard, common very fine vertical and few fine horizontal cracks, common fine, few medium pores, many fine, few medium roots. Many fine shells and shell fragments. Gradual wavy boundary to:
B1	20-40	Very dark greyish brown (10YR 3/2) with few fine faint dark brown (10YR 3/3) mottles, clay, weak medium prismatic to moderate fine to medium angular blocky structure, dry very hard, common fine and medium roots. Common very fine $CaCO_3$ nodules and fine manganese stains, common shell and shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	40-75	Dark greyish brown (10YR 4/2) with few fine distinct yellowish brown (10YR 5/4) mottles, clay, weak medium wedge structure, slightly moist extremely firm, common fine to medium vertical cracks, few fine pores, common fine and few medium roots. Patchy slickensides, occasional very fine soft secondary carbonate deposits, many fine $CaCO_3$ nodules, common fine shells and shell fragments, patches of red (2.5YR 4/6) cemented sand, common grey (10YR 5/1) sand inclusions. Gradual smooth boundary to:
B3	75-150	Dark brown (10YR 3/3) clay, massive to weak medium wedge structure, slightly moist extremely firm, few fine to medium vertical cracks, few fine pores, common fine roots. Well developed slickensides, common very fine $CaCO_3$ and manganese nodules, few fine gypsum crystals, patches red (2.5YR 4/6) cemented sand inclusions. Gradual smooth boundary to:
C1	150-200	Dark brown (10YR 3/3) with fine manganese stains, clay, weak to moderate medium wedge structure, moist very firm, few fine pores, few fine roots. Well developed slickensides, and cutans on ped faces, common very fine secondary $CaCO_3$ and manganese nodules, few fine shell fragments and fine gypsum crystals.

Pit Nr:	T125
Soil class:	Jb1
Land class	U2s/R1
Location:	Line O 3.0W
API legend:	Jb
Topography:	Lower slope of levee, flat plain
Micro-relief:	Flat
Vegetation:	60% tree cover **Acacia nilotica**
Surface:	Fine surface tilth wet sticky after rains
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Moderately well structured dark brown clay surface horizons with well developed vertical cracks, common fine pores and roots extend to 60 cm. The subsoil has dark grey brown to dark brown clays with fine wedge structures, few pores and fine roots. Well developed slickensides occur below 60 cm. Fine carbonate and manganese nodules occur below 60 cm. Fine carbonate and manganese nodules occur throughout the profile.

Horizon	Depth (cm)	Description
A1	0-30	Very dark greyish brown very fine sandy clay, low organic matter content, moderate fine subangular blocky structure with slightly platy surface, slightly moist very firm, many fine vertical cracks, common fine pores, common fine and few medium roots. Common fine shell fragments along cracks, common very fine $CaCO_3$ nodules, occasional lenses of very fine sandy clay loam with abundant 2 to 3 mm ferromanganese nodules. Clear wavy boundary to:
B1	30-60	Dark brown (10YR 3/3) heavy silt clay, weak to moderate fine to medium angular blocky structure, moist extremely firm, common fine vertical cracks, few fine pores, common fine and medium roots. Weakly developed cutans on ped faces. Many fine 1 to 3 mm $CaCO_3$ and ferromanganese concretions, many fine shell fragments, sand coats along vertical cracks, Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	60-94	Dark greyish brown (10YR 4/2) clay, moderate fine wedge structure, moist extemely firm, many medium diagonal and vertical cracks, few fine pores. Common fine, few medium roots. Well developed slickensides, common fine shell fragments, many fine 2-5 mm ferromanganese coated carbonate nodules. Occasional hard red (2.5YR 4/6) sandstone fragments. Gradual smooth boundary to:
B3	94-180	Dark brown (10YR 3/3) silt clay, massive moist firm, very few fine vertical cracks, few fine pores, few fine roots. Patchy vertical slickensides, few fine shell fragments, common fine 1 to 2 mm black ferromanganese carbonate nodules, common fine sand coats to ped faces, occasional lenses very fine carbonate rich material.

Pit Nr:	T126
Soil class:	Jmxl
Land class:	4s (U2s/R3t)
Location:	Line O 1.2W
API legend:	Jmx
Topography:	Low weakly undulating levee in meander complex
Micro-relief:	Weakly undulating
Vegetation:	10% tree cover scrub with **Dobera glabra** and palms
Surface:	Thin leaf litter layer, dry, hard, dark grey brown
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Moderately well structured very dark greyish brown and dark brown heavy clay loam and silt clay surface horizons have well developed vertical cracks, common fine pores and roots. Below 37 cm there are dark yellowish brown clays and sandy clays with more massive structures, many pores and few roots. At 145 cm there is a brown very fine sandy loam. Fine carbonates occur throughout the profile with gypsum crystals below 37 cm.

Horizon	Depth (cm)	Description
A1	0-15	Very dark greyish brown (10YR 3/2) heavy clay loam, low organic matter content, moderate fine angular blocky with medium platy surface structure, slightly moist firm, few medium vertical cracks, abundant fine, few medium pores, few medium, common fine roots. Common fine sand coats to ped faces, few fine $CaCO_3$ nodules. Diffuse wavy boundary to:
B1	15-37	Brown (10YR 4/3) silt clay, moderate medium to coarse subangular blocky structure, slightly moist extremely firm to medium vertical, few coarse horizontal cracks, common fine, few medium pores, common fine, few medium roots. Many fine to medium secondary carbonates, few shell fragments, common inclusions of upper horizon. Gradual smooth boundary to:
B2	37-112	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, massive, slightly moist extremely firm, few medium vertical cracks, few fine pores; common fine, few medium and coarse roots. Common fine black manganese stains, few fine shell fragments, common fine secondary carbonate deposits, weak cutans, few fine gypsum crystals. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B3	112-145	Dark yellowish brown (10YR 4/4) common medium distinct yellowish brown (10YR 5/4) mottles, very fine sandy clay loam, moderate fine subangular blocky structure, moist firm to friable, common fine pores, common fine, few medium and coarse roots. Common termite activity, abundant 2 to 5 mm carbonate nodules, few fine black manganese stains. Clear smooth boundary to:
C1	145-210	Dark brown (7.5YR 4/4) with few fine faint grey (10YR 5/1) mottles, very fine sandy loam, weak subangular blocky to single grain structure, moist very friable abundant fine pores, common fine, few medium roots. Common fine black manganese stains, top of horizon marked by band of 2 to 5 mm carbonate nodules, occasional hard $CaCO_3$ nodules below, few fine gypsum crystals common faunal activity.

Pit Nr:	T127
Soil class:	Jb
Land class:	U2s/R2g
Location:	Line N 2.4W
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Slight hollow (M0-M1)
Vegetation:	30% tree cover **Acacia nilotica**, grassland
Surface:	Slightly self mulching, thin grass litter layer
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A heavy textured dark brown to brown clay soil with a fine structured surface passing into coarser structured more massive subsurface horizons. Well developed porosity with roots extending to 120 cm. Calcium carbonate and gypsum concentrated in lenses below the surface horizon.

Horizon	Depth (cm)	Description
A1	0-20	Dark brown (10YR 4/3), clay, moderate fine subangular blocky structure slightly platy surface, dry hard, low organic matter content, many very fine vertical cracks, common fine pores, abundant fine, few medium roots. Abundant very fine $CaCO_3$ nodules, few shell fragments, common fine red sand grits 1 mm in size. Diffuse boundary to:
B1	20-56	Brown (10YR 4/3), clay, dry very hard, weak coarse prismatic to medium angular blocky structure, common fine vertical, few fine horizontal cracks, few fine pores, many fine, few medium roots. Abundant very fine 1 mm ferromanganese coated $CaCO_3$ nodules, occasional dense lenses of $CaCO_3$ and gypsum common 1 mm sized red sand grits. Diffuse boundary to:
B2	56-120	Brown (10YR 4/3), clay, massive, weak medium angular blocky structure slightly moist extremely firm, common fine to medium vertical cracks, few fine, pores, common fine few medium roots. Occasional lenses dense very fine $CaCO_3$ nodules common fine sand lenses with 1 mm red sand grits. Common fine gypsum and $CaCO_3$. Diffuse boundary to:

B3	120-200	Dark brown to dark yellowish brown (10YR 3/3 to 3/4), clay, massive to moderate, medium subangular blocky structure, moist extremely firm, few fine vertical cracks, few fine pores, few fine roots. Weakly developed slickensides, common fine sand inclusions with fine 1 mm red sand grits, occasional lenses $CaCO_3$ nodules, common fine shells, common fine gypsum.

Pit Nr:	T128
Soil class:	Jb2
Land class:	U2sg/R3g
Location:	Line N 0.8E
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Weakly undulating (M2)
Vegetation:	Thin scrub
Surface:	Fine surface tilth, irregular cracks, dark grey brown
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Moderately well structured angular blocky dark brown clay loam and clay surface horizons with fine vertical cracks common pores and roots pass into dark yellowish brown clays at 50 cm. The subsoil has medium wedge structures with few fine pores and roots. Fine carbonate and ferromanganese nodules occur throughout the profile with fine gypsum below 1 m.

Horizon	Depth (cm)	Description
A1P	0-15	Very dark greyish brown (10YR 3/2) clay loam, low organic matter content, moderate medium to coarse subangular blocky structure, dry slightly hard, common fine vertical and horizontal cracks, common fine pores, common fine roots. Abundant fine $CaCO_3$ nodules, many fine to medium shell fragments, common secondary carbonate coatings on ped faces. Gradual smooth boundary to:
B1	15-50	Dark brown (10YR 3/3) clay, weak coarse prismatic to moderate medium angular blocky structure, slightly moist extremely firm, common fine to medium vertical cracks, few fine pores, common fine roots. Abundant secondary carbonates and ferromanganese stains. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	50-107	Dark brown to brown (10YR 3/3 to 4/3) clay, moderate medium wedge structure, slightly moist firm, common fine to medium vertical cracks, few fine pores, common fine roots. Common very fine ferromanganese coated carbonate nodules, common shell fragments, well developed slickensides on wedge ped faces, increase in carbonates towards base of horizon. Diffuse boundary to:
B3	107-200	Dark brown to brown (10YR 3/3 to 4/3) with few fine faint red brown (5YR 4/3) mottles, clay, weak medium wedge structure, moist extremely firm, very few fine vertical and few fine horizontal cracks, few fine pores, few fine roots. Few fine shell fragments, common very fine black ferromanganese and carbonate nodules, few 2 to 5 mm carbonate nodules, weakly developed slickensides, common 1 to 2 cm patches of secondary carbonates and gypsum crystals.

Pit Nr:	T133
Soil class:	Jb2
Land class:	U3s/R2g
Location:	Line K 3.0W
API legend:	Jb
Topography:	Northern end of water-filled depressional area
Micro-relief:	Flat to very slightly undulating (M1)
Land use:	Maize, sesame
Surface:	Fine surface mulch, common shell fragments, irregular cracks
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark greyish brown to dark brown moderately well structured clays with fine vertical cracks, many pores and fine roots extend to 50 cm. The subsoil clays have coarse prismatic to fine wedge structures and dark brown to dark yellowish brown colours. Diagonal cracks occur in the subsoil with few roots and pores. Fine carbonates and ferromanganese nodules occur throughout the profile with gypsum below 175 cm.

Horizon	Depth (cm)	Description
A1P	0-20	Dark greyish brown (10YR 4/2) clay, low organic matter content moderate medium subangular blocky structure with fine prismatic substructure, slightly moist extremely firm, common very fine vertical and horizontal cracks, many fine tubular pores, few fine roots. Abundant 1 to 3 mm $CaCO_3$ nodules few fine manganese nodules, common shell fragments. Gradual smooth boundary to:
B1	20-50	Dark brown (10YR 3/3) clay, weak to moderate medium to fine subangular blocky structure, slightly moist extremely firm, common fine and medium vertical cracks, common fine pores, common fine roots. Abundant 1 to 3 mm $CaCO_3$ and ferromanganese coated nodules, common fine shell fragments, common fine lenses $CaCO_3$ and ferromanganese concretions, few weak cutans. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2t	50-100	Very dark greyish brown dark brown (10YR 2.5) clay, moderate coarse prismatic structure, slightly moist extremely firm, common fine and medium vertical and diagonal cracks, common fine pores, common fine roots. Abundant very fine $CaCO_3$ nodules, many 1 to 2 mm ferromanganese coated carbonate nodules with lenses as above, few shell fragments, weakly developed cutans. Gradual smooth boundary to:
B31	100-175	Dark brown (10YR 3/3) with few fine faint yellow brown (10YR 5/4) mottles, clay, moderate fine to medium wedge structure, moist extremely firm, common fine diagonal cracks, few fine pores, few fine roots. Few fine shell fragments, many 1 to 3 mm ferromanganese coated $CaCO_3$ nodules, many well developed shear faces, occasional very fine sand lenses along vertical cracks. Gradual smooth boundary to:
B32	175-210	Dark yellowish brown (10YR 3/4) with common fine faint strong brown (7.5YR 5/6) mottles, clay, moderate medium wedge structure, moist extremely firm, very few fine horizontal cracks, few fine pores, rare fine roots. Common fine secondary carbonates fine gypsum, and hard nodular carbonates.

Pit Nr:	T134
Soil class:	Jb
Land class	U2s/R1
Location:	Line K 2.35W
API legend:	Jb
Topography:	Flat level plain
Micro-relief:	Smooth even (M1)
Land use:	Tobacco and maize
Surface:	Dry hard, dark grey brown, slight surface sand wash, irregular shallow cracks.
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark brown well structured surface horizons of very fine sandy clay loam and clay pass into more massive clays below 70 cm. Porosity and cracks are well developed near the surface. Roots extend to 2 m. Calcium carbonate and gypsum increase at depth.

Horizon	Depth (cm)	Description
A1P	0-15	Dark brown (10YR 3/3), heavy, very fine sandy clay loam, weak fine subangular blocky breaking to very fine subangular blocky structure, dry slightly hard, moderately high organic matter content, common very fine horizontal and few fine vertical cracks, abundant very fine pores, common fine, few medium roots, Common mica sand coats to horizontal ped faces, few shell fragments, common fine ferromanganese coated $CaCO_3$ concretions. Clear smooth boundary to:
B1	15-70	Dark brown (10YR 3/3), clay moderate medium prismatic breaking to moderate fine to medium subangular blocky structure, dry hard, few medium vertical, few fine horizontal cracks, common fine pores, common fine, few medium roots. Common broken and few complete shells. Abundant 1 to 3 mm $CaCO_3$ nodules occasionally coated with ferromanganese. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	70-150	Dark brown dark yellowish brown (10YR 3/3.5), clay massive, weak fine to medium subangular blocky structure, slightly moist very firm, few fine vertical and horizontal cracks, few fine pores, few fine and medium roots. Few fine manganese nodules, common pockets of ferromanganese coated $CaCO_3$ nodules, weak slickensides, few fine gypsum crystals. Gradual smooth boundary to:
B3	150-200	Brown (10YR 4/3), with few fine faint red brown (5YR 4/3) mottles, clay, massive, slightly moist extremely firm, very few fine vertical few fine diagonal and horizontal cracks few fine pores, few fine roots. Common shell fragments, few complete shells, few fine lenses ferromanganese coated and fine $CaCO_3$ nodules, mica sand coats to few ped faces, common fine manganese nodules, few fine gypsum crystals.

Pit Nr:	T188
Soil class:	Jb
Land class:	U2s/R2g
Location:	Line P 1.75E
API legend:	Jb
Topography:	Flat plain
Micro-relief:	(M1)
Vegetation:	60% tree cover, **Acacia nilotica**
Surface:	Light grey brown capped surface, sink holes around cracks.
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A heavy textured coarse structured clay, increase in both calcium carbonate and gypsum at depth. Well developed pores and well rooted to two metres.

Horizon	Depth (cm)	Description
A1	0-40	Dark brown (10YR 3/3) heavy clay loam, weak coarse prismatic to moderate fine subangular blocky structure dry hard, low organic matter content, many very fine vertical and horizontal cracks, many fine pores, many fine roots,medium roots, few very fine shell fragments. Gradual smooth boundary to:
B1t	40-85	Dark brown (10YR 3/3) clay weak fine wedge structure, slightly moist extremely firm, common fine vertical cracks, many fine pores, common fine roots. Many fine 1 mm manganese concretions, common fine shell fragments, common very fine $CaCO_3$ concretions, weak slickensides. Gradual smooth boundary to:
B2t	85-180	Dark brown (10YR 3/3) clay, moderate medium subangular blocky structure, moist firm, few fine cracks, few fine pores, few fine roots, many fine manganese concretions, few shell fragments, common fine patches 1 to 5 mm $CaCO_3$ and gypsum powdery concretions, nodules and crystals.

Pit Nr:	T189
Soil class:	Jmxl
Land class:	4s(U3s/R2s)
Location:	Line P 0.0
API legend:	Jmx
Topography:	Low levee in meander complex
Micro-relief:	Flat
Vegetation:	Fl
Surface:	Light brown, slightly capped irregular cracks cracks.
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

Dark yellowish brown very fine sandy clay loam and sandy loam surface horizons are moderately well structured angular blocky with abundant fine pores and common roots. The dark brown silt clay and clay subsoil below 42 cm is more coarsely structured with medium vertical cracks, few fine pores and roots. There are mica sand coats to ped faces throughout the profile with fine carbonates below 80 cm and gypsum at 120 cm.

Horizon	Depth (cm)	Description
A1	0-18	Dark yellowish brown (10YR 3/4) very fine sandy clay loam, moderate fine crumb to granular structure, dry slightly hard, abundant fine pores, common fine roots. Few fine shell fragments and shells. Gradual smooth boundary to:
B1	18-42	Dark yellowish brown (10YR 3/6) very fine sandy loam, weak medium subangular blocky structure, dry hard, abundant fine pores common fine roots. Abundant fine mica sand flakes. Clear smooth boundary to:
B2	42-80	Dark yellowish brown (10YR 3/4) light silt clay, moderate medium to coaarse prismatic to medium angular blocky structure, moist extremly firm, common medium vertical cracks, few fine pores, common fine roots. Many fine shell fragments near top of horizon. Fine mica sand coats to all ped faces, weak cutans, common fine manganese nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B3	80-120	Dark brown (10YR 3/3) with common medium black manganese stains, clay, weak coarse prismatic to medium angular blocky structure, moist extremely firm, common medium vertical cracks, few fine cracks, many fine pores, many fine roots. Common sand coats on ped faces, weak cutans, common very fine $CaCO_3$ nodules, common fine shell fragments. Gradual smooth boundary to:
C1	120-300 200 + augured	Dark brown (10YR 3/3) clay, weak medium wedge structure, moist extremely firm, few vertical and horizontal cracks, few fine pores, few fine roots. Patchy slickensides, common medium distinct black manganese stains, common secondary powdery carbonates and gypsum crystals.
C21	300-380	Dark yellowish brown (10YR 4/4) very fine sandy clay loam, moist friable, very heterogeneous horizon with some patches (10YR 3/4) clay and secondary carbonates and gypsum, very common fine manganese nodules, becoming few fine below 320 cm.
C22	380-500	Brown (10YR 4/3) very fine sandy clay loam moist firm to friable. Occasional fine gypsum crystals, occasional white powdery secondary carbonates. At 480 cm few fine faint yellow brown (10YR 5/4) mottles.

Pit Nr:	T190
Soil class:	Jmxl
Land class	4S(U3s/R2t)
Location:	Line P 2.0W
API legend:	Jmx
Topography:	Basin site in meander complex
Micro-relief:	Uneven gilgai(M2)
Land use:	Maize
Surface:	Brown, medium surface tilth, medium cracks, common shell fragments
Profile drainage:	Imperfect
Depth to water table:	More than 5 m

Brief Description:

A dark brown clay soil with moderate prismatic and wedge structures throughout and finely developed vertical cracks to two metres. Few fine pores and roots extend to two metres. There are well developed slickensides in the subsoil below 30 cm. Secondary carbonates occur throughout the profile with fine manganese nodules and fine gypsum crystals below 80 cm.

Horizon	Depth (cm)	Description
A1	0-30	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, heavy clay loam, low organic matter content, weak medium prismatic to moderate medium subangular blocky structure, dry slightly hard, common medium vertical cracks, many fine pores, common fine roots. Common fine shell fragments, abundant very fine $CaCO_3$ nodules, occasional 1 to 5 mm hard $CaCO_3$ nodules. Diffuse boundary to:
B1	30-80	Dark brown (10YR 3/3), clay, weak coarse wedge structure, slightly moist extremely firm, common medium vertical common fine horizontal and few fine diagonal cracks few fine pores, common fine and few medium roots. Compact horizon. Well developed slickensides, many to abundant very fine $CaCO_3$ nodules, many shell fragments, few 1 to 3 mm $CaCO_3$ nodules. Occasional fine black manganese stains. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	80-200 200 + augered	Dark brown (10YR 3/3) clay, moderate medium wedge structure moist extremely firm, common fine vertical, horizontal and diagonal cracks, few fine pores, few fine roots. Well developed slickensides, common fine shell fragments increasing towards base, many fine 1 to 3 mm $CaCO_3$ nodules, common very fine black manganese nodules, common fine gypsum crystals.
B3	200-380	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, silt clay, moist firm, common fine manganese nodules, few fine $CaCO_3$ and medium manganese nodules, common patches white secondary carbonates, and fine gypsum crystals.
C1	380-450	Brown (10YR 4/3) fine sandy clay loam, moist friable, few medium manganese nodules, few fine $CaCO_3$ nodules. Occasional deposits white powdery secondary carbonates and fine gypsum crystals, few manganese stains.
C2	450-500	Very dark greyish brown (10YR 3/2) few fine faint yellow brown (10YR 5/4) mottles, clay, moist firm, few fine $CaCO_3$ nodules, common deposits secondary white carbonates increasing towards base of horizon, few gypsum crystals.

Pit Nr:	T192
Soil class:	Jb2-3
Land class	U3s/R2g
Location:	Line Q 0.1E
API legend:	Jb
Topography:	Flat plain
Micro-relief:	Moderate gilgai (M2)
Vegetation:	Grassland
Surface:	Friable, dark grey, common shell fragments, common sink holes
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

The surface is a moderate to strongly structured very dark greyish brown heavy clay loam with common cracks, fine pores and roots. Below 20 cm the soil is more massive and wedge structured with dark greyish brown clays, common vertical cracks to two metres, few fine pores and common fine roots. Fine carbonate nodules increase in frequency with depth and there are well developed slickensides in the subsoil.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) heavy clay loam, low organic matter content, moderate to strong medium subangular blocky structure, dry hard, common coarse 7-8 cm vertical and fine horizontal cracks, common fine pores, few medium, common fine roots. Common fine shell fragments, many fine 1 to 3 mm carbonate nodules. Gradual smooth boundary to:
B1	20-52	Dark greyish brown (25YR 4/2) clay, massive weak coarse prismatic structure, slightly moist firm, common fine vertical cracks, few fine pores, common fine and few medium roots. Abundant 2 to 3 mm $CaCO_3$ nodules, common fine secondary carbonate deposits, many fine manganese nodules, occasional lenses 1 to 3 cm powdery secondary carbonates. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	52-90	Dark greyish brown (2.5YR 4/2) clay, weak medium wedge structure, slightly moist extremely firm, common coarse 7 cm vertical cracks, few fine pores, common fine, few medium roots. Well developed diagonal slickensides, common very fine $CaCO_3$ nodules, few fine ferromanganese nodules, few shell fragments. Gradual smooth boundary to:
B3	90-190	Dark greyish brown (2.5YR 4/2) clay, weak to moderate medium wedge structre, slightly moist extremely firm, few coarse vertical, common very fine diagonal cracks, few fine pores, common fine roots. Massive diagonal slickensides, common fine shell fragments, common very fine $CaCO_3$ nodules increasing towards base of horizon few fine manganese nodules.

Horizon	Depth (cm)	Description
B2	52-90	Dark greyish brown (2.5YR 4/2) clay, weak medium wedge structure, slightly moist extremely firm, common coarse 7 cm vertical cracks, few fine pores, common fine, few medium roots. Well developed diagonal slickensides, common very fine $CaCO_3$ nodules, few fine ferromanganese nodules, few shell fragments. Gradual smooth boundary to:
B3	90-190	Dark greyish brown (2.5YR 4/2) clay, weak to moderate medium wedge structre, slightly moist extremely firm, few coarse vertical, common very fine diagonal cracks, few fine pores, common fine roots. Massive diagonal slickensides, common fine shell fragments, common very fine $CaCO_3$ nodules increasing towards base of horizon few fine manganese nodules.

Pit Nr:	T246
Soil class:	Jb3
Land class	U3sg/R3g
Location:	Line O 2.35E
API legend:	Jb
Topography:	Flat basin area between levee complexes
Micro-relief:	Moderate to strong gilgai (M2 to M3)
Vegetation:	Shrub grassland
Surface:	Dry powdery to slightly hard
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Moderately structured very dark greyish brown clay surface horizon becomes prismatic structured below 20 cm and wedge structured below 90 cm. Finely developed vertical cracks occur throughout the profile with strong slickensides below 90 cm. Roots and pores extend to 2 m. Fine carbonate nodules occur throughout the profile with gypsum at 90 cm.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) clay, low organic matter content, moderate medium subangular blocky structure, dry slightly hard, common fine vertical cracks, abundant fine, few medium pores, many fine roots. Common fine $CaCO_3$ nodules, common fine shell fragments, few fine manganese stains. Gradual smooth boundary to:
B1t	20-50	Dark brown (10YR 3/3) with common black manganese stains, clay, weak medium prismatic breaking to fine subangular blocky structure, dry hard common fine and medium vertical, few fine horizontal cracks, common fine pores, common fine roots. Many fine 1 to 3 mm $CaCO_3$ nodules, weak cutans, few fine shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	50-90	Dark brown (10YR 3/3) clay, weak medium prismatic to moderate medium angular blocky structure, slightly moist extremely firm, common medium vertical cracks, few fine tubular pores, common fine roots. Sand coats along crack faces, moderately developed slickensides, many fine 1-2 mm $CaCO_3$ nodules and fine manganese nodules, few fine shell fragments, recent alluvial reddish streaking on ped faces. Gradual smooth boundary to:
B3	90-190	Dark greyish brown (2.5YR 4/2) heavy clay, moderate medium wedge structure, moist extremely firm, few medium vertical common fine diagonal cracks, few fine pores, common fine roots. Strongly developed diagonal slickensides, common fine shell fragments, common sand coatings on ped faces, common fine nodular carbonates, very few fine gypsum crystals, common fine manganese nodules.

Pit Nr:	T247
Soil class:	Jmxl
Land class:	4s(U3st/R2st)
Location:	Line O 1.55E
API legend:	Jmx
Topography:	Low levee area in meander complex
Micro-relief:	Smooth even, scattered 1 to 1.5 m termite hills
Vegetation:	Open woodland **Dobera glabra, Salvadora sp, Thespesia sp**
Surface:	Dry hard, yellowish brown slight surface sand wash
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark yellowish brown clay loam to very fine sandy clay loam textures are weak fine to medium subangular blocky structured to 60 cm with few medium vertical cracks well developed pores and common roots. Structures are more massive in the subsoil with yellowish brown to dark brown colours, no cracks and few roots. Sand coats occur on ped faces throughout the profile with fine shells and shell fragments. Carbonates occur as fine nodules below 60 cm associated with ferromanganese coatings.

Horizon	Depth (cm)	Description
A1	0-20	Dark yellowish brown (10YR 4/4) heavy clay loam, weak fine subangular blocky structure, dry slightly hard, few medium and common fine vertical cracks, common fine, few medium roots. Few fine manganese nodules, few shells and shell fragments, sand coats to ped faces. Gradual smooth boundary to:
B1	20-60	Dark yellowish brown (10YR 4/4) very fine sandy clay loam, weak medium subangular blocky structure, dry hard, few medium few fine diagonal and horizontal cracks, abundant fine pores, common fine, few medium roots. Common fine manganese nodules, few very fine carbonate nodules and broken shells, common mica sand coats to ped faces. Clear smooth boundary to:

Horizon	Depth (cm)	Description
B21	60-120	Yellowish brown (10YR 5/4) very fine sandy clay loam, massive to weak single grain crumb structure, dry slightly hard, very few fine and medium roots. Abundant mica sand coats to ped faces, abundant 2 to 5 mm manganese nodules, abundant 1 to 3 mm $CaCO_3$ nodules, few complete shells, abundant shell fragments. Gradual smooth boundary to:
B22	120-170	Dark brown (7.5YR 4/4) very fine sandy clay loam, massive structureless, dry extremely hard, abundant fine pores, few fine roots. Abundant secondary powdery carbonates in laminar bands, abundant 1 to 5 mm manganese nodules, abundant broken shell fragments and mica sand coats to ped faces.

Pit Nr:	T248
Soil class:	J1
Land class:	U2s/R3s
Location:	Line M 0.95E
API legend:	J1
Topography:	Very slightly undulating low levee area, less than 2% slope to west
Micro-relief:	Weak undulations (M1)
Vegetation:	Cleared for cultivation
Surface:	Ploughed, very cloddy
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark brown moderately well structured very fine sandy clay loams extend to 50 cm with fine vertical cracks, abundant fine pores and common roots. Structure becomes weaker below 50 cm but cracks, pores and roots extend to 160 cm. Below this depth there is a dark brown faintly mottled silt clay with a weak prismatic structure. Mica sand flakes are common throughout the profile. Fine secondary carbonates and gypsum crystals are only found in the deeper subsoil.

Horizon	Depth (cm)	Description
A1	0-20	Dark brown (10YR 3/3) very fine sandy clay loam, moderate medium subangular blocky structure, dry slightly hard, few fine vertical cracks, abundant fine, few medium pores, common fine roots. Some faunal chambers 1 to 2 mm across, common mica sand coats to ped faces, few fine nodules $CaCO_3$. Gradually smooth boundary to:
B1	20-50	Dark brown (7.5YR 3/2) very fine sandy clay loam, moderate medium subangular blocky structure, slightly moist extremely firm, few fine vertical cracks, abundant fine, few medium pores, common fine roots. Abundant fine mica sand flakes, few very weak cutans, few shells and shell fragments. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	50-85	Dark brown (7.5YR 4/4) heavy very fine sandy clay loam, weak medium subangular blocky structure, slightly moist very firm, few fine vertical cracks, abundant fine pores, common fine, few medium roots. Abundant mica sand flakes on ped faces, abundant fine manganese nodules, few shell fragments. Gradual smooth boundary to:
B3	85-160	Dark brown and dark yellowish brown (10YR 3/3 and 3/4) heavy very fine sandy clay loam massive to weak medium prismatic breaking to angular blocky structure, slightly moist extremely firm, few fine vertical cracks, few fine pores. Many mica sand coats to ped faces, common fine manganese stains and few black manganese nodules, few fine shell fragments. Gradual smooth boundary to:
C1	160-190	Dark brown to dark yellowish brown (10YR 3/3 to 3/4) with few faint yellowish brown (10YR 5/4) mottles, silt clay, massive to weak medium prismatic breaking to angular blocky structure, slightly moist extremely firm, few fine roots. Increase in secondary carbonates, many fine gypsum crystals, occasional fine 1 to 3 mm ferro-manganese nodules.

Pit Nr:	T249
Soil class:	Jl
Land class:	U3s/R6s
Location:	Line L 1.55E
API legend:	Jl
Topography:	Low rise in clay plain (possibly old, buried levee)
Micro-relief:	Smooth even
Land Use:	Cotton
Surface:	Dry hard, dark yellowish brown to brown, slightly capped
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Surface horizons are granular and sandy in texture with abundant fine pores and many roots. Below 35 cm there is a band of dark yellowish brown clay with moderate medium subangular blocky structure fine vertical cracks and common pores. Between 80 and 140 cm there is a band of dark yellowish brown very porous very fine loamy sand, this passes into a faintly mottled clay subsoil with moderate subangular blocky structure, few fine vertical cracks and fine pores. Roots extend to 80 cm. The whole profile is dominated by fine mica sand flake coatings on ped faces, carbonate and manganese nodules occur in the deeper subsoil clays.

Horizon	Depth (cm)	Description
A1	0-15	Very dark greyish brown/dark brown (10YR 3/2.5) very fine sandy loam, weak fine single grain to crumb structure, low organic matter content, dry slightly hard, common fine vertical cracks, abundant fine pores, abundant fine roots. Abundant fine $CaCO_3$ nodules, few fine manganese nodules, common mica sand coats to ped faces. Clear wavy boundary to:
IC1	15-35	Dark yellowish brown (10YR 4/6) very fine sand, weak fine single grain to fine crumb structure, dry loose, abundant fine pores, few fine roots. Abundant mica sand coats to ped faces. Clear wavy boundary to:

Horizon	Depth (cm)	Description
IIB1	35-80	Dark yellowish brown (10YR 4/4) with few fine faint red brown (5YR 4/3) mottles, clay, moderate medium subangular blocky to fine subangular blocky structure, dry extremely hard, few medium few fine vertical and horizontal cracks, common fine pores, few fine roots. Few fine $CaCO_3$ nodules, few shell fragments abundant fine manganese nodules, common mica sand coats to ped faces. Gradual smooth boundary to:
IIIBC	80-140	Dark yellowish brown (10YR 4/4) with few faint red and yellow brown (5YR 4/3 and 10YR 5/4) mottles, very fine loamy sand massive to single grain crumb structure, dry loose, abundant fine tubular pores. Common mica sand coats to ped faces, distinctive old root channel pores, common fine manganese nodules, occasional yellow sand inclusion, loose shell sand horizon of varying thickness at base of horizon. Abrupt wavy boundary to:
IVC2	140-195	Dark yellowish brown (10YR 3/4) with few faint red brown (5YR 4/3) mottles, clay, moderate medium subangular blocky structure, dry extremely hard, few fine vertical and horizontal cracks, few fine pores. Abundant manganese nodules and fine stains, few broken shells, abundant 1 to 3 mm $CaCO_3$ nodules few weak cutans, common mica sand coats to ped faces.

Pit Nr:	T250
Soil class:	Jb1-2
Land class	U3s/R2g
Location:	Line K 0.2E
API legend:	Jb
Topography:	Basin area with few minor channels
Micro-relief:	Slightly undulating (M2)
Land use:	Sesame and maize
Surface:	Slight cracking up to 50 mm, dry hard, dark brown, slight mulch
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

Dark brown mottled very fine sandy clay loam to clay loam surface horizons are weak to moderately well structured subangular blocky. Below 66 cm there are weak to moderately structured prismatic to wedge shaped peds in dark brown clays. Fine to medium vertical cracks extend to one metre where they become more diagonal in form. Roots and pores extent throughout the profile. Well developed slickensides occur in the subsoil. Fine carbonate nodules and lenses of carbonates occur below 30 cm with fine gypsum below 1 m.

Horizon	Depth (cm)	Description
A1	0-30	Dark brown (10YR 3/3) with many medium distinct strong brown (7.5YR 5/6) mottles, very fine sandy clay loam, moderate medium subangular blocky structure, dry slightly hard, few fine vertical cracks, many fine pores, common fine roots. Common yellowish brown (10YR 5/4) sand streaks, common fine shell fragments, slightly platy surface. Gradual irregular boundary to :
B1	30-66	Dark brown (10YR 3/3) with common fine distinct yellow brown (10YR 5/4) mottles, clay loam, weak medium subangular blocky structure, slightly moist extremely firm, few fine and medium vertical cracks increasing with depth, few fine pores, common fine roots. Common fine lenses $CaCO_3$ nodules, many fine manganese nodules, common shell fragments, washed down from surface, common very fine nodules of $CaCO_3$, common sand coats on ped faces. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
B2	66-110	Dark brown (10YR 3/3) clay, weak medium to coarse prismatic structure, slightly moist extremely firm, common fine and medium vertical cracks, few fine tubular pores, many fine roots. Moderately well developed slickensides, many fine $CaCO_3$ nodules and shell fragments, common fine manganese nodules. Clear smooth boundary to :
B3	110-200	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, moderate fine to medium wedge structure, moist extremely firm, common fine horizontal and diagonal cracks, few fine pores, common fine roots. Common fine shell fragments, occasional fine gypsum crystals, well developed short slickensides on ped faces, reddish staining and patches of lighter alluvium coating ped faces. Common fine 1 to 2 mm $CaCO_3$ and manganese nodules.

Pit Nr:	T251
Soil class:	Jmxl
Land class	U3s/R1
Location:	Line J 1.0W
API legend:	Jmx
Topography:	Low levee near old channel course
Micro-relief:	Smooth even
Vegetation:	Scrub woodland **Dobera sp. Thespesia sp., Salvadora sp,** palms.
Surface:	Dark brown, slightly moist, scattered termite hills
Profile drainage:	Moderately well
Depth to water table:	More than 5 m

Brief Description:

The surface is a dark brown moderately well structured very heavy very fine sandy clay loam. Below 35 cm there are more weakly structured dark brown clays. At 160 cm there is a massive dark yellowish brown very fine sandy clay loam. Fine vertical cracks extend to 160 cm with fine pores and roots throughout the profile. Carbonates occur below 35 cm usually in fine to medium nodular form.

Horizon	Depth (cm)	Description
A1	0-35	Dark brown (10YR 3/3) heavy very fine sandy clay loam, moderate medium subangular blocky structure, low organic matter content, dry slightly hard, few fine vertical very few fine horizontal cracks, abundant fine pores, abundant fine, few medium roots. Few fine shell fragments, very few fine $CaCO_3$ concretions. Gradual smooth boundary to :
B1	35-60	Brown (10YR 4/3) clay, weak fine subangular blocky to single grain structure, dry hard, very few fine vertical cracks, abundant fine pores, few fine very few medium roots. Common broken shell fragments, abundant fine $CaCO_3$ nodules occasionally ferromanganese coated common fine manganese nodules, very weak cutans zone of $CaCO_3$ accumulation. Gradual smooth boundary to :

Horizon	Depth (cm)	Description
B2	60-160	Dark brown (7.5YR 4/4) clay weak fine subangular blocky to single grain crumb structure, dry hard, very few fine vertical cracks, common fine pores, few medium, few fine roots. Common mica sand coats on ped faces, abundant fine shells and shell fragments, common 5 to 6 mm manganese nodules, few 5 to 6 mm $CaCO_3$ nodules. Diffuse boundary to :
C1	160-370 205 + augered	Dark yellowish brown (10YR 4/6) very fine sandy clay loam, massive, slightly moist firm, common fine, few medium pores, very few fine roots. Abundant mica sand coats on ped faces, few hard $CaCO_3$ nodules, very few fine manganese nodules, few lenses very fine sandy material.
C2	370-390	Brown (10YR 4/3) very fine sand, moist loose, few fine ferromanganese stains.
C3	390-500	Dark yellowish brown, light very fine sandy clay loam, moist, few powdery nodules $CaCO_3$, common fine ferromanganese stains, approaching water table at 500 cm.

Pit Nr:	T253
Soil class:	J1
Land class:	U2s/R1
Location:	Line E 1.2E
API legend:	Jb1
Topography:	Lower slope of Juba levee
Micro-relief:	Smooth even few slight hollows
Land Use:	Fallow, ploughed
Surface:	Very cloddy, red brown
Profile drainage:	Moderately well
Depth to water table:	More than 2 m

Brief Description:

A dark yellowish brown clay loam to clay profile with a granular surface structure becoming moderate prismatic below 30 cm and angular blocky below 80 cm. Finely developed cracks extend to 150 cm associated with fine pores, and roots which extend to 80 cm. Fine carbonate and manganese nodules occur below 30 cm with fine crystalline gypsum below 150 cm.

Horizon	Depth (cm)	Description
A1	0-30	Dark yellowish brown (10YR 4/6) clay loam, weak fine subangular blocky to single grain crumb structure, dry slightly hard, few fine vertical and horizontal cracks, abundant fine pores, common fine roots. Few very fine manganese nodules. Clear wavy boundary to:
B1	30-80	Dark yellowish brown (10YR 3/4) clay, moderate medium prismatic to weak medium subangular blocky structure, slightly moist extremely firm, few fine diagonal, common medium vertical and few medium horizontal cracks, common fine pores, few fine roots. Common sand coats on ped faces of red sands washed down cracks, common fine $CaCO_3$ nodules and shell fragments, common fine ferromanganese stains, common weak cutans. Diffuse boundary to:

Horizon	Depth (cm)	Description
B2	80-150	Dark yellowish brown (10YR 3/4) clay, strong coarse angular blocky breaking to medium angular blocky structure, slightly moist extremely firm, few large coarse vertical, few medium diagonal cracks, very fine pores, no roots. Common mica sand coats to ped faces, common fine to medium $CaCO_3$ nodules, few fine manganese *nodules, well developed slickensides, few shell* fragments. Diffuse boundary to:
B3	150-180	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, moderate medium angular blocky structure, slightly moist extremely firm. Common well developed slickensides and clay skins, common very fine crystalline gypsum, some fine sand inclusions *around ped faces few very fine $CaCO_3$ nodules and fine* manganese nodules.

Pit Nr:	T256
Soil class:	Jmx1
Land class:	U6d/R2g
Location:	Line H 1.8W
API legend:	Jmx
Topography:	Depression in meander complex
Micro-relief:	Uneven gilgai (M2)
Vegetation:	3% tree cover, low scrub and sedges
Surface:	Dry hard, coarse cracks, dark grey, common shell fragments
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

A dark brown faintly mottled clay soil passing into dark yellowish brown distinctly mottled fine sandy loam at 160 cm. Prismatic structures with strongly developed vertical cracks extend to 1 m, the subsoil is weakly structured angular blocky in form. Roots and pores extend throughout the profile. Fine sand lenses are common in the clays. Fine carbonate and manganese nodules occur from the surface with fine gypsum below 20 cm.

Horizon	Depth (cm)	Description
A1	0-30	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles, heavy clay loam, low organic matter content, fine platy surface to 5 cm then weak coarse prismatic structure, dry extremely hard, common medium to coarse vertical cracks, common fine pores, abundant fine roots. Many fine shell fragments at surface, many fine 1 mm $CaCO_3$ nodules, few fine red brown (5YR 4.3) sandstone fragments, few fine 1 to 2 mm manganese nodules. Gradual smooth boundary to:

Horizon	Depth (cm)	Description.
B1	30-70	Variegated dark brown (60 percent) and very dark greyish brown (10YR 3/2 and 3/3) with few fine faint red brown (5YR 4/3) mottles very fine sandy clay, massive to moderate medium subangular blocky structure, dry hard, common medium vertical cracks, common fine pores, common fine roots. Many fine 1 to 3 mm $CaCO_3$ nodules few carbonate filaments, few 1 to 5 mm ferromanganese coated nodules up to 9 cm wide loamy very fine sand lenses at base, common mica sand coats to peds. Diffuse boundary to:
B2	70-120	Dark brown (10YR 3/3) with few fine faint strong brown (7.5YR 5/6) mottles, clay, weak medium prismatic breaking to fine angular blocky structure, moist firm, common fine vertical cracks, few fine pores, common fine roots. Moderately well developed slickensides, many fine 1 to 3 mm ferromananese coated carbonate nodules, common manganese staining at base in thin discontinuous very fine sand lens 3 to 4 cm wide. Clear wavy boundary to:
B3	120-160	Dark brown to dark yellowish brown (10YR 3/3 to 3/4) with common medium distinct strong brown (7.5YR 5/6) mottles, clay strong fine angular blocky to fine crumb structure, moist firm, common fine pores, rare fine roots. Abundant 1 to 10 mm $CaCO_3$ and ferromanganese coated nodules, abundant fine cutans, few fine gypsum crystals. Abrupt smooth boundary to:
C1	160-200	Dark yellowish brown (10YR 3/4) with common meduim distinct strong brown (7.5YR 5/6) mottles, heavy fine sandy loam, single grain structure, extremely moist friable, abundant fine pores rare fine roots. Abundant mica sand flakes, clay movement along pore spaces, common manganese stains.

Pit Nr:	T257
Soil class:	Jmxd
Land class	U3s/R2g
Location:	Line G 0.6W
API legend:	Jmx
Topography:	Flat depression in meander complex
Micro-relief:	Uneven gilgai (M2)
Vegetation:	Sedges and low scrub species
Surface:	Common medium cracks and shell fragments, dry hard
Profile drainage:	Imperfect
Depth to water table:	More than 2 m

Brief Description:

Very dark greyish brown to dark brown clay loam and clay soil. The surface is moderately well structured subangular blocky passing into moderate prismatic structures below 20 cm with fine to medium wedge structure below 120 cm. Fine vertical cracking and fine pores are developed throughout the profile. Roots extend to 190 cm. Well developed slickensides occur below 60 cm, fine carbonate nodules occur from the surface with secondary carbonates and fine gypsum below 120 cm.

Horizon	Depth (cm)	Description
A1	0-20	Very dark greyish brown (10YR 3/2) heavy clay loam, low organic matter content, slightly laminar surface to 5 cm then moderate medium subangular blocky structure, dry hard, common medium (3cm) vertical cracks, few fine pores, many fine roots. Many shells and large shell fragments, many fine $CaCO_3$ nodules common secondary carbonate coatings on ped faces. Clear wavy boundary to:
B1	20-60	Dark brown (10YR 3/3), clay, moderate coarse prismatic to angular blocky structure at base, dry slightly hard, many coarse vertical cracks, few fine pores common fine roots. Abundant fine 1-3 mm $CaCO_3$ nodules, many fine ferromanganese nodules, many shell fragments, charcoal coats to crack faces. Gradual smooth boundary to:

Horizon	Depth (cm)	Description
B2	60-120	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, weak coarse prismatic to moderate medium wedge structure, slightly moist extremely firm, common fine to medium vertical cracks, few fine pores, common fine roots. Well developed slickensides, common very fine shell fragments, and carbonate nodules, occasional patches of powdery carbonates, few fine manganese nodules. Clear smooth boundary to:
B3	120-190	Dark yellowish brown (10YR 3/4) with few medium faint yellow red (5YR 5/6) mottles, light clay, moderate fine to medium wedge structure, moist very firm, very fine horizontal cracks, few fine pores, few fine roots. Many fine gypsum crystals, abundant fine filaments of secondary carbonates, common fine manganese nodules, few fine shell fragments, common fine secondary carbonate nodules and manganese stains well developed slickensides.

Pit Nr: T258

Soil class: Jmxl

Land class U6st/R6st

Location: Line E 2.3W

API legend: Jmx

Topography: Low levee in meander complex

Micro-relief: Moderately undulating

Vegetation: Riverine forest

Surface: Light grey, fine sandy tilth, leaf litter layer

Profile drainage: Imperfect

Depth to water table: More than 2 m

Brief Description:

A weakly structured coarse textured profile. Surface horizons are dark greyish brown to yellowish brown fine sandy clay loams with fine to medium mottles. Between 57 and 84 cm there is a dark brown loamy sand, below this the sand becomes progressively coarser and lighter in colour. Pores and roots extend throughout the profile. Fine manganese stains are common in the subsoil with fine carbonate nodules.

Horizon	Depth (cm)	Description
A1	0-25	Very dark greyish brown (10YR 3/2) with fine faint red brown (5YR 4/3) mottles, fine sandy clay loam, weak medium subangular blocky structure, low organic matter content, dry extremely hard, abundant fine pores, common fine, few medium roots. Gradual smooth boundary to :
B1	25-57	Dark yellowish brown (10YR 3/4) with common medium distint red brown (5YR 4/3) mottles, light fine sandy clay loam, weak medium wedge to subangular blocky structure, dry extremely hard, abundant fine pores, common fine few medium roots. Occasional fine secondary carbonates, abundant fine mica flakes, common black manganese stains, few shell fragments. Gradual smooth boundary to :
B2	57-84	Dark brown (7.5YR 4/4) with fine manganese stains, loamy sand, medium single grain structure, dry slightly hard, abundant fine pores, common fine few medium roots. Abundant fine mica sand flakes, few fine black manganese stains, few fine carbonate nodules, few shell fragments.

Horizon	Depth (cm)	Description
B3	84-150	Dark yellowish brown (10YR 4/4) fine sand, massive single grain, dry slightly hard, common fine, few medium pores, common fine, few medium roots. Common fine manganese stains, common 1-2 mm hard $CaCO_3$ nodules, common fine bands ferromanganese nodules, becoming more compact towards base. Clear smooth boundary to :
C1	150-200	Brown (10YR 4/3) coarse sand, apedal, dry loose, many fine pores, few fine and medium roots. Abundant mica flakes, few fine manganese stains.

APPENDIX III

SELECTED BORE SITE

DESCRIPTIONS

Bore Nr: G048

Soil class: Jb3

Land class: U3sg/R3g

Location: QE 0.3 km

Topography: Weakly undulating flood plain

Vegetation: Open low scrub grassland

Drainage: Moderately well

Surface: Moderately to strongly developed gilgai, fine cracks slightly mulched surface

Depth to water table: More than 2 m

Profile Description

Depth (cm)	Description
0-30	Very dark greyish brown (10YR 3/2) clay, dry loose, common fine carbonate nodules, occasional shell fragments.
30-150	Very dark grey brown (10YR 3/2) fine sandy clay, moist firm, common fine carbonate nodules, occasional patches fine powdery carbonates.
150-200	Very dark greyish brown (10YR 3/2) with few fine faint red brown (5YR 4/3) mottles, fine sandy clay, many fine carbonate nodules, common gypsum crystals and patches white powdery secondary carbonates, common shell fragments, few fine manganese nodules.

Bore Nr: G012

Soil class: Jb2

Land class: U3se/R1

Location: BW 3.2 km

Topography: Flat nearly level plain

Vegetation: Grassland with 5% cover mainly **Dobera glabra**

Drainage: Imperfect

Surface: Slightly capped, many shell fragments, even.

Depth to water table: More than 2 m

Profile Description

Depth (cm)	Description
0-30	Dark yellowish brown (10YR 3/4) very fine sandy clay loam, dry loose, few fine carbonate nodules, many shell fragments.
30-75	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, moist friable, few fine carbonate nodules, some fine powdery secondary carbonates, few shells.
75-130	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, moist firm, few fine carbonates, little secondary carbonates, few shells, few fine manganse nodules.
130-170	Dark brown (10YR 3/3) with common medium distinct red brown (5YR 4/3) mottles, clay, moist firm, few fine carbonates, abundant secondary powdery carbonates and gypsum, few medium manganese nodules.
170-200	Dark brown (0YR 3/3) with common medium distinct red (2.5YR 4/6) mottles, clay, moist firm, few fine carbonate nodules, abundant secondary powdery carbonates, few fine manganese nodules, abundant gypsum crystals.

Bore Nr: G014

Soil class: Jmxl

Land class: U3s/R2s

Location: BW 2.6 km

Topography: Less than 1 degree slopes, slight levee formation

Vegetation: Dense tree cover, **Thespesia daria, Terminalia** sp., **Hyphaene coriacea**

Drainage: Imperfect

Surface: Slightly capped, grass dead twigs and leaf litter, small hummocks

Depth to groundwater table: More than 2 m

Profile Description:

Depth (cm)	Description
0-30	Dark brown (10YR 3/3) light clay loam, dry loose, few fine carbonate nodules.
30-75	Dark yellowish brown (10YR 3/4) heavy clay loam, dry loose, few fine carbonate nodules some powdery secondary carbonates.
75-100	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, heavy clay loam, dry loose, abundant carbonate nodules coarse white nodules up to 10 mm abundant secondary carbonates.
100-170	Dark yellowish brown (10YR 4/4) with common fine faint red brown (5YR 4/3) mottles, very fine sandy clay loam, abundant carbonate nodules up to 10 mm in diameter, few powdery carbonates.
170-200	Dark yellowish brown (10YR 4/4) with common fine faint brown (5YR 4/4) and common fine distinct red brown (5YR 4/3) mottles, very fine sandy clay loam, dry loose, abundant carbonate nodules, abundant carbonate nodules, abundant patches of powdery white carbonates.

Bore Nr:	G019
Soil class:	Jb1
Land class:	U2se/R2t
Location:	BW 0.7 km
Topography:	Less than 1 degree slopes, levee area
Vegetation:	80% tree cover, **Dobera glabra, Thespesia** sp, slight grass cover thin scrub undergrowth
Drainage:	Moderately well
Surface:	Slight surface capping, thin leaf litter layer some large
Depth to groundwater table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-35	Dark brown (10YR 3/3) light silt clay loam, dry loose, very few fine carbonate nodules, occasional shell fragments.
35-130	Dark yellowish brown (10YR 4/4) heavy silt clay loam, dry loose, few fine carbonate nodules, some patches secondary carbonates.
130-200	Strong brown (7.5YR 5/6) with few fine faint yellowish brown (10YR 4/4) mottles, heavy silt clay loam, moist friable, common fine carbonate nodules, abundant secondary powdery carbonate and gypsum crystals.

Bore Nr:	G040
Soil class:	Jbl
Land class:	U2se/R2st
Location:	CE 0.95 km
Topography:	Level plain
Land use:	Tomatoes
Drainage:	Imperfect
Surface:	Slightly capped, many shell fragments, even
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-30	Dark yellowish brown (10YR 3/4) very fine sandy clay loam, dry loose, few fine carbonate nodules, many shell fragments.
30-75	Dark brown (10YR 3/3) with few faint brown (10YR 4/3) mottles, clay loam, moist friable, few fine carbonate nodules, some fine powdery secondary carbonates, few shells.
75-130	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay, moist firm, few fine carbonates, little secondary carbonates, few shells, few fine manganese nodules.
130-170	Dark brown (10YR 3/3) with common medium distinct red brown (5YR 4/3) mottles, clay, moist firm, few fine carbonates, abundant secondary powdery carbonates and gypsum, few medium manganese nodules.
170-200	Dark brown (10YR 3/3) with common medium distinct red (2.5YR 4/6) mottles, clay, moist firm, few fine carbonate nodules, abundant secondary powdery carbonates, few fine manganese nodules, abundant gypsum crystals.

Bore Nr:	T193
Soil class:	Jb1
Land class:	U3ea/R2t
Location:	DE 1.2 km
Topography:	Very weakly undulating
Vegetation:	F1 grassland
Drainage:	Moderately well
Surface:	Dry hard reddish brown, uneven
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-15	Very dark greyish brown (10YR 3/2) heavy clay loam, dry slightly hard.
15-60	Dark brown (10YR 3/3) clay, moist extremely firm, few fine carbonates, few shell fragments.
60-110	Dark brown (10YR 3/3) clay, moist extremely firm, few red brown (5YR 4/3) recent alluvial inclusions.
110-200	Dark brown (10YR 3/3) with few fine faint yellow brown (10YR 5/4) mottles, clay, moist extremely firm, many fine powdery carbonates and fine gypsum crystals.

Bore Nr:	G045
Soil class:	Jmxl
Land class	U2s/R3st
Location:	DW 2.0 km
Topography:	Nearly flat levee unit in meander complex
Vegetation:	Thick bush few emergents **Thespesia** sp and **Hyphaene coriacea**
Drainage:	Moderately well
Surface:	Thin leaf litter layer, fine tilth/mulch, small undulations, few local termitaria
Depth to groundwater table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-25	Very dark greyish brown (10YR 3/2) clay loam, dry loose, few fine calcium carbonate nodules.
25-75	Dark yellowish brown (10YR 3/4) fine sandy loam, dry firm, few fine carbonate nodules, some fine powdery secondary carbonates.
75-120	Dark brown (7.5YR 4/4) fine sandy loam, dry firm, some powdery secondary carbonates with band of abundant secondary carbonates 80 to 90 cm.
120-180	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, clay loam, dry very firm, few fine carbonate nodules and calcium carbonate coated manganese nodules, abundant powdery secondary carbonates and fine gypsum crystals.
180-200	Dark yellowish brown (10YR 4/4) with few fine faint yellowish brown (10YR 5/4) mottles, sand, dry loose, abundant mica sand flakes.

Bore Nr:	T183
Soil class:	Jb3
Land class:	U3sg/R3g
Location:	EW 1.1 km
Topography:	Nearly flat level plain
Land use:	Sesame
Drainage:	Imperfect
Surface:	Dry slightly self mulching, dark brown, many shell fragments and carbonate nodules, irregular cracks, M3 micro-relief
Depth to groundwater table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-30	Very dark grey to very dark grey brown (10YR 3/1.5) clay, dry hard, abundant fine nodular carbonates, common fine shell fragments.
30-60	Very dark grey brown to dark brown (10 YR 3/2.5) clay, slightly moist firm, abundant fine carbonates.
60-160	Very dark greyish brown to dark brown (10 YR 3/2.5) with common fine faint dark brownish red (5YR 3/2) mottles, clay, moist extremely firm, many fine carbonates and shell fragments, common fine manganese nodules.
160-200	Dark brown to dark yellowish brown (10YR 3/3.5) with common fine faint dark red brown (5YR 3/2) mottles, clay, moist extremely firm, common 1 to 3 mm patches powdery carbonates and common fine gypsum crystals, common fine black manganese stains.

Bore Nr:	G123
Soil class:	Jmxd
Land class:	U3st/R3st
Location:	FW 2.4 km
Topography:	Weakly undulating depressional area in meander complex
Land use:	Sesame
Drainage:	Imperfect
Surface:	Medium cracks, grey brown colour, common shell fragments
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-35	Very dark grey brown (10YR 3/2) silt clay loam, dry loose, few fine carbonate nodules, abundant shell fragments.
35-60	Dark brown (10YR 3/3) with few faint yellowish brown (10YR 5/4) mottles, silt clay loam, moist firm, few fine carbonate nodules, common white powdery secondary carbonates.
60-150	Dark yellowish brown (10YR 4/4) with common fine distinct strong brown (7.5YR 5/6) mottles, very fine sandy clay loam, moist firm, few fine carbonate nodules, and fine manganese nodules, abundant white powdery secondary carbonates and fine gypsum crystals.
150-160	Dark yellowish brown (10YR 4/4) with common fine distinct red brown (5YR 4/3) mottles, loamy sand, moist loose, common mica sand flakes.
160-180	Dark yellowish brown (10YR 4/4) with common fine distinct orange brown (2.5YR 4/4) mottles, fine sandy loam, moist friable, few fine manganese nodules and stains, few fine carbonate nodules.
180-200	Dark yellowish brown (10YR 4/4) with common fine distinct red brown (5YR 4/3) mottles, coarse sand, moist loose, abundant mica sand flakes.

Bore Nr:	G104
Soil class:	Jmxl
Land class:	U6east/R6et
Location:	GW 3.5 km
Topography:	Weakly undulating, less than 1 degree, levee area
Vegetation:	Thin riverine forest, **Dobera glabra, Thespesia** sp, **Hyphaene coriaceae**
Drainage:	Imperfect
Surface:	Thin leaf litter, light grey brown, finely cracked, slightly self mulching
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-30	Dark brown (10YR 3/3) silt clay loam, dry loose, few fine carbonate nodules.
30-50	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, silt clay, few fine carbonate nodules, occasional manganese nodules, common white powdery secondary carbonates and fine gypsum crystals.
50-100	Dark yellowish brown (10YR 3/4) clay, moist firm, few fine carbonate nodules.
100-150	Dark yellowish brown (10YR 4/4) with few fine faint red brown (5YR 4/3) mottles, silt clay, moist friable, few 1 to 2 mm carbonate nodules, occasional manganese nodules, some lighter fine sand lenses.
150-180	Dark yellowish brown (10YR 3/4) with common medium distinct red brown (5YR 4/3) mottles, clay, moist firm, few fine carbonate nodules, few fine manganese nodules, and some 3 to 4 mm black/grey nodules, occasional patches secondary carbonates.
180-200	Dark yellowish brown (10YR 4/4) with few fine faint orange red (5YR 4/6) mottles sandy loam, moist friable, few carbonate nodules, and fine gypsum crystals, common mica sand flakes.

Bore Nr:	T165
Soil class:	Jmxd
Land class:	U3s/R2d
Location:	HW 3.05 km
Topography:	On margin of perennially flooded depression in meander complex
Vegetation:	Bare ground after flooding
Drainage:	Imperfect to poor
Surface:	Dry crusted, dark grey, slightly self mulching, many shell fragments
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-15	Very dark grey (10YR 3/1) clay, moist firm, many fine carbonates, few shell fragments.
15-60	Very dark greyish brown to dark brown (10YR 3/2.5) with common fine distinct red brown (5YR 4/3) mottles, clay, very moist firm, common shell fragments, common fine carbonate nodules.
60-130	Dark brown (7.5YR 3/2) with abundant coarse prominant red brown (5YR 4/3) mottles, clay, moist slightly plastic, common fine carbonate nodules.
130-160	Brown to dark brown (10YR to 7.5YR 3/2) with common medium distinct red brown (5YR 4/3) mottles, very fine sandy clay loam, moist sticky, abundant mica sand flakes, few carbonate nodules.
160-200	Brown (7.5YR 4/2) with common fine distinct red brown (5YR 4/3) mottles, silt clay, moist firm, common mica sand flakes, patchy nodules of carbonates and ferromanganese.

Bore Nr:	G119
Soil class:	Jmxd
Land class:	Uβs/R3t
Location:	IW 1.4 km
Topography:	Depression in meander complex
Vegetation:	Thick low scrub with 5% tree cover
Drainage:	Imperfect
Surface:	Dark grey brown, slight mulch, common shell fragments strongly undulating
Depth to ground water table:	More than 2 m

Profile description:

Depth (cm)	Description
0-35	Very dark greyish brown (10YR 3/2) with few fine faint yellowish brown (10YR 5/4) mottles, silt clay loam, few fine carbonates and shell fragments.
35-50	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, silt clay loam, moist firm, few fine carbonate and occasional gypsum crystals, some fine manganese nodules.
50-130	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, silt clay, moist firm, few fine carbonates and occasional gypsum crystals, some powdery white secondary carbonates, few fine manganese nodules.
130-150	Brown (10YR 4/3) loamy sand, moist friable, abundant mica sand flakes, occasional deposits secondary, some fine grey organic matter stains.
150-200	Brown (10YR 4/3) medium sand, moist loose, abundant mica sand flakes, common grey/black organic matter stains.

Bore Nr:	T099
Soil class:	Jmxl
Land class:	U3s/Rst
Location:	JW 1.6 km
Topography:	Very weakly undulating levee complex
Vegetation:	Thick scrub woodland mainly **Hyphaene coriaceae** and **Dobera glabra** .
Drainage:	Imperfect
Surface:	Dry hard, grey brown, scattered large termitaria
Depth to ground water table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-15	Dark brown (10YR 3/3) heavy very fine sandy loam, dry hard, few fine shell fragments.
15-45	Brown (10YR 4/3) light very fine sandy clay loam, dry slightly hard, common mica sand flakes.
45-65	Dark yellowish brown (10YR 3/4) with few fine distinct strong brown (7.5YR 5/6) mottles, silt clay loam, slightly moist firm, few fine carbonate nodules.
65-85	Dark greyish brown (10YR 4/2) clay, moist firm, common mica sand flakes on ped faces.
85-125	Brown (10YR 4/3) with few fine distinct strong brown (7.5YR 5/6) motties, very fine sand/silt clay loam, moist firm, common fine carbonates, common mica sand flakes on ped faces.
125-200	Dark yellowish brown (10YR 4/4) light very fine sandy loam, moist friable, few fine carbonates, common mica sand flakes.

Bore Nr:	T091
Soil class:	Jb2-3
Land class:	U3sg/R3g
Location:	KW 2.0 km
Topography:	Flood plain, uneven
Land use:	Maize
Drainage	Imperfect
Surface:	Dry crusted dark brown, irregular surface cracks, M2/3 micro-relief
Depth to ground water table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-20	Dark greyish brown (10YR 4/2) very fine sandy clay loam, dry hard, common fine mica sand flakes, common fine carbonates.
20-45	Dark brown (10YR 3/3) clay loam, dry slightly hard, mica sand flakes on ped faces, common fine carbonate nodules.
45-90	Dark brown (10YR 3/3) with common fine faint black manganese stains, clay, moist very firm, very few fine carbonate nodules.
90-200	Dark yellowish brown (10YR 3/4) with common fine faint manganese stains, clay, very moist slightly plastic, common fine carbonates and gypsum crystals.

Bore Nr:	T233
Soil class:	Jb1-2
Land class:	U3s/R2g
Location:	LE 0.8 km
Topography:	Margin of Juba river levee
Land use:	F1 (maize)
Drainage:	Imperfect
Surface:	Dry hard, deeply cracked, slightly self mulching
Depth to ground water table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-20	Very dark greyish brown (10YR 3/2) heavy clay loam, dry slightly hard, abundant very fine carbonate nodules.
20-80	Dark brown (10YR 3/3) with few fine faint strong brown (7.5YR 5/6) mottles, light clay, moist firm, common very fine carbonate concretions, common fine shell fragments.
80-200	Dark brown (10YR 3/3) clay, moist very firm, abundant very fine secondary carbonates, common fine black 1 mm nodules manganese.

Bore Nr:	T043
Soil class:	Jb3
Land class:	U3sg/R3g
Location:	LW 2.0 km
Topography:	Flat depressional area in flood plain
Land use:	Maize, sesame, groundnuts
Drainage:	Imperfect
Surface:	Dry hard dark grey brown, scattered shell fragments
Depth to ground water table:	More than 2 m

Profile Description

Depth (cm)	Description
0-30	Very dark greyish brown (10YR 3/2) clay, dry slightly hard, common fine shell fragments.
30-60	Dark brown (10YR 3/3) with common fine faint strong brown (7.5YR 5/6) mottles, clay, slightly moist firm, patchy fine carbonate nodules.
60-110	Dark brown (10YR 3/3) with common medium faint strong brown (7.5YR 5/6) mottles, clay, moist firm, common fine carbonate nodules and powdery secondary carbonates, few fine gypsum crystals.
110-200	Dark brown (10YR 3/3) with common fine faint strong brown (7.5YR 5/6) mottles, clay, moist firm to slightly plastic, patchy fine carbonates, and common fine manganese nodules.

Bore Nr:	T049
Soil class:	Jmxd
Land class:	4S (U3aest/R3t)
Location:	MW 0.8 km
Topography:	Less than 1 degree slopes on margin of levee sub-unit of meander complex
Vegetation:	Shrub woodland, 30% tree cover **Albizzia** sp, **Dobera glabra**
Drainage:	Moderately well
Surface:	*Dry hard, yellowish brown, uneven, many termitaria*
Depth to ground water table:	More than 2 m

Profile Description:

Depth (cm)	*Description*
0-20	Dark brown (10YR 3/3) silt clay loam, dry slightly hard.
20-60	Dark brown (10YR 3/3) silt clay, slightly moist friable, few fine carbonates.
60-110	Dark yellowish brown (10YR 3/4) clay, moist firm, common fine powdery carbonates.
110-150	Dark yellowish brown (10YR 3/4) with few fine distinct strong brown (7.5YR 5/6) mottles, light clay, moist friable, common fine powdery carbonates, occasional 1 cm hard nodules.
150-200	Dark yellowish brown (10YR 4/6) with few fine faint strong brown (7.5YR 5/6) mottles, very fine sandy clay loam becoming lighter at depth, moist friable, common mica sand flakes, occasional hard 1 cm carbonate nodules, common powdery carbonates.

Bore Nr:	T213
Soil class:	Jb2-3
Land class	U6aseg/R3g
Location:	NE 1.4 km
Topography:	Lower slope of Juba levee on flood plain
Vegetation:	F1 grassland
Drainage:	Moderately well
Surface:	Dry hard, brownish grey, irregular surface cracks, M2/3 gilgai
Depth to ground water table:	More than 2 m

Profile Description:

Depth (cm)	Description
0-30	Dark brown (10YR 3/3) heavy clay loam, dry slightly hard, abundant fine carbonate nodules, very coarse vertical cracks, few shell fragments.
30-95	Very dark greyish brown (10YR 3/2), clay, slightly moist firm, many very fine carbonate nodules, very granular structure.
95-200	Dark brown (10YR 3/3) common fine faint red brown mottles, clay, moist extremely firm, many to abundant fine secondary carbonates, common fine black manganese stains and nodules.

Bore Nr:	T071
Soil class:	Jb1-2
Land class	U6eas/R2g
Location:	NW 2.6
Topography:	Mid-slope of levee/flood plain of Juba river
Vegetation:	Mixed stand **Dobera glabra** and **Acacia nilotica**
Drainage:	Moderately well
Surface:	Dry hard, grey brown, irregular cracks, M1/2 gilgai
Depth to ground water table:	More than 2 m

Profile Description

Depth (cm)	Description
0-10	Very dark greyish brown (10YR 3/2) clay, dry hard, many fine carbonate nodules, few shell fragments.
10-30	Dark brown (10YR 3/3) clay, slightly moist firm, common fine carbonate nodules, few powdery secondary carbonates.
30-100	Dark brown (10YR 3/3) clay, moist firm, common very fine powdery granular carbonates.
100-200	Dark brown (10YR 3/3) with few fine faint strong brown (7.5YR 5/6) mottles, clay, moist firm, very granular structure, many fine powdery carbonates and hard nodules.

Bore Nr:	T113
Soil class:	Jb2
Land class	U3st/R3t
Location:	OW 0.4 km
Topography:	Site on margin of old meander channel
Vegetation:	F2, **Dalbergia sp.** and **Thespesia sp.** regrowth
Drainage:	Imperfect
Surface:	Dry hard, dark brown, uneven rolling, many termitaria
Depth to ground water table:	More than 2 m

Profile Description

Depth (cm)	Description
0-20	Brown (10YR 4/3) light silt clay loam, dry very hard.
20-45	Dark brown (10YR 3/3) heavy silt clay loam, slightly moist firm, few fine carbonates, occasional hard nodules.
45-90	Dark brown (10YR 3/3) with common fine faint strong brown (7.5YR 5/6) mottles, silt clay loam, moist firm, common fine carbonates.
90-110	Dark brown (10YR 3/3) with common medium distinct strong brown (7.5YR 5/6) mottles, silt clay, moist friable common fine black manganese nodules and common powdery carbonates.
110-200	Dark yellowish brown (10YR 3/4) with abundant coarse prominent strong brown (7.5YR 5/6) mottles, clay, moist extremely firm, many coarse powdery carbonate deposits, common fine black manganese nodules, common fine carbonate nodules.

Bore Nr:	G082
Soil class:	Jl
Land class	U3se/R1
Location:	PE 2.0
Topography:	Lower slope of present Juba levee
Vegetation:	90% **Acacia nilotica** and **Acacia zanzibaria** trees, no grass cover
Drainage:	Moderately well
Surface:	Fine to medium cracks, flat
Depth to ground water table:	More than 2 m

Profile Description

Depth cm	Description
0-50	Dark brown (10YR 3/3) heavy clay loam, dry loose, common fine carbonate nodules, few medium carbonate nodules, common shell fragments, occasional patches white powdery secondary carbonates.
50-110	Dark brown (10YR 3/3) silt clay, moist very firm, few fine carbonate nodules, few fine manganese nodules, some fine gypsum crystals.
110-170	Dark yellowish brown (10YR 3/4) with few fine faint red brown (5YR 4/3) mottles, clay, moist very firm, common fine carbonate nodules, few fine manganese nodules, abundant gypsum crystals and common white powdery secondary carbonates.
170-200	Dark brown (10YR 3/3) with common medium distinct yellow brown (10YR 5/4) mottles, fine sandy clay, moist very firm, common fine carbonate nodules, occasional manganese nodules, common fine powdery secondary carbonates and fine gypsum crystals.

Bore Nr:	G080
Soil class:	Jb3
Land class	U3sg/R3g
Location:	PE 1.2
Topography:	Moderately undulating flood plain area
Vegetation:	**Acacia zanzibaria** with grass species
Drainage:	Imperfect
Surface:	Common sink holes and fine cracks
Depth to ground water table:	More than 2 m

Profile Description

Depth (cm)	Description
0-30	Very dark greyish brown (2.5YR 3/2) heavy clay loam, dry loose, common fine carbonate nodules, common shell fragments.
30-50	Very dark greyish brown (2.5YR 3/2) clay, moist firm, common fine carbonate nodules, common shell fragments.
50-120	Very dark greyish brown (2.5YR 3/2) with few fine faint brown (10YR 4/3) mottles, silt clay, moist firm, common fine carbonate nodules, few fine manganese nodules, rare fine powdery secondary carbonates, and some fine gypsum crystals occasional shell fragments.
120-170	Dark brown (10YR 3/3) with few fine faint red brown (5YR 4/3) mottles, silt clay, moist firm, common fine carbonate nodules, few fine manganese nodules, abundant powdery secondary carbonates and gypsum crystals.
170-200	Very dark greyish brown (10YR 3/2) with few fine faint yellowish brown (10YR 5/4) mottles with few medium distinct red (2.5YR 4/6) mottles at base of horizon, silt clay, moist very firm, common fine carbonate nodules, occasional fine manganese nodules, very abundant powdery white secondary carbonates and gypsum crystals.

Bore Nr:	G094
Soil class:	J1
Land class	U2s/R3s
Location:	QE 2.55 km
Topography:	Weakly undulating to flat plain
Vegetation:	Cultivated fallow
Drainage:	Imperfect
Surface:	Slightly capped, yellowish brown, fine cracks and sink holes.
Depth to ground water table:	More than 2 m

Profile Description

Depth (cm)	Description
0-30	Dark yellowish brown (10YR 4/4) very fine sandy loam, dry loose, few fine carbonate nodules, occasional shell fragments.
30-50	Dark brown (10YR 3/3) clay loam, moist firm, few fine carbonate nodules, occasional shell fragments.
50-110	Dark brown (10YR 3/3) with few fine faint brown (10YR 5/3) mottles, clay loam moist firm, few fine carbonate nodules, occasional shell fragments, few fine manganese nodules, common fine gypsum crystals.
110-150	Very dark grey brown to dark brown (10YR 3/2 to 3/3) with few fine distinct brown (10YR 4/3) mottles, clay, moist firm, common fine carbonate nodules, few fine manganese nodules, common fine gypsum crystals, and common powdery secondary carbonates increasing towards base.
150-200	Very dark greyish brown (10YR 3/2) with common fine distinct brown (10YR 4/3) mottles, clay, inclusions as above horizon.

APPENDIX IV

BORE ANALYSIS RESULTS

APPENDIX IV

BORE ANALYSIS RESULTS

IV.1 Bore Analysis Results

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T001/1	0-25	Jmxl	8.44	7.86	1.25	0.86		
T001/2	25-50		8.64	8.05	2.80	4.38	35.42	12.3
T001/3	50-100		8.21	8.03	10.01	4.82	22.61	21.3
T001/4	100-150		8.14	8.09	8.48	1.87	23.65	7.9
T002/1	0-25	Jd2	8.00	7.62	1.43	0.41		
T002/2	25-50		8.20	7.65	0.78	0.54		
T002/3	50-100		8.15	7.67	1.16	1.03	17.40	5.9
T002/4	100-150		8.00	7.78	2.72	1.49	18.75	7.0
T003/1	0-25	Jmxl	7.89	7.60	1.70	0.21		
T003/2	25-50		8.00	7.70	2.16	0.23		
T003/3	50-100		8.11	7.86	3.50	3.36	24.33	13.5
T003/4	100-150		8.17	8.01	10.32	6.70	21.40	31.3
T004/1	0-25	Jb1	8.34	7.76	1.29	0.73		
T004/2	25-50		8.28	7.80	1.88	0.63		
T004/3	50-100		8.64	8.00	2.02	2.15	29.30	7.3
T004/4	100-150		8.11	7.84	4.89	1.15	28.13	4.0
T007/1	0-25	Jb1	8.27	7.75	0.99	0.24		
T007/2	25-50		8.24	7.78	1.04	0.40		
T007/3	50-100		8.06	7.75	3.40	0.46		
T007/4	100-150		7.84	7.76	6.09	0.72		
T011/1	0-25	BM	8.00	7.45	1.15	0.10		
T011/2	25-50		7.92	7.15	0.56	0.12		
T011/3	50-100		8.62	7.95	0.83	0.32		
T011/4	100-150		8.37	7.98	0.87	0.20		
T013/1	0-25	Jd1	8.21	7.71	1.92	1.40	36.16	3.8
T013/2	25-50		8.15	7.80	4.70	7.29	27.29	26.7
T013/3	50-100		8.42	8.06	6.51	9.45	23.35	40.4
T015/1	0-25	BM	7.32	6.86	1.01	0.15		
T015/2	25-50		7.50	6.78	0.72	0.13		
T015/3	50-100		8.47	7.85	0.90	0.21		
T015/4	100-150		8.60	7.96	0.77	0.35		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T017/1	0-25	Jdl	7.84	7.38	1.19	0.47		
T017/2	25-50		8.26	7.68	1.61	2.30	23.30	9.8
T017/3	50-100		8.06	7.71	3.10	3.92	35.62	11.0
T017/4	100-150		7.87	7.57	5.33	1.49	27.80	5.3
T018/1	0-25	Jt	7.79	7.42	2.62	0.22		
T018/2	25-50		8.31	7.65	1.04	0.34		
T018/3	50-100		8.60	7.80	1.08	0.86		
T018/4	100-150		8.11	7.71	3.11	0.20		
T035/1	0-25	Jmxl	8.20	7.79	1.22	0.20		
T035/2	25-50		8.50	8.00	1.37	0.26		
T035/3	50-100		8.45	7.95	1.03	0.31		
T035/4	100-150		8.42	7.85	0.78	0.33		
T037/1	0-25	Jmxd	8.24	7.67	1.06	0.42		
T037/2	25-50		8.12	7.59	0.96	0.56		
T037/3	50-100		8.18	7.71	1.31	0.62		
T037/4	100-150		8.19	8.02	6.57	2.00	23.53	8.4
T039/1	0-25	Jl	8.17	7.77	1.35	0.58		
T039/2	25-50		8.53	7.91	1.12	1.08	30.24	3.5
T039/3	50-100		8.21	7.93	6.28	3.42	26.34	12.9
T039/4	100-150		8.20	8.02	5.98	0.98		
T041/1	0-25	Jb3	8.16	7.66	0.90	0.28		
T041/2	25-50		8.11	7.67	1.43	0.40		
T041/3	50-100		8.34	7.79	0.92	0.65		
T041/4	100-150		8.22	7.81	1.04	0.47		
T043/1	0-25	Jb3	7.92	7.68	1.85	0.56		
T043/2	25-50		8.11	7.72	1.31	0.58		
T043/2	50-100		8.07	7.77	1.28	0.34		
T043/3	100-150		8.19	7.89	4.15	2.10	31.11	6.7
T045/1	0-25	Jmxl	8.25	7.79	0.80	0.26		
T045/2	25-50		8.44	7.92	0.74	0.31		
T045/3	50-100		8.67	8.21	0.83	1.10	18.79	5.8
T045/4	100-150		8.76	8.32	3.29	1.13	14.6	7.7
T047/1	0-25	Jmxl	8.26	7.86	1.49	0.13		
T047/2	25-50		8.36	7.91	0.88	0.18		
T047/3	50-100		8.32	7.91	1.05	0.26		
T047/4	100-150		8.64	8.07	0.61	0.14		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T049/1	0-25	Jmxd	8.23	7.90	1.70	0.73		
T049/2	25-50		8.79	8.25	1.11	1.38	20.06	6.8
T049/3	50-100		8.78	8.36	3.50	5.38	20.25	26.5
T049/4	100-150		8.55	8.34	8.66	5.18	22.17	23.3
T051/1	0-25	Jmxd	8.08	7.78	1.13	0.29		
T051/2	25-50		8.16	7.77	1.25	0.31		
T051/3	50-100		8.46	7.87	0.51	0.22		
T051/4	100-150		8.55	7.88	0.60	0.20		
T053/1	0-25	Jmxd	8.13	7.77	1.16	0.21		
T053/2	25-50		8.07	7.78	1.88	0.28		
T053/3	50-100		8.05	7.78	2.08	0.22		
T053/4	100-150		8.27	7.84	2.06	0.24		
T055/1	0-25	Jbl	7.89	7.67	3.90	0.27		
T055/2	25-50		7.92	7.55	3.60	0.48		
T055/3	50-100		8.05	7.78	4.70	1.10	23.61	3.8
T055/4	100-150		8.21	7.99	7.45	3.05	30.47	10.0
T057/1	0-25	Jt	8.30	8.02	4.30	0.20		
T057/2	25-50		8.31	7.78	1.00	0.11		
T057/3	50-100		8.52	7.95	1.15	0.56		
T057/4	100-150		8.72	8.10	1.97	1.00	19.05	5.2
T059/1	0-25	Jt	8.27	7.78	1.05	0.31		
T059/2	25-50		8.86	8.00	1.63			
T059/3	50-100		8.26	8.09	8.63	2.00	18.25	10.9
T059/4	100-150		8.69	8.40	10.87	4.82	19.30	2.5
T061/1	0-25	Jmxd	8.16	7.76	1.05	0.15		
T061/2	25-50		8.31	7.77	0.64	0.29		
T061/2	50-100		8.44	7.92	0.87	0.82		
T061/3	100-150		8.33	7.96	2.00	0.78		
T063/1	0-25	Jmxd	8.20	7.76	1.11	0.40		
T063/2	25-50		8.17	7.76	1.10	0.44		
T063/3	50-100		8.32	7.82	1.00	0.90		
T063/4	100-150		8.19	8.11	2.28	1.37	27.10	5.0
T065/1	0-25	Jmxd	8.30	7.82	1.53	0.22		
T065/2	25-50		8.62	7.95	1.10	0.58		
T065/3	50-100		8.72	8.12	1.03	1.07	19.55	5.4
T065/4	100-150		8.62	8.16	1.72	0.84		
T067/1	0-25	Jmxl	8.00	7.79	2.50	0.25		
T067/2	25-50		7.90	7.77	3.30	0.28		
T067/3	50-100		7.87	7.76	3.40	0.30		
T067/4	100-150		8.02	7.82	3.00	0.17		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T069/1	0-25	Jb1	8.44	7.81	1.12	0.45		
T069/2	25-50		8.35	7.86	1.26	0.59		
T069/3	50-100		8.00	7.85	3.40	0.34		
T069/4	100-150		8.57	7.89	0.78	0.66		
T071/1	0-25	Jb1	8.03	7.75	2.40	0.54		
T071/2	25-50		8.10	7.70	2.08	0.53		
T071/3	50-100		8.53	8.37	11.81	7.75	26.10	29.6
T071/4	100-150		8.12	7.77	6.96	5.41	28.92	18.7
T073/1	0-25	Jb3	7.90	7.46	1.34	0.19		
T073/2	25-50		8.27	7.61	1.17	2.26	24.13	9.3
T073/3	50-100		8.47	7.93	2.50	7.30	26.58	27.4
T073/4	100-150		8.04	7.70	6.09	2.75	29.12	9.4
T083/1	0-25	Jb1	8.33	7.79	1.25	0.48		
T083/2	25-50		8.49	7.98	1.33	1.10	33.80	3.2
T083/3	50-100		8.72	8.05	0.93	3.88	31.42	12.3
T083/4	100-150		8.23	7.93	6.20	3.12	7.35	4.2
T085/1	0-25	Jmxl	7.84	7.62	3.27	0.13		
T085/2	25-50		7.81	7.61	3.43	0.49		
T085/3	50-100		7.94	7.73	4.15	0.22		
T085/4	100-150		8.23	7.81	1.47	0.24		
T087/1	0-25	Jmxd	8.05	7.64	0.93	0.10		
T087/2	25-50		8.25	7.84	1.00	0.24		
T087/3	50-100		8.30	7.86	1.08	0.28		
T087/4	100-150		8.37	7.89	1.02	0.28		
T089/1	0-25	Jmxd	8.07	7.63	1.08	0.50		
T089/2	25-50		7.66	7.36	1.42	0.64		
T089/2	50-100		8.12	7.66	1.14	0.54		
T089/3	100-150		8.14	7.92	1.75	0.59		
T091/1	0-25	Jb2-3	8.13	7.67	0.99	0.20		
T091/2	25-50		8.17	7.61	0.86	0.50		
T091/3	50-100		8.42	7.71	0.96	0.82		
T091/4	100-150		8.44	7.89	1.52	1.00	28.70	3.4
T093/1	0-25	Jb2	8.05	7.57	1.64	0.26		
T093/2	25-50		8.31	7.81	0.83	0.30		
T093/3	50-100		8.32	7.75	1.28	0.24		
T093/4	100-150		8.62	7.92	1.63	0.38		
T095/1	0-25	Jb1-2	8.14	7.75	0.98	0.20		
T095/2	25-50		8.25	7.77	1.20	0.20		
T095/3	50-100		8.37	7.84	0.75	0.60		
T095/4	100-150		8.82	8.04	0.85	0.94		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T097/1	0-25	Jmxl	8.02	7.65	1.33	0.18		
T097/2	25-50		8.34	7.84	0.84	0.40		
T097/3	50-100		7.98	7.73	2.89	0.28		
T097/4	100-150		7.97	7.75	3.01	0.18		
T099/1	0-25	Jmxl	8.11	7.67	1.65	0.24		
T099/2	25-50		8.20	7.71	0.86	0.26		
T099/3	50-100		8.15	7.68	0.87	0.36		
T099/4	100-150		8.46	7.81	0.92	0.26		
T101/1	0-25	Jmxd	8.04	7.72	1.18	0.24		
T101/2	25-50		8.11	7.71	1.06	0.43		
T101/3	50-100		7.93	7.73	3.80	0.75		
T101/4	100-150		8.04	7.84	5.87	0.44		
T103/1	0-25	Jb1	7.82	7.49	1.44	0.21		
T103/2	25-50		8.22	7.81	1.12	0.39		
T103/3	50-100		8.25	7.82	0.98	0.68		
T103/4	100-150		8.40	8.16	1.77	1.69	25.85	6.5
T105/1	0-25	Jb3	8.37	7.77	1.09	0.20		
T105/2	25-50		8.36	7.88	0.84	0.40		
T105/3	50-100		8.24	7.82	1.33	0.58		
T105/4	100-150		8.47	7.87	1.30	1.05		
T107/1	0-25	Jb2-3	8.27	7.76	0.74	0.68		
T107/2	25-50		8.52	7.85	1.01	1.24	33.95	3.6
T107/3	50-100		8.49	7.89	1.37	1.68	34.69	4.8
T107/4	100-150		8.20	7.96	5.98	4.25	33.05	12.8
T109/1	0-25	Jb3	8.02	7.73	1.55	0.15		
T109/2	25-50		8.38	7.82	0.96	0.34		
T109/3	50-100		8.60	7.90	0.73	1.00	26.25	3.8
T109/4	100-150		8.27	7.84	3.15	2.95	29.72	9.9
T111/1	0-25	Jmxl	8.01	7.58	1.52	0.13		
T111/2	25-50		8.21	7.76	1.06	0.29		
T111/3	50-100		8.48	7.96	0.90	0.38		
T111/4	100-150		9.04	8.25	1.51	2.80	16.95	16.5
T113/1	0-25	Jmxd	8.20	7.78	1.51	0.18		
T113/2	25-50		8.14	7.69	0.90	0.27		
T113/3	50-100		7.98	7.68	2.66	0.33		
T113/4	100-150		8.04	7.74	2.67	0.29		
T115/1	0-25	Jmxl	8.34	7.95	1.53	0.34		
T115/2	25-50		8.31	7.89	1.42	0.24		
T115/3	50-100		7.98	7.81	3.75	0.53		
T115/4	100-150		8.17	7.96	5.00	0.72		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T117/1	0-25	Jmxl	8.12	7.60	1.23	0.18		
T117/2	25-50		7.94	7.68	1.96	0.50		
T117/3	50-100		8.12	7.72	0.93	0.44		
T117/4	100-150		8.32	7.83	1.01	0.24		
T119/1	0-25	Jmxd	7.74	7.44	1.53	0.50		
T119/2	25-50		8.03	7.63	1.20	0.40		
T119/3	50-100		8.08	7.66	1.28	0.44		
T119/4	100-150		8.04	7.71	2.01	0.49		
T121/1	0-25	Jmxd	8.05	7.60	1.02	0.20		
T121/2	25-50		8.04	7.63	0.90	0.21		
T121/3	50-100		8.32	7.79	0.86	0.54		
T121/4	100-150		8.04	7.84	4.24	0.96		
T123/1	0-25	Jmxl	8.10	7.68	1.60	0.18		
T123/2	25-50		8.00	7.67	2.06	0.64		
T123/3	50-100		8.25	7.85	2.43	0.15		
T123/4	100-150		8.45	7.89	2.70	3.62	30.34	11.9
T131/1	0-25	Jt	8.06	7.55	1.37	0.58		
T131/2	25-50		8.56	7.99	2.52	3.37	27.25	12.3
T131/3	50-100		8.27	8.02	6.63	0.38		
T141/1	0-25	Jmxl	8.16	7.77	1.13	0.31		
T141/2	25-50		8.40	7.79	1.08	0.25		
T141/3	50-100		8.56	7.78	0.66	0.20		
T141/4	100-150		7.90	7.76	8.59	11.75	33.85	34.7
T143/1	0-25	Jmxl	8.12	7.77	2.10	0.43		
T143/2	25-50		8.64	8.23	2.82	0.67		
T143/3	50-100		9.00	8.64	3.20	4.29	20.34	21.0
T143/4	100-150		8.97	8.55	3.59	7.07	20.5	34.4
T145/1	0-25	Jmxd	7.94	7.66	1.55	0.64		
T145/2	25-50		8.26	7.77	0.96	0.62		
T145/3	50-100		8.28	7.76	0.81	0.55		
T145/4	100-150		8.26	7.92	3.72	2.19	26.1	8.3
T147/1	0-25	Jmxd	8.07	7.66	1.15	0.24		
T147/2	25-50		8.26	7.74	0.86	0.34		
T147/3	50-100		8.33	7.89	0.92	0.09		
T147/4	100-150		8.50	7.83	0.95	0.13		
T149/1	0-25	BM	7.92	7.63	1.31	0.16		
T149/2	25-50		8.25	7.79	1.57	0.22		
T149/3	50-100		8.69	8.02	1.72	0.86		
T149/4	100-150		8.36	8.13	10.33	7.37	17.82	41.3

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T151/1	0-25	Jb/Jt	8.62	7.98	0.09	0.42		
T151/2	25-50		8.72	8.24	2.31	4.48	24.91	17.9
T151/3	50-100		8.01	7.91	8.7		20.50	
T153/1	0-25	Jbl	8.28	7.63	1.14	0.47		
T153/2	25-50		8.69	7.80	0.82	0.60		
T153/3	50-100		8.76	7.97	2.25	5.44	32.5	16.7
T153/4	100-150		8.05	7.79	7.93	1.05	28.65	3.6
T155/1	0-25	Jmxd	7.53	6.94	0.74	0.31		
T155/2	25-50		9.31	7.61	0.62	0.48		
T155/3	50-100		8.34	7.70	0.75	0.62		
T155/4	100-150		8.26	7.69	1.06	5.14	29.50	17.4
T157/1	0-25	Jbl	7.32	7.12	0.04	0.55		
T157/2	25-50		8.14	7.67	0.66	0.48		
T157/3	50-100		7.81	7.74	1.18	0.79		
T157/4	100-150		8.12	7.62	0.87	0.82		
T159/1	0-25	Jmxd	7.89	7.48	1.06	0.42		
T159/2	25-50		8.11	7.71	1.30	0.47		
T159/3	50-100		8.19	7.96	3.30	1.82	20.8	8.7
T161/1	0-25	Jmxd	7.87	7.51	1.37	0.28		
T161/2	25-50		8.24	7.83	0.93	0.26		
T161/3	50-100		7.99	7.77	3.85	0.26		
T161/4	100-150		7.97	7.80	3.70	0.17		
T163/1	0-25	Jbl	8.23	7.88	3.40	0.25		
T163/2	25-50		8.36	8.07	0.64	2.00	32.75	6.1
T163/3	50-100		8.44	8.22	10.81	4.20	25.30	16.6
T163/4	100-150		8.42	8.26	10.11	9.37	23.50	39.8
T165/1	0-25	Jmxd	8.06	7.61	0.97	0.35		
T165/2	25-50		8.33	7.75	0.74	0.48		
T165/3	50-100		8.29	7.78	1.48	0.44		
T165/4	100-150		8.17	7.75	1.73	0.64		
T167/1	0-25	Jmxd	8.36	7.79	1.08	0.54		
T167/2	25-50		8.33	7.83	1.23	0.22		
T167/3	50-100		8.68	7.93	1.07	2.16	36.65	5.9
T167/4	100-150		7.97	7.78	4.89	1.60	27.70	5.7
T169/1	0-25	Jbl	8.28	7.67	0.76	0.35		
T169/2	25-50		8.59	7.87	0.64	0.18		
T169/3	50-100		8.58	7.88	0.76	0.45		
T169/4	100-150		8.25	7.81	1.42	0.40		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T171/1	0-25	Jmxl	8.25	7.85	1.60	0.20		
T171/2	25-50		7.87	7.39	0.98	0.24		
T171/3	50-100		8.03	7.79	1.62	0.45		
T171/4	100-150		8.54	7.83	0.42	0.08		
T173/1	0-25	Jb3	8.41	7.78	0.60	0.31		
T173/2	25-50		8.54	7.84	0.54	0.55		
T173/3	50-100		8.73	7.89	0.74	0.50		
T173/4	100-150		8.39	7.89	2.23	3.02	31.92	9.4
T175/1	0-25	Jdl	7.95	7.56	2.25	0.40		
T175/2	25-50		8.61	7.88	0.81	0.22		
T175/3	50-100		8.65	7.98	1.90	2.06		
T175/4	100-150		8.07	7.87	7.93	7.00	27.65	25.3
T177/1	0-25	Jmxl	8.45	7.87	0.97	0.46		
T177/2	25-50		8.22	7.73	1.00	0.27		
T177/3	50-100		8.24	7.93	4.35	1.10	31.75	3.4
T177/4	100-150		8.14	7.96	5.87	0.35		
T179/1	0-25	Jmxl	8.11	7.51	0.65	0.04		
T179/2	25-50		8.28	7.77	0.75	0.20		
T179/3	50-100		8.48	7.87	0.88	0.39		
T179/4	100-150		8.38	7.89	1.07	0.83		
T181/1	0-25	Jmxd	8.18	7.67	1.34	0.14		
T181/2	25-50		8.52	7.87	0.46	0.79		
T181/3	50-100		8.61	7.93	0.55	1.19		
T181/4	100-150		8.39	7.79	1.30	0.10		
T183/1	0-25	Jb3	8.18	7.68	1.08	0.35		
T183/2	25-50		8.48	7.76	0.74	0.47		
T183/3	50-100		8.61	7.89	1.46	0.56		
T183/4	100-150		8.68	8.00	1.48	2.50	30.8	8.1
T185/1	0-25	Jb3	8.33	7.70	0.88	0.16		
T185/2	25-50		8.49	7.78	0.90	0.16		
T185/3	50-100		8.43	7.78	0.88	0.26		
T185/4	100-150		7.90	7.67	2.44	0.13		
T187/1	0-25	Jb2	8.16	7.74	1.38	0.24		
T187/2	msg							
T187/3	50-100		8.54	7.81	1.16	1.08	31.55	3.4
T187/4	100-150		8.39	7.84	2.22	2.50	28.87	8.6
T193/1	0-25	Jbl	8.53	7.79	1.42	2.14	36.75	5.8
T193/2	25-50		8.76	8.36	2.85	7.00	37.18	18.8
T193/3	msg							
T193/4	100-150		8.23	8.05	9.13	4.92	27.6	17.8

Note: msg - sample missing

Site sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T195/1	0-25	Jb3	8.40	7.75	0.87	0.69		
T195/2	25-50		8.33	7.72	1.19	1.10	41.57	2.6
T195/4	100-150		8.47	7.94	2.40	3.25	32.7	9.9
T197/1	0-25	Jb2	8.26	7.76	1.18	0.96		
T197/2	25-50		8.28	7.88	2.15	2.05	37.05	5.5
T197/3	50-100		8.42	8.10	3.50	3.84	37.50	10.2
T199/1	0-25	Jb1	8.24	7.74	1.25	0.94		
T199/2	25-50		8.70	7.92	1.51	2.82	36.65	7.6
T199/3	50-100		8.48	8.10	7.61	6.12	33.42	18.3
T199/4	100-150		8.22	7.69	11.49	0.75		
T202/1	0-25	Jb3	8.10	7.55	0.74	0.68		
T202/2	25-50		8.00	7.59	1.35	0.93		
T202/3	50-100		8.38	7.75	0.83	1.88	36.25	5.1
T202/4	100-150		8.18	8.04	3.30	2.13	28.8	7.3
T205/1	0-25	Jl	8.08	7.68	1.55	0.82		
T205/2	25-50		8.40	7.83	0.78	1.45	30.15	4.8
T205/3	50-100		8.33	7.88	1.70	3.90	30.30	12.8
T205/4	100-150		8.47	7.99	2.60	3.10	29.45	10.5
T207/1	0-25	Jb3	8.11	7.74	0.85	0.31		
T207/2	25-50		8.27	7.77	0.84	0.36		
T207/3	50-100		8.30	7.71	0.92	0.67		
T207/4	100-150		8.13	7.85	3.94	1.94	33.49	5.7
T209/1	0-25	Jb1-2	8.09	7.65	2.05	0.21		
T209/2	25-50		8.21	7.74	0.56	0.35		
T209/3	50-100		8.41	7.75	0.81	0.60		
T209/4	100-150		8.78	8.02	1.53	0.12		
T211/1	0-25	Jb2	8.22	7.72	0.91	0.56		
T211/2	25-50		7.88	7.68	3.85	1.37	36.10	3.7
T211/3	50-100		8.11	7.81	2.70	0.51		
T211/4	100-150		7.98	7.80	7.34	0.34		
T213/1	0-25	Jmxl	8.14	7.75	1.34	0.53		
T213/2	25-50		8.28	7.81	0.89	0.44		
T213/3	50-100		7.93	7.75	4.00	1.74	26.66	6.5
T213/4	100-150		8.16	7.95	5.54	0.16		
T215/1	0-25	Jmxd	7.87	7.38	0.82	0.16		
T215/2	25-50		8.25	7.55	0.78	0.15		
T215/3	50-100		8.16	7.68	1.23	0.21		
T215/4	100-150		8.51	7.85	0.86	0.08		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T218/1	0-25	Jb2-3	8.11	7.70	0.85	0.26		
T218/2	25-50		8.54	7.80	1.06	1.77	38.3	4.6
T218/3	50-100		8.84	7.90	2.50	2.83	36.66	7.7
T218/4	100-150		8.09	7.90	7.24	3.75	10.05	37.3
T219/1	0-25	Jb2-3	8.18	7.68	0.89			
T219/2	25-50		8.33	7.79	1.25	0.59		
T219/3	50-100		7.85	7.61	3.05	0.05		
T219/4	100-150		8.34	7.76	1.32	0.82		
T221/1	0-25	Jmxd	8.07	7.65	1.64	0.48		
T221/2	25-50		8.20	7.75	1.10	0.91		
T221/3	50-100		8.43	7.86	1.32	1.81	31.22	5.7
T221/4	100-150		8.14	7.93	6.05	2.50	28.15	8.8
T224/1	0-25	Jmxd	7.90	7.46	1.06	0.24		
T224/2	25-50		8.00	7.68	1.95	0.45		
T224/3	50-100		8.43	7.78	0.74	0.17		
T224/4	100-150		8.47	7.83	0.64	0.16		
T225/1	0-25	Jb1	8.11	7.62	0.78	0.30		
T225/2	25-50		8.05	7.64	1.46	0.62		
T225/3	50-100		8.28	7.75	1.06	0.05		
T225/4	100-150		8.17	7.83	3.51	2.37	32.78	7.2
T227/1	0-25	Jb2	8.26	7.84	0.65	1.66	39.21	4.2
T227/2	25-50		8.12	7.65	1.02	0.57		
T227/3	50-100		8.40	7.74	1.05	1.92	40.05	4.7
T227/4	100-150		8.02	7.85	7.45	2.27	29.95	7.5
T229/1	0-25	Jb2	8.47	7.79	0.98	0.42		
T229/2	25-50		8.29	7.76	0.76	0.55		
T229/3	50-100		8.25	7.68	0.80	0.62		
T229/4	100-150		8.18	7.78	2.13	0.39		
T231/1	0-25	Jb2	8.27	7.67	0.77	0.44		
T231/2	25-50		8.37	7.70	0.52	0.61		
T231/3	50-100		8.20	7.74	1.43	0.23		
T231/4	100-150		8.22	7.89	3.02	2.96	33.3	8.8
T233/1	0-25	Jb1-2	7.95	7.63	1.44	0.24		
T233/2	25-50		8.03	7.64	1.38	0.20		
T233/3	50-100		8.00	7.76	2.90	0.20		
T233/4	100-150		7.97	7.72	3.86	1.10	28.7	3.8
T235/1	0-25	Jmxl	7.88	7.68	2.71	0.32		
T235/2	25-50		7.94	7.75	2.50	0.48		
T235/3	50-100		8.11	7.86	3.30	1.71	27.65	6.1
T235/4	100-150		8.09	7.90	6.26	3.85	19.88	19.3

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T237/1	0-25	Jb2	8.22	7.77	0.82	0.06		
T237/2	25-50		8.17	7.72	0.98	0.20		
T237/3	50-100		8.25	7.73	0.62	0.21		
T237/4	100-150		8.64	7.94	1.11	0.75		
T239/1	0-25	Jmxd	8.17	7.69	0.86	0.27		
T239/2	25-50		8.23	7.72	0.72	0.25		
T239/3	50-100		8.09	7.99	4.30			
T239/4	100-150		8.05	7.74	3.00	1.31	21.0	6.2
T241/1	0-25	Jmxl	7.96	7.69	1.80	1.07	35.36	3.0
T241/2	25-50		8.08	7.67	2.20	1.77	32.04	
T241/3	50-100		8.06	7.86	7.23	5.12	32.46	5.5
T241/4	100-150		8.78	8.48	6.36	12.50	25.8	48.4
T243/1	0-25	Jmxd	8.48	7.78	0.52	1.04	38.50	2.7
T243/2	25-50		8.07	7.59	0.91	0.47		
T243/3	50-100		8.10	7.65	1.05	0.27		
T243/4	100-150		8.51	7.79	0.74	0.64		
T245/1	0-25	Jmxd	7.78	7.57	2.90	0.86		
T245/2	25-50		8.08	7.69	0.88	0.42		
T245/3	50-100		8.29	7.82	2.76	0.58		
T245/4	100-150		8.12	7.78	2.87	1.00	29.8	3.3
G001/1	0-25	Jb1	7.81	7.44	1.10	0.39		
G001/2	25-50		8.16	7.67	0.80	0.69		
G001/3	50-100		8.23	7.66	1.12	1.23	34.15	3.6
G001/4	100-150		8.39	7.97	3.70	4.72	27.55	17.1
G003/1	0-25	Jb2	7.96	7.55	0.86	0.46		
G003/2	25-50		8.12	7.60	1.03	0.90		
G003/3	50-100		8.22	7.73	1.55	0.90		
G003/4	100-150		7.98	7.71	5.54	0.67		
G006/1	0-25	Jb1	8.10	7.70	1.25	1.03	40.75	2.5
G006/2	25-50		8.66	8.22	1.68	2.79	40.58	6.8
G006/3	50-100		8.13	7.86	5.70	5.71	39.25	14.5
G006/4	100-150		8.26	8.10	8.29	7.62	26.98	28.2
G008/1	0-25	Jb1	8.11	7.66	0.78	0.27		
G008/2	25-50		8.57	8.17	2.72	0.68		
G008/3	50-100		8.05	7.85	8.24	2.36	30.90	7.6
G008/4	100-150		8.13	7.73	3.48	0.27		
G010/1	0-25	Jb1	8.33	7.77	0.84	1.02	39.25	2.5
G010/2	25-50		8.28	7.79	2.70	3.07	37.10	8.2
G010/3	50-100		8.18	7.70	1.41	0.96		
G010/4	100-150		8.20	7.99	11.09	9.70	26.60	36.4

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G012/1	0-25	Jb1	8.21	7.72	0.70	0.17		
G012/2	25-50		8.36	7.80	0.88	0.24		
G012/3	50-100		8.65	8.20	2.55	2.11		
G012/4	100-150		8.17	8.01	8.86	3.12	24.55	12.7
G014/1	0-25	Jmxl	7.91	7.55	1.38	0.11		
G014/2	25-50		8.25	7.76	0.94	0.23		
G014/3	50-100		8.42	7.90	0.64	0.22		
G014/4	100-150		8.65	8.06	0.79	0.11		
G016/1	0-25	Jb3	8.14	7.68	1.15	1.09	34.40	3.1
G016/2	25-50		8.16	7.65	0.96	0.37		
G016/3	50-100		8.02	7.60	1.50	0.33		
G016/4	100-150		8.40	7.85	2.06	2.94	26.51	11.0
G019/1	0-25	Jmxl	8.18	7.78	1.00	0.17		
G019/2	25-50		8.35	7.88	0.83	0.22		
G019/3	50-100		8.28	7.95	1.34	0.26		
G019/4	100-150		8.21	8.02	5.11	0.55		
G020/1	0-25		8.03	7.68	0.41	NIL		
G020/2	25-50		8.38	7.82	0.77	0.41		
G020/3	50-100		8.06	7.72	2.72	0.59		
G020/4	100-150		8.06	7.92	7.84	1.05	19.0	5.5
G022/1	0-25	Jmxl	8.10	7.62	1.34	0.31		
G022/2	25-50		8.12	7.82	1.17	0.21		
G022/3	50-100		7.86	7.52	3.10	0.21		
G022/4	100-150		8.11	7.87	3.70	0.50		
G025/1	0-25	Jb1	8.40	7.72	1.05	1.10	37.77	2.9
G025/2	25-50		7.98	7.70	4.70	1.49	37.78	3.9
G025/3	50-100		8.00	7.86	7.93	4.80	37.27	12.8
G028/1	0-25	Jb1	8.72	7.98	1.19	2.23	37.16	6.0
G028/2	25-50		8.75	8.25	3.70	9.85	37.33	26.3
G028/3	50-100		8.20	8.02	12.28	6.37	36.50	17.4
G028/4	100-150		8.57	8.37	9.46	2.20	11.75	18.7
G030/1	0-25	Jb1	8.00	7.68	1.45	0.13		
G030/2	25-50		7.98	7.78	4.20	NIL		
G030/3	50-100		8.10	8.00	8.37	1.25	19.59	6.3
G030/4	100-150		8.54	8.32	9.24	1.37	18.7	7.3
G032/1	0-25	Jmxl	8.22	7.68	0.85	0.20		
G032/2	25-50		8.43	7.95	0.94	1.29	31.40	4.1
G032/3	50-100		7.97	7.80	5.90	1.35	33.74	4.0
G032/4	100-150		8.34	8.14	9.02	1.37	23.33	5.8

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G062/1	0-25	Jt	8.49	7.77	1.02	0.32		
G062/2	25-50		8.56	7.82	0.54	0.50		
G062/3	50-100		8.60	8.08	1.28	1.39	26.75	5.2
G062/4	100-150		8.65	8.21	2.71	2.68	25.99	10.3
G064/1	0-25	Jmxl	8.35	7.71	0.73	1.09	39.55	2.8
G064/2	25-50		8.47	7.77	0.89	1.99	38.90	5.1
G064/3	50-100		8.21	7.80	3.50	2.98	39.61	7.5
G064/4	100-150		7.97	7.80	6.28	0.70		
G066/1	0-25	Jdl	8.18	7.66	0.82	0.38		
G066/2	25-50		7.89	7.48	0.82	0.37		
G066/3	50-100		8.08	7.71	1.45	0.97		
G066/4	100-150		8.18	7.66	1.49	0.18		
G068/1	0-25	Jd	8.27	7.73	0.84	0.50		
G068/2	25-50		8.24	7.67	0.83	0.65		
G068/3	50-100		8.10	7.75	2.68	2.65	34.85	7.6
G068/4	100-150		8.38	7.90	2.34	2.81	33.3	8.4
G070/1	0-25	Jmxl	8.05	7.56	0.86	0.44		
G070/2	25-50		8.18	7.69	1.17	0.23		
G070/3	50-100		8.24	7.70	0.88	0.20		
G070/4	100-150		8.33	7.82	1.71	0.21		
G072/1	0-25	Jmxd	8.15	7.51	0.62	0.52		
G072/2	25-50		8.40	7.73	0.67	1.08	27.45	3.9
G072/3	50-100		8.02	7.77	4.60	0.72		
G072/4	100-150		8.12	7.93	5.32	1.81	26.10	6.9
G074/1	0-25	Jmxl	8.07	7.61	0.94	0.30		
G074/2	25-50		8.14	7.68	1.17	0.70		
G074/3	50-100		7.89	7.69	4.60	1.08	26.97	4:0
G074/4	100-150		8.05	7.83	3.75	0.63		
G076/1	0-25	Jmxl	8.25	7.80	1.09	0.78		
G076/2	25-50		8.46	7.81	0.95	0.74		
G076/3	50-100		8.33	7.85	1.78	2.06	37.15	5.5
G076/4	msg							
G078/1	0-25	Jbl	8.37	7.80	0.77	0.50		
G078/2	25-50		8.43	7.82	0.78	0.64		
G078/3	50-100		8.31	7.83	1.12	0.87		
G078/4	100-150		8.09	7.78	5.57	0.79		
G080/1	0-25	Jb3	8.31	7.71	0.66	0.91		
G080/2	25-50		8.45	7.78	0.62	0.77		
G080/3	50-100		8.54	7.84	1.10	1.59	40.17	3.9
G080/4	100-150		8.29	7.89	3.41	2.19	35.80	6.1

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G034/1	0-25	Jl	8.38	7.90	0.84	0.11		
G034/2	25-50		8.42	8.00	0.76	0.16		
G034/3	50-100		8.00	7.80	3.50	NIL		
G034/4	100-150		8.64	8.13	1.20	0.55		
G036/1	0-25	Jbl	8.06	7.57	1.75	0.39		
G036/2	25-50		7.91	7.64	2.62	0.74		
G036/3	50-100		7.76	7.55	2.65	0.37		
G036/4	100-150		8.16	7.77	2.06	0.14		
G038/1	0-25	Jbl	8.57	7.85	0.94	3.28	39.25	8.3
G038/2	25-50		8.43	8.00	4.10	10.75	37.89	28.3
G038/3	50-100		8.21	7.97	8.59	5.37	39.01	13.7
G038/4	msg							
G040/1	0-25	Jbl	8.08	7.70	0.94	0.18		
G040/2	25-50		8.06	7.72	1.70	0.26		
G040/3	50-100		7.80	7.64	2.68	0.19		
G040/4	100-150		8.52	8.16	6.52	2.98	25.07	11.9
G042/1	0-25	Jmxl	8.17	7.77	0.68	0.08		
G042/2	25-50		8.21	7.73	0.88	0.28		
G042/3	50-100		8.24	7.67	0.83	0.11		
G042/4	100-150		8.40	7.86	1.41	0.83		
G043/1	0-25	Jmxd	7.51	7.13	1.12	0.20		
G043/2	25-50		8.08	7.53	1.30	0.41		
G043/3	50-100		7.88	7.63	3.80	0.75		
G043/4	100-150		8.49	7.84	0.89	0.58		
G045/1	0-25	Jmxl	7.91	7.48	1.13	0.17		
G045/2	25-50		8.20	7.68	0.96	0.15		
G045/3	50-100		8.31	7.83	1.09	0.15		
G045/4	100-150		8.75	8.07	1.20	0.65		
G047/1	0-25	Jmxl	7.75	7.60	6.45	0.29		
G047/2	25-50		8.28	7.82	1.17	0.16		
G047/3	50-100		8.02	7.79	4.10	0.60		
G047/4	100-150		8.37	8.16	7.50	5.37	24.15	22.2
G049/1	0-25	Jmxl	8.09	7.74	2.41	0.60		
G049/2	25-50		7.95	7.77	4.20	0.54		
G049/3	50-100		8.17	8.04	7.42	1.22	21.61	5.6
G049/4	100-150		9.09	8.74	6.20	9.87	16.3	60.6

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G082/1	0-25	Jl	8.21	7.79	1.13	1.64	35.45	4.6
G082/2	25-50		8.37	7.80	0.95	1.00	35.70	2.8
G082/3	50-100		8.07	7.85	3.45	1.94	33.00	5.8
G082/4	100-150		7.92	7.77	5.91	4.81	26.5	18.2
G084/1	0-25	Jb3	8.14	7.66	0.94	0.69		
G084/2	25-50		8.24	7.72	1.06	0.98		
G084/3	50-100		8.42	7.84	0.74	0.32		
G084/4	100-150		8.18	7.78	2.38	1.56	36.27	4.3
G086/1	0-25	Jb3	7.95	7.50	1.00	0.45		
G086/2	25-50		8.21	7.68	1.46	1.05	41.32	2.5
G086/3	50-100		8.34	7.79	0.99	0.80		
G086/4	100-150		8.22	7.85	2.55	1.42	34.00	4.2
G088/1	0-25	Jb2	7.91	7.45	1.10	0.53		
G088/2	25-50		8.31	7.67	0.97	0.82		
G088/3	50-100		8.26	7.70	1.04	0.77		
G088/4	100-150		8.28	7.85	2.02	1.43	35.45	4.0
G090/1	0-25	Jb1	8.43	7.82	0.96	0.76		
G090/2	25-50		8.40	7.84	1.30	0.88		
G090/3	50-100		8.18	7.81	2.86	0.72		
G090/4	100-150		8.26	7.86	1.38	0.80		
G092/1	0-25	Jb2	8.30	7.74	0.80	0.75		
G092/2	25-50		8.43	7.82	0.64	1.07	41.28	2.5
G092/3	50-100		8.52	7.88	0.73	1.10	40.35	2.7
G092/4	100-150		8.52	7.91	1.24	0.29		
G094/1	0-25	Jl	8.41	7.70	0.90	0.50		
G094/2	25-50		8.57	7.75	0.91	0.92		
G094/3	50-100		8.18	7.60	1.38	0.65		
G094/4	100-150		8.51	7.88	1.75	4.34	33.0	13.2
G096/1	0-25	Jmxd	8.17	7.69	0.87	0.53		
G096/2	25-50		8.15	7.73	1.04	0.70		
G096/3	50-100		8.04	7.63	0.89	0.27		
G096/4	100-150		8.12	7.91	6.06	4.01	25.55	15.7
G098/1	0-25	Jb1	8.42	7.78	0.85	0.63		
G098/2	25-50		8.68	7.90	1.09	1.82	31.85	5.7
G098/3	50-100		8.75	8.10	2.72	6.38	34.00	18.0
G098/4	100-150		8.24	8.03	7.77	1.37	30.8	4.4
G100/1	0-25	Jb2	8.57	7.90	0.74	0.24		
G100/2	25-50		9.02	8.22	1.80	5.32	28.97	18.3
G100/3	50-100		8.49	8.19	6.66	8.77	29.07	30.1
G100/4	100-150		8.29	8.10	12.77	5.62	28.07	20.0

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G102/1	0-25	Jmxl	8.01	7.63	1.34	0.42		
G102/2	25-50		8.40	7.90	1.06	0.38		
G102/3	50-100		8.19	7.94	3.50	0.87		
G102/4	100-150		8.09	7.88	4.24	0.75		
G104/1	0-25	Jmxl	8.30	7.81	2.24	2.52	28.70	8.7
G104/2	25-50		8.12	7.96	8.16	1.25	27.55	4.5
G104/3	50-100		8.08	7.85	6.78	1.37	30.82	4.4
G104/4	100-150		8.55	8.36	11.70	14.57	26.08	55.9
G106/1	0-25	Jmxd	7.96	7.55	1.11	0.25		
G106/2	25-50		8.06	7.70	2.30	0.81		
G106/3	50-100		7.93	7.63	5.17	2.47	30.96	7.9
G106/4	100-150		8.10	7.91	6.81	0.51		
G107/1	0-25	BM	6.88	6.70	0.86	0.08		
G107/2	25-50		7.56	7.00	0.92	0.08		
G107/3	50-100		7.95	7.39	0.84	0.37		
G107/4	100-150		8.88	8.43	10.87	3.26	9.51	34.3
G109/1	0-25	BM	8.20	7.69	0.96	0.18		
G109/2	25-50		8.64	7.91	1.02	0.46		
G109/3	50-100		8.90	8.23	2.11	0.35		
G109/4	100-150		8.99	8.01	1.52	7.71	9.75	79.0
G111/1	0-25	Jmxl	8.08	7.70	1.85	0.26		
G111/2	25-50		8.62	7.97	0.93	0.47		
G111/3	50-100		8.52	8.19	3.50	2.62	22.98	11.4
G111/4	100-150		8.03	7.89	3.91	0.04		
G113/1	0-25	Jmxl	7.93	7.53	1.07	0.17		
G113/2	25-50		8.19	7.70	0.99	0.33		
G113/3	50-100		8.13	7.72	1.20	0.56		
G113/4	100-150		8.33	7.91	1.20	0.68		
G115/1	0-25	Jmxd	8.33	7.68	0.67	0.33		
G115/2	25-50		8.33	7.73	0.78	0.37		
G115/3	50-100		8.40	7.86	0.92	0.56		
G115/4	100-150		7.96	7.83	4.89	1.02	23.65	4.3
G117/1	0-25	Jmxd	8.16	7.66	0.76	0.37		
G117/2	25-50		8.31	7.73	0.69	0.75		
G117/3	50-100		8.43	7.81	0.80	0.62		
G117/4	100-150		8.44	7.94	1.78	0.87		
G119/1	0-25	Jmxd	8.02	7.51	0.93	0.22		
G119/2	25-50		8.25	7.65	0.98	0.27		
G119/3	50-100		8.42	7.78	0.57	0.34		
G119/4	100-150		8.38	7.73	1.08	0.47		

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
G121/1	0-25	Jb1	8.48	7.83	0.69	0.22		
G121/2	25-50		8.64	7.85	0.60	1.03	23.98	4.2
G121/3	50-100		8.94	8.14	1.32	0.77		
G121/4	100-150		8.81	8.09	1.47	0.88		
G124/1	0-25	Jmxl	8.40	7.80	1.09	0.20		
G124/2	25-50		8.56	7.98	1.42	0.06		
G124/3	50-100		8.27	8.02	5.91	0.40		
G124/4	100-150		8.58	8.21	3.60	2.67	21.82	12.2
G126/1	0-25	Jmxl	8.35	7.77	1.04	0.22		
G126/2	25-50		8.36	7.85	0.83	0.36		
G126/3	50-100		8.02	7.86	4.00	0.80		
G126/4	100-150		8.05	7.84	7.50	3.10	23.66	13.1
G128/1	0-25	Jmxl	8.20	7.60	1.67	0.37		
G128/2	25-50		8.42	7.73	1.15	0.42		
G128/3	50-100		8.45	7.86	0.97	0.66		
G128/4	100-150		8.82	8.08	1.5	0.06		
G130/1	0-25	Jmxl	8.19	7.68	1.30	0.32		
G130/2	25-50		8.43	7.87	0.93	0.31		
G130/3	50-100		8.67	7.98	0.81	0.23		
G130/4	100-150		8.61	7.89	0.71	0.20		
G132/1	0-25	Jb2	8.38	7.73	0.71	0.37		
G132/2	25-50		8.54	7.82	0.68	0.30		
G132/3	50-100		8.53	7.95	*	0.78		
G132/4	100-150		8.70	8.45	1.90	2.50	25.4	9.8
G134/1	0-25	Jb3	8.21	7.69	1.04	0.42		
G134/2	25-50		8.40	7.88	5.55	1.31	28.90	4.5
G134/3	msg							
G134/4	100-150		8.06	7.77	3.91	1.16	30.00	3.0
D001/1	0-25	Jb1	8.41	7.94	1.16	1.21	26.30	4.6
D001/2	25-50		8.82	8.40	1.46	4.60	25.76	17.8
D001/3	50-100		8.24	8.13	8.86	6.08	23.87	25.8
D001/4	100-150		8.38	8.13	8.15	6.45	20.95	30.8
D005/1	0-25	Jmxd	7.94	7.57	1.55	0.16		
D005/2	25-50		8.05	7.75	1.03	0.42		
D005/3	50-100		8.03	7.74	1.15	0.64		
D005/4	100-150		8.16	7.83	3.80	0.14		
D006/1	0-25	Jmxd	7.90	7.63	1.61	0.74		
D006/2	25-50		7.94	7.65	1.27	0.68		
D006/3	50-100		8.13	7.79	0.76	0.43		
D006/4	100-150		7.86	7.66	6.85	0.20		

Note : * Insufficient sample.

IV.2 Deep Bore Routine Sample Analysis

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T077/5	200-250	Jl	8.20	8.01	7.72	6.52	27.02	24.1
T077/6	250-300		8.13	7.96	8.48	4.62	28.39	16.3
T077/7	300-350		8.36	8.02	6.85	6.50	25.64	25.4
T077/8	350-400		8.34	7.96	7.28	2.22	18.72	11.9
T077/9	400-450		8.12	7.82	9.24	2.47	19.44	12.7
T077/10	450-500		8.09	7.85	10.22	0.44		
T081/5	200-250	Jdl	8.10	8.00	9.01	0.38	27.00	1.0
T081/6	250-300		8.33	8.10	8.90	1.84	25.00	7.3
T081/7	300-350		8.36	8.21	8.45	1.68	23.00	7.3
T081/8	350-400		8.59	8.42	8.67	0.71	23.00	3.0
T081/9	400-450		8.68	8.34	5.55	2.60	22.00	11.8
T081/10	450-500		8.69	8.37	5.77	2.65	23.00	11.5
T136/5	200-250	Jmxd	8.45	8.15	1.54	0.53	26.00	2.0
T136/6	250-300		8.30	8.11	3.24	0.80	34.00	2.3
T136/7	300-350		8.01	7.94	4.63	1.12	31.00	3.6
T136/8	350-400		8.65	8.10	2.06	0.05	19.00	-
T136/9	400-450		8.94	8.26	0.81	0.07	3.00	-
G137/4	200-250	Jmxd	8.90	8.40	2.49	1.88		
G137/5	250-300		8.91	8.28	4.36	0.14		
G137/6	300-350		8.67	8.21	4.58	0.10		
G137/7	350-400		8.80	8.32	4.04	NIL		
T139/6	200-250	Jbl	8.28	8.21	8.34	1.32	32.00	4.1
T139/7	250-300		8.46	8.31	9.23	0.19	31.00	-
T139/8	300-350		8.50	8.90	3.75	3.75	31.00	12.0
T139/9	350-400		8.51	8.42	9.34	0.63	31.00	-
T139/10	400-450		8.50	8.38	8.34	4.70	34.00	13.8
T139/11	450-500		8.55	8.45	9.79	2.70	34.00	7.9
T020/6	200-250	Jbl	8.70	8.51	14.99	11.62	20.98	55.4
T020/7	250-300		8.67	8.48	14.77	4.92	26.72	18.4
T020/8	300-350		8.69	8.53	14.54	7.62	30.98	24.6
T020/9	350-400		8.59	8.37	15.34	10.05	31.58	31.8
T020/10	400-450		8.39	8.23	14.88	5.95	26.82	22.2
T020/11	450-475		8.38	8.29	13.87	2.42	21.48	11.3
T020/12	475-500		9.19	8.70	17.61	8.00	20.52	39.0
T024/6	200-250	Jmxl	8.75	8.37	32.38	0.45		
T024/7	250-300		8.76	8.34	4.20	0.24		
T024/8	300-350		8.61	8.32	2.36	0.42		
T024/9	350-400		8.50	8.22	2.90	0.08		
T024/10	400-450		8.73	8.21	2.59	0.12		
T024/11	450-500		8.84	8.21	1.59	0.09		

IV.2 Deep Bore Routine Sample Analysis (cont)

Site/ sample number	Depth (cm)	Class	pH 1:2½ soil/ water	pH KCl	ECe mmhos/ cm	Ex.Na meq/ 100 g	CEC meq/ 100 g	ESP
T029/5	200-250	Jb1	7.97	7.85	6.73	1.12	22.02	5.1
T029/6	250-300		8.38	8.10	8.18	6.87	32.86	20.9
T029/7	300-350		8.11	7.98	9.99	6.25	34.12	18.3
T029/8	350-400		8.05	7.88	10.91	1.37	35.10	3.9
T029/9	400-450		7.85	7.97	11.59	NIL	-	-
T032/5	200-250	BM	8.81	8.57	0.78	16.25	17.48	9.3
T032/6	250-300		8.81	8.49	15.75	12.41	16.14	76.9
T032/7	300-350		8.88	8.51	13.19	4.52	17.08	26.5
T032/8	350-400		8.82	8.39	11.92	2.47	15.72	15.7
T032/9	400-450		9.03	8.48	9.15	0.97		
T076/5	200-250	Jb2	8.17	7.99	6.82	1.16	20.98	5.5
T076/6	250-300		8.45	7.89	1.39	0.10		
T076/7	300-350		8.60	8.11	4.24	0.52		
T076/8	350-400		8.15	7.97	6.20	0.69		
T076/9	400-450		8.18	8.00	7.96	9.80	32.82	29.9
T076/10	450-500		8.11	7.90	6.52	1.37	33.48	4.1

IV.3 Microleaching Sample Analyses

IV.3.1 Non-leached Samples

Sample Nr	Depth (cm)	ECe (mmhos/cm)	Ca	Mg	Na	K (meq/100 g)	HCO_3	SO_4	Cl	SAR
T020/1	0-25	3.22	4.93	2.42	26.25	0.20	2.4	6.04	19.00	13.7
T020/2	25-50	6.49	4.33	2.98	71.25	0.10	2.2	47.92	27.33	37.0
T020/3	50-75	12.72	19.75	12.73	148.75	0.22	1.2	126.04	53.00	37.0
T020/4	75-100	13.70	20.40	14.13	165.5	0.24	1.4	136.46	61.00	40.0
G141/1	0-25	1.05	5.70	1.54	3.50	0.28	2.6	6.04	2.80	1.8
G141/2	25-50	1.53	2.33	1.90	11.75	0.09	3.0	7.08	5.60	8.1
G141/3	50-75	3.99	4.58	5.00	34.63	0.11	2.2	17.08	25.00	16.4
G141/4	75-100	9.57	15.53	19.00	92.50	0.24	2.0	60.4	67.33	22.5
G052/1	0-25	1.35	7.88	2.21	4.25	0.19	1.8	7.81	4.40	1.9
G052/2	25-50	3.00	9.13	4.48	17.10	0.09	1.8	15.62	14.00	6.5
G052/3	50-75	1.36	4.75	2.51	5.55	0.09	1.8	5.52	6.50	2.9
G052/4	75-100	3.50	6.55	4.80	25.00	0.13	2.0	19.17	18.00	10.8

IV.3.2 Leached Samples

T020/1	0-25	6.40	19.6	8.68	66.0	0.28	2.5	84.58	12.0	17.8
T020/2	25-50	4.63	2.5	1.10	50.0	0.13	4.0	34.17	18.0	38.0
T020/3	50-75	14.13	21.4	13.38	159.4	0.29	2.5	143.33	60.0	38.0
T020/4	75-100	14.67	22.5	13.8	166.3	0.26	2.5	161.67	62.0	39.0
G141/1	0-25	1.72	15.7	3.13	8.3	0.16	2.5	14.88	4.5	2.7
G141/2	25-50	1.64	1.8	1.04	14.8	0.07	6.0	7.17	6.5	12.4
G141/3	50-75	5.23	4.3	3.45	30.5	0.17	3.5	19.50	37.3	16.0
G141/4	75-100	9.67	16.3	19.75	125.0	0.34	3.0	63.33	63.3	29.7
G052/1	0-25	6.70	3.4	1.32	3.83	0.11	2.2	4.17	3.3	2.5
G052/2	25-50	0.71	1.9	0.60	4.25	0.07	2.8	4.06	3.3	3.8
G052/3	50-75	1.53	2.3	1.25	8.88	0.11	2.6	8.46	6.0	6.8
G052/4	75-100	2.54	2.8	1.90	22.5	0.08	2.8	15.50	10.7	15.0

APPENDIX V

SOIL PHYSICS

APPENDIX V

DETAILED SOIL PHYSICS DETERMINATIONS

V.1 Surface Infiltration

A total of 20 surface infiltration sites was investigated using double ring infiltrometers.

At each site, triplicate infiltration rings were installed to a depth of 150 mm, and an approximately constant head of water (of a quality comparable with that of proposed irrigation waters) was maintained in each of the rings.

Hourly infiltration rates were measured over a period of two days, although during the overnight period it was not practicable to maintain a constant head, when the equipment was left unattended. Results from the 20 sites examined are summarised in Table V.1. Additional surface infiltration tests were carried out at a number of non-representative sites to ascertain the effects of disturbance of the soil surface on initial and final infiltration rates. These tests were conducted at five sites over two and three day periods. They were concentrated in the east of the area on the basin clay soils. One site duplicated the results already obtained in an earlier assessment (T020), the results of the other tests are presented in Table V.1.

In Table V.1 the data have not been corrected for evaporation during the test period. Separate observations over a 14 day period using a Class A evaporation pan indicated that 24 hour evaporation rates were approximately 7 mm.

Tables V.2 to V.7 and Figures V.1 to V.5 illustrate the data for each test site. In the tables t (hours and minutes) and Σi (mm) are mean values of observations recorded from the three tests at each site except where otherwise indicated. Data for all the sites have been averaged to produce a value representative of the mapping unit.

In preparing Figures V.1 to V.5, the field sheets have been used to derive cumulative infiltration test at the site. Normally, this represents a mean of three tests, unless otherwise stated.

Infiltration rates overnight have been estimated throughout using the following procedure:

(a) Measurements of final infiltration rate on day 1 and initial rate on day 2 were compared. If similar, (e.g. $\pm$ 5 mm) then the mean value has been assumed as being representative of the overnight infiltration rate. From this value, the cumulative infiltration rate during the night was calculated, and a linear relationship was assumed.

(b) If, on comparing the infiltration rates on day 1 and day 2 as above the difference was significantly large (e.g. $> \pm$ 5 mm), then on an arbitrary basis the data for day 1 and day 2 were studied, a run of similar readings selected and used as above to calculate firstly the mean infiltration rate overnight and secondly the cumulative infiltration during the night. Again, a linear relationship is assumed.

TABLE V.1

Surface Infiltration

Test	Soil mapping unit	Surface texture	Approximate initial intake rate[1][5]	Approximate initial intake rate[2][5]	Approximate time required for infiltration of: 50 mm		100 mm		150 mm	
					h	min	h	min	h	min
T008	Jb1	Clay loam	157	20	0	15	1	05	2	12
D012	Jb1	Clay	70	8	0	30	1	50	3	35
T020	Jb1	Silty clay (light)	258	4	0	10	0	50	1	50
T029	Jb1	Clay	426	22	0	10	0	25	1	00
T139	Jb1	Silty clay	120	13	0	35	2	00	4	00
G052	Jb2-3	Clay loam (heavy)	198	28	0	15	0	50	1	35
T076	Jb3	Silty clay (heavy)	276	40	0	10	0	35	1	00
T009	J1	Silty clay loam (heavy)	134	22	0	10	0	50	1	50
T027	J1	Clay loam	138	20	0	40	1	36	2	50
T077	J1	Clay loam (light)	168	11	0	40	2	25	4	50
T078	J1	Very fine sandy loam	228	55	0	15	0	50	1	25
D008[7]	Jmx1	Silty clay loam	294	18	0	10	0	40	1	25
T021	Jmx1	Silty clay loam (heavy)	306	77	0	10	0	25	0	40
T024[6]	Jmx1	Fine sandy loam (heavy)	318	93	0	15	0	35	1	00
T135	Jmx1	Very fine sandy clay loam	176	17	0	25	1	15	2	25
T081[7]	Jd1	Clay	250	6	0	10	0	35	1	25
T032	BM	Silty clay	654	167	-	-	-	-	0	15
T136	Jmxd	Silty clay	234	16	0	15	1	10	2	25
G137	Jmxd	Clay loam	138	13	0	40	2	15	4	15
T028	MP	Very fine sandy clay loam	282	20	0	10	1	00	1	50
Near T206[8]	Jb	Clay loam	0	1	-	-	-	-	-	-
Near T228[9]	Jb	Clay loam (light)	640	12	2	00	4	50	8	00
T226[9]	Jb	Clay	830	5	-	-	-	-	-	-
Near T253[9] E1.9E	Jb	-	29	10	0	40	2	10	4	40

Notes:
(1) Estimated from graphical plots and data and standardised for elapsed time of 10 min.
(2) Estimated from graphical plots by inspection of terminal section of curve.
(3) Refers to data which have not been corrected for evaporation.
(4) Measured from graphical plots. Values are approximate.
(5) Figures are means of triplicate tests except where otherwise stated.
(6) Single reading only.
(7) Mean of 2 readings.
(8) Test on preflooded surface.
(9) Tests performed on disturbed soil surface to 30 cm.

TABLE V.2

Infiltration Data for Juba Basin Clays Mapping Unit Jb1 (none to slight gilgai)

T008			D012			T020			T029			T139			Jb1 unit		
t		Σ i	t		Σ i	t		Σ i	t		Σ i	t		Σ i	t		Σ i
(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)
0	15	17	0	15	34	0	10	43	0	10	71	0	10	20	0	12	48
0	25	75	0	35	54	0	30	79	0	30	106	0	30	47	0	30	72
1	05	114	1	15	79	1	10	121	1	10	172	1	10	72	1	10	112
2	05	132	2	15	113	2	10	165	2	10	244	2	10	104	2	10	152
3	05	166	3	15	144	3	10	195	3	10	276	3	10	130	3	10	182
4	05	215	4	15	170	4	10	215	4	10	329	4	10	156	4	10	217
5	05	253	5	15	193	5	10	229	5	10	370	5	10	187	5	10	246
6	05	287	6	15	215	6	10	242	6	10	413	6	10	209	6	10	273
21	35	737	7	15	237	7	10	267	7	10	447	7	10	229	23	16	609
22	35	761	23	15	525	23	10	357	23	10	863	23	10	517	24	16	626
23	35	782	24	15	538	24	10	363	24	10	899	24	10	532	25	16	639
24	35	800	25	15	548	25	10	368	25	10	919	25	10	544	26	16	654
25	35	818	26	15	559	26	10	372	26	10	938	26	10	558	27	16	667
26	35	845	27	15	569	27	10	375	27	10	956	27	10	569	28	16	678
27	35	865	28	15	570	28	10	379	28	10	974	28	10	583			
28	35	885	29	15	578	29	10	382	29	10	993	29	10	596			
			30	15	587				30	10	1 012	30	10	608			

TABLE V.3

Infiltration Data for Juba Basin Clays Mapping Units Jb2 and Jb3

(moderate to severe gilgai)

G052			T076			Jb2-3 and Jb3 unit		
t (h)	t (min)	Σ i (mm)	t (h)	t (min)	Σ i (mm)	t (h)	t (min)	Σ i (mm)
0	10	33	0	10	46	0	10	40
0	30	76	0	30	92	0	30	84
1	10	118	1	10	161	1	10	140
2	10	163	2	10	245	2	10	204
3	10	211	3	10	321	3	10	266
4	10	271	4	10	396	4	10	334
5	10	308	5	10	461	5	10	385
6	10	352	6	10	523	6	10	438
7	10	390	7	10	600	7	10	495
22	10	945	23	10	1 432	23	10	1 206
23	10	980	24	10	1 480	24	10	1 245
24	10	1 009	25	10	1 522	25	10	1 277
25	10	1 032	26	10	1 568	26	10	1 316
26	10	1 063	27	10	1 609	27	10	1 348
27	10	1 086	28	10	1 648	28	10	1 384
28	10	1 119	29	10	1 689			
			30	10	1 729			

TABLE V.4 .

Infiltration Data Juba Levee Mapping Unit Jl

T009			T027			T077			T078			Jl unit		
(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)
0	15	51	0	10	23	0	10	28	0	10	38	0	11	35
0	35	81	0	30	44	0	30	48	0	30	75	0	31	62
1	15	118	1	10	81	1	10	68	1	10	140	1	11	102
2	15	167	2	10	130	2	10	94	2	10	206	2	11	149
3	15	212	3	10	169	3	10	120	3	10	279	3	11	195
4	15	250	4	10	211	4	10	138	4	10	346	4	11	236
5	15	292	5	10	253	5	10	160	5	10	397	5	11	276
6	15	331	6	10	302	6	10	178	6	10	453	6	11	316
7	15	368	7	10	333	7	10	193	7	10	497	7	11	348
23	35	880	23	10	733	23	10	401	23	10	1 345	23	16	840
24	35	904	24	10	751	24	10	411	24	10	1 418	24	16	871
25	35	928	25	10	768	25	10	421	25	10	1 499	25	16	904
26	35	949	26	10	787	26	10	431	26	10	1 561	26	16	932
27	35	970	27	10	803	27	10	441	27	10	1 610	27	16	956
28	35	989	28	10	826	28	10	450	28	10	1 663	28	16	982
29	35	1 009	29	10	843	29	10	459	29	10	1 717	29	16	1 007
30	35	1 030	30	10	861	30	10	469	30	10	1 763	30	16	1 031

TABLE V.5

Infiltration Data Meander Complex Levee Unit Jmxl

D008			T021			T024			T135			Jmxl unit		
(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)	(h)	t (min)	Σ i (mm)
0	10	49	0	10	51	0	10	53	0	10	29	0	10	46
0	30	88	0	30	107	0	30	96	0	30	57	0	30	87
1	10	135	1	10	185	1	10	174	1	10	96	1	10	148
2	10	191	2	10	287	2	10	287	2	10	134	2	10	225
3	10	242	3	10	374	3	10	374	3	10	172	3	10	291
4	10	284	4	10	467	4	10	467	4	10	203	4	10	355
5	10	333	5	10	555	5	10	564	5	10	238	5	10	422
6	10	368	6	10	638	6	10	665	6	10	268	6	10	485
7	10	401	7	10	722	7	10	746	7	10	299	7	10	542
24	10	945	24	10	2 167	23	55	2 153	23	30	707	24	26	1 519
25	10	976	25	10	2 253	24	55	2 240	24	30	725	25	26	1 574
26	10	1 005	26	10	2 335	25	55	2 327	25	30	741	26	26	1 629
27	10	1 030	27	10	2 408	26	55	2 417	26	30	759	27	26	1 681
20	10	1 053	28	10	2 481	27	55	2 513	27	30	773	28	26	1 736
			29	10	2 545	28	55	2 615	28	30	795			
			30	10	2 624	29	55	2 706	29	30	807			
			31	10	2 603	30	55	2 804	30	30	823			

TABLE V.6

Infiltration Data for Meander Complex Depression Unit Jmxd

T136			G137			Jmxd unit		
t		Σ i	t		Σ i	t		Σ i
(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)
0	10	39	0	10	23	0	10	31
0	30	63	0	30	45	0	30	54
1	10	93	1	10	67	1	10	80
2	10	137	2	10	97	2	10	117
3	10	172	3	10	121	3	10	147
4	10	202	4	10	148	4	10	175
5	10	234	5	10	171	5	10	203
6	10	264	6	10	193	6	10	229
7	10	292	7	10	208	7	10	250
23	10	676	23	10	480	23	10	578
24	10	696	24	10	498	24	10	597
25	10	714	25	10	510	25	10	612
26	10	729	26	10	521	26	10	625
27	10	745	27	10	535	27	10	640
28	10	760	28	10	549	28	10	655
29	10	776	29	10	560	29	10	668
30	10	790	30	10	573	30	10	682

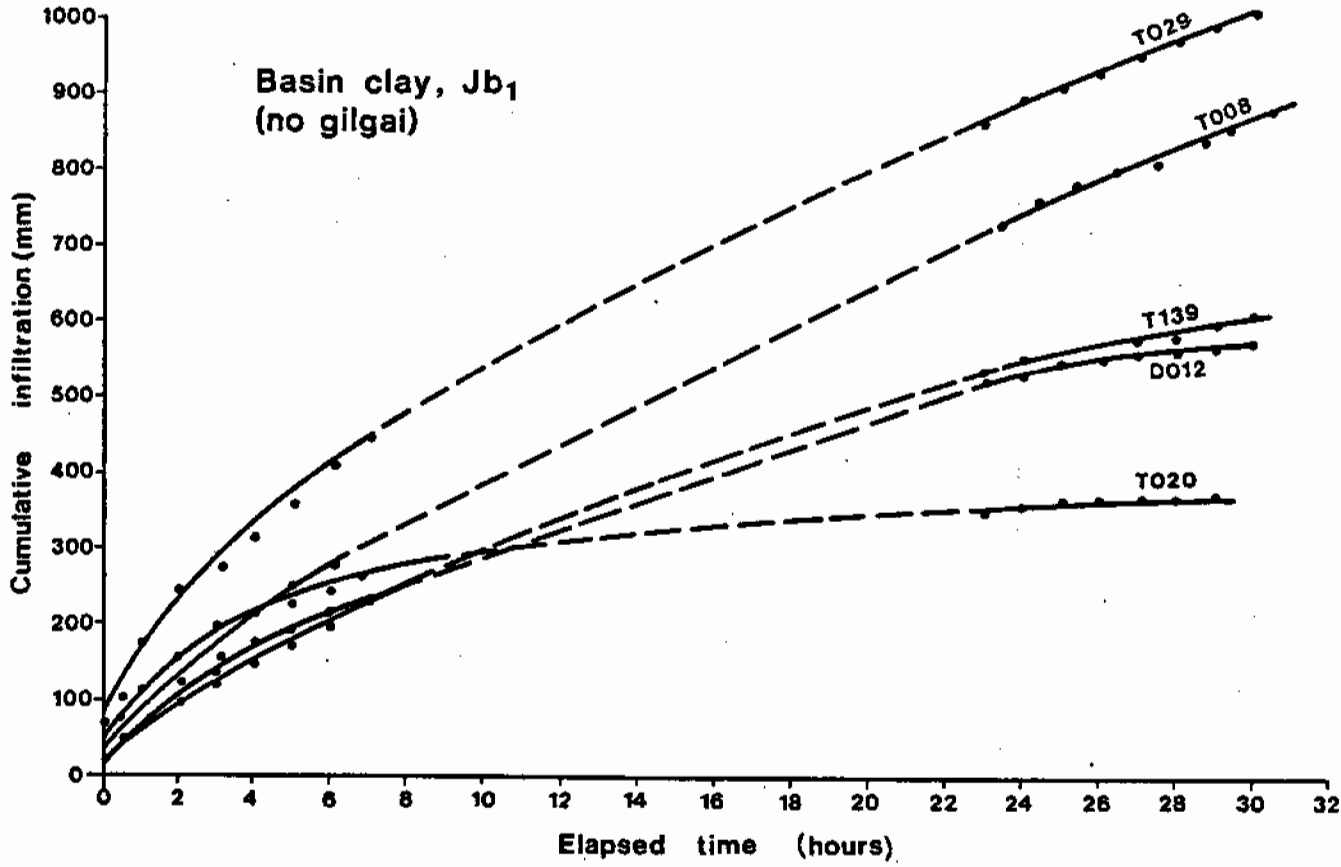
TABLE V.7

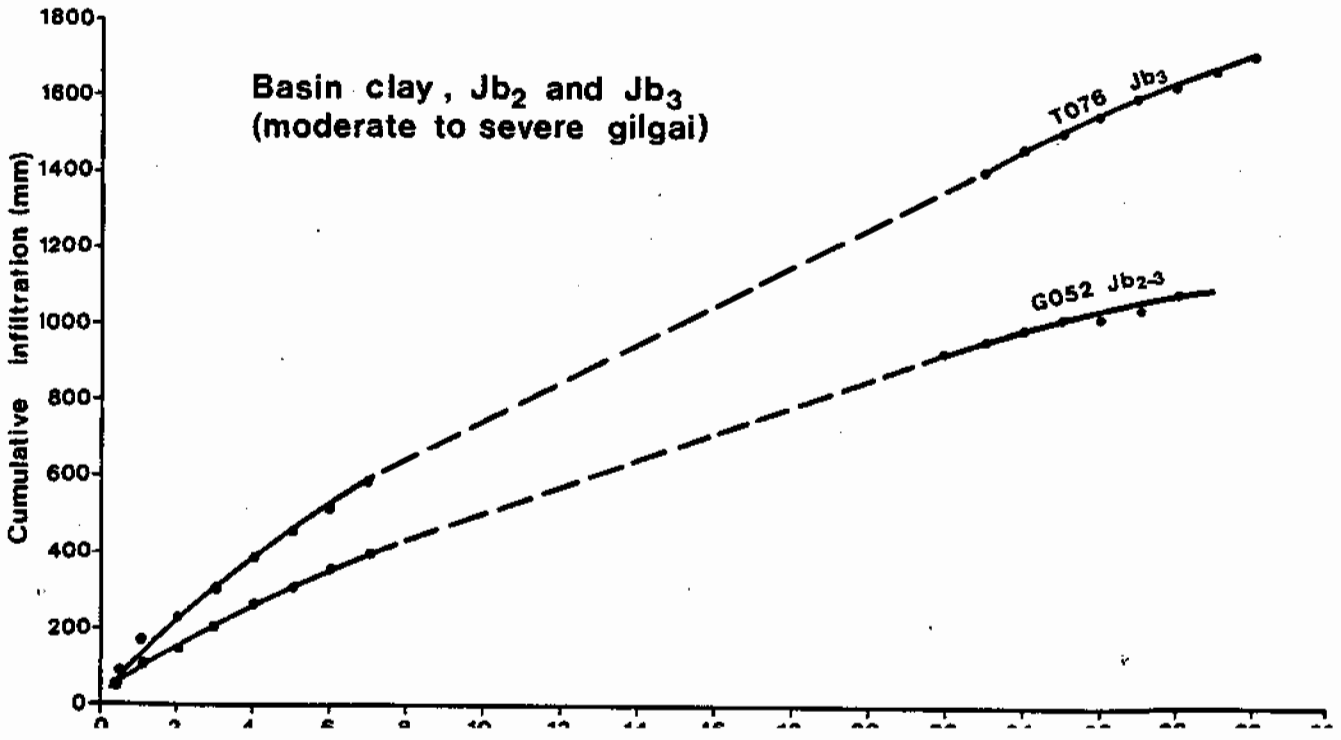
Infiltration Data for Juba Depression Jd, Beach Remmant Bm, and Marine Plain MP, Mapping Units

Soil unit Jdl T081			Soil unit BM T032			Soil unit MP T028		
t		Σ i	t		Σ i	t		Σ i
(h)	(min)	(mm)	(h)	(min)	(mm)	(h)	(min)	(mm)
0	10	42	0	10	109	0	10	47
0	30	89	0	30	220	0	30	79
1	10	138	1	10	373	1	10	119
2	10	193	2	10	574	2	10	173
3	10	237	3	10	751	3	10	222
4	10	275	4	10	930	4	10	259
5	25	319	5	10	1 121	5	10	298
6	25	342	6	10	1 281	6	10	337
22	55	590	7	10	1 448	7	10	373
23	55	597	24	10	4 338	23	10	869
24	55	604	25	10	4 565	24	10	890
25	55	609	26	10	4 746	25	10	927
26	55	614	27	10	4 917	26	10	946
27	55	619	28	10	5 090	27	10	966
28	55	628	29	10	5 246	28	10	980
29	55	635	30	10	5 398	29	10	990
			31	10	5 547	30	10	1 005

Cumulative infiltration rates

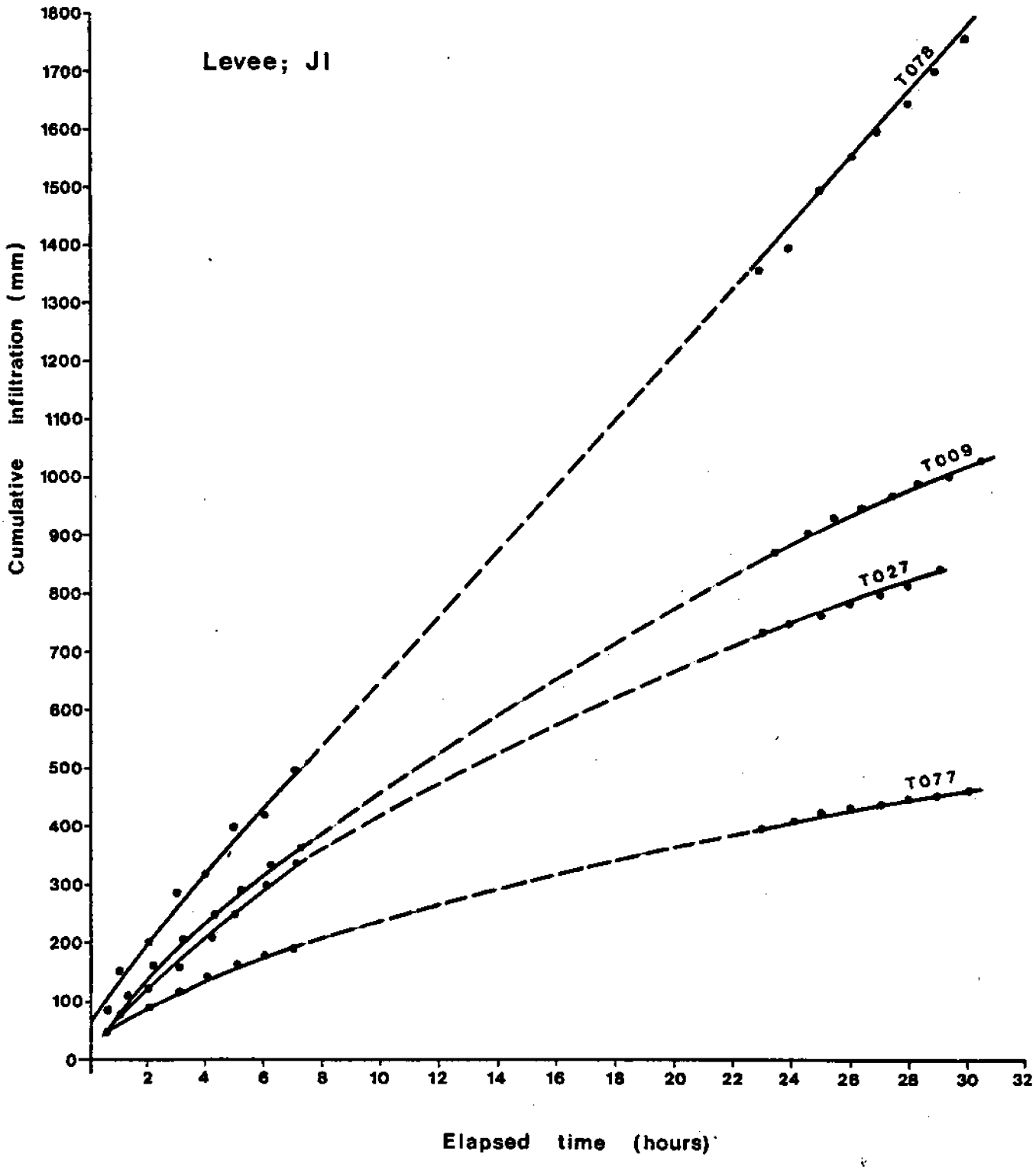
V.1





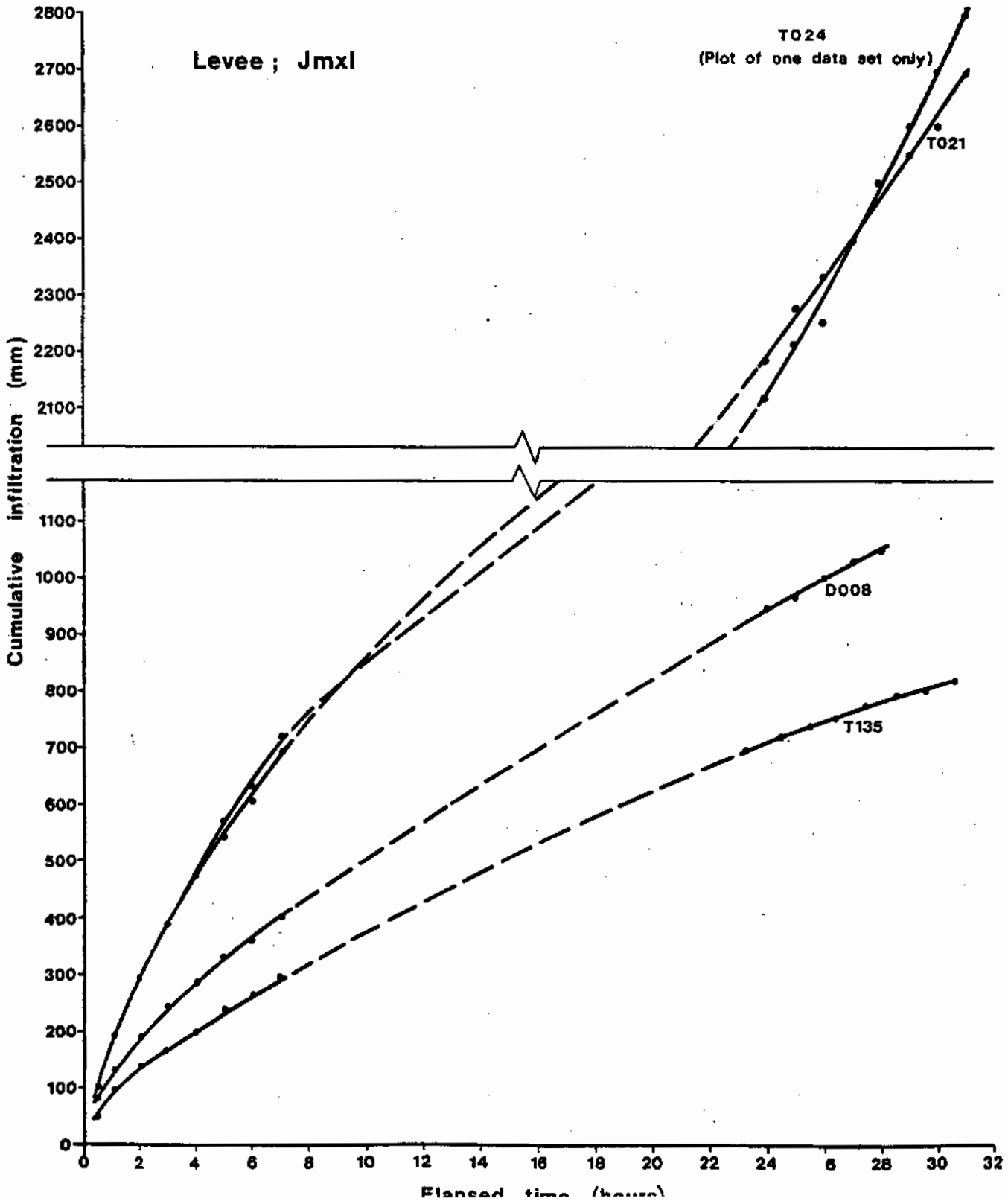
Cumulative infiltration rates

V.2



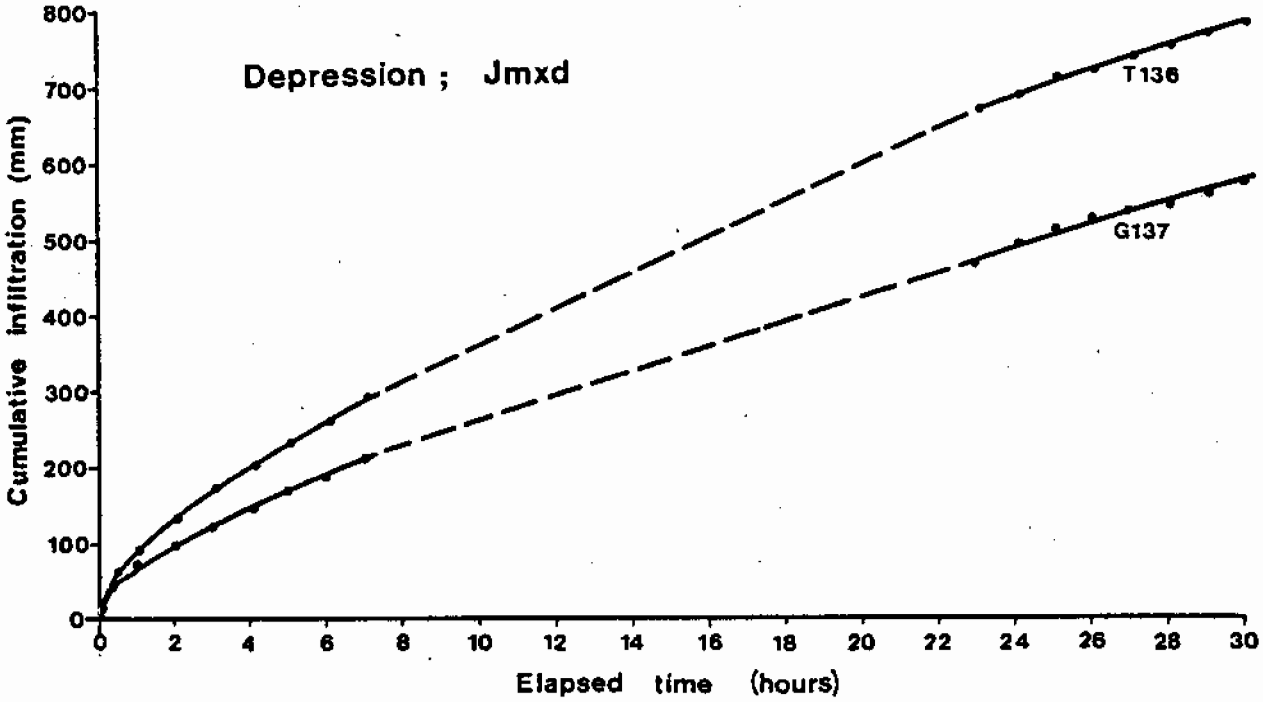
Cumulative infiltration rates

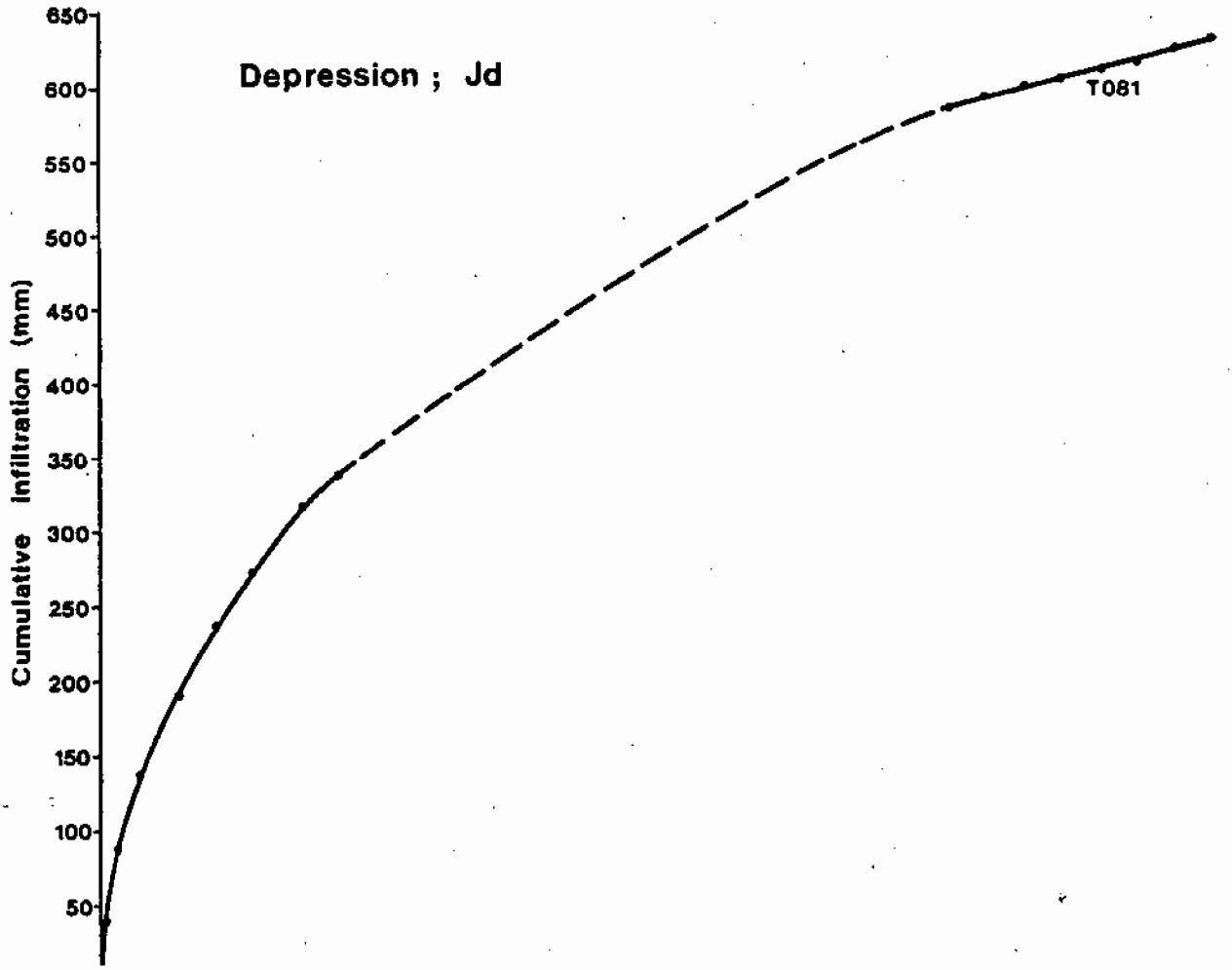
V.3



Cumulative infiltration rates

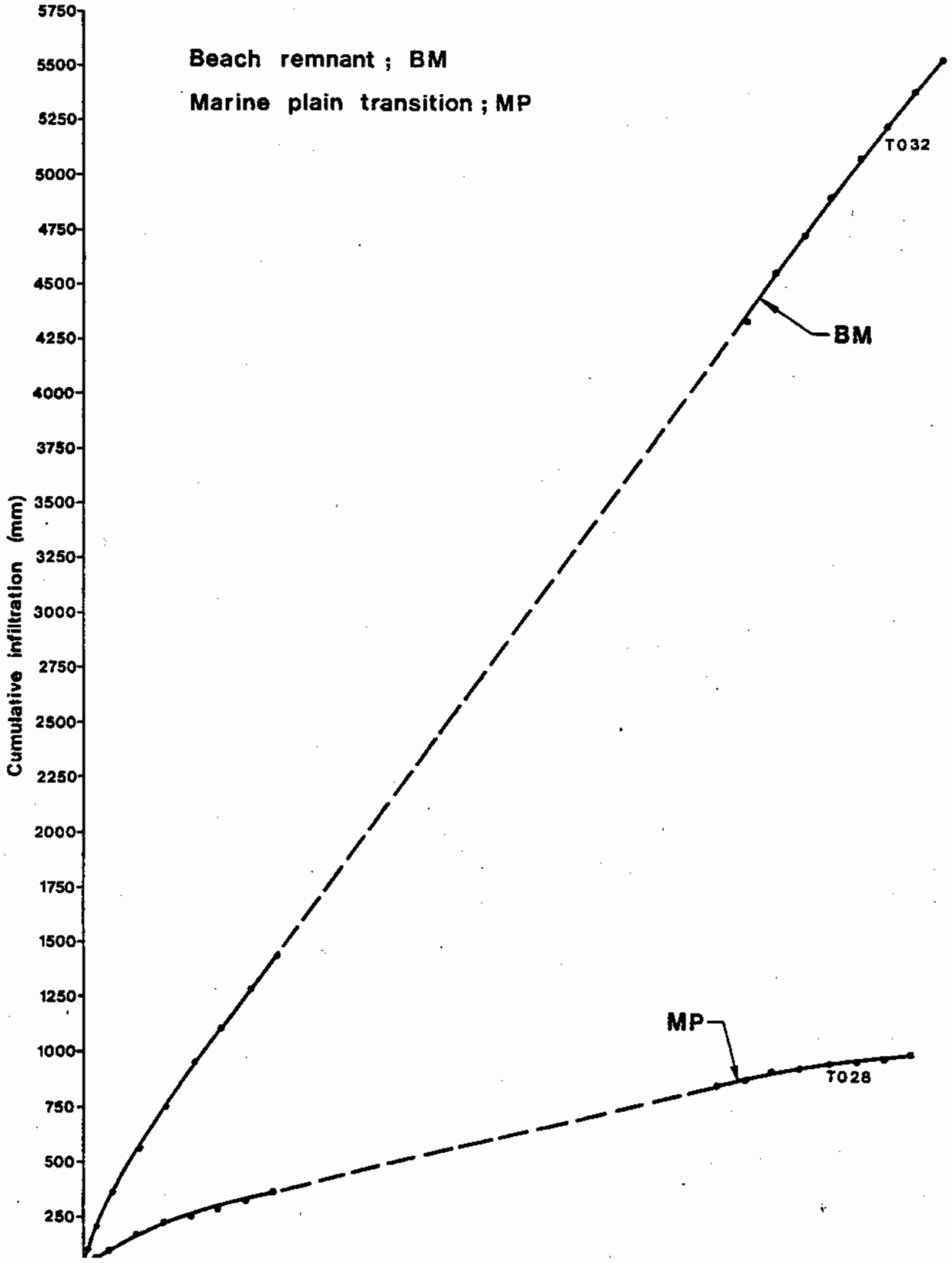
V.4



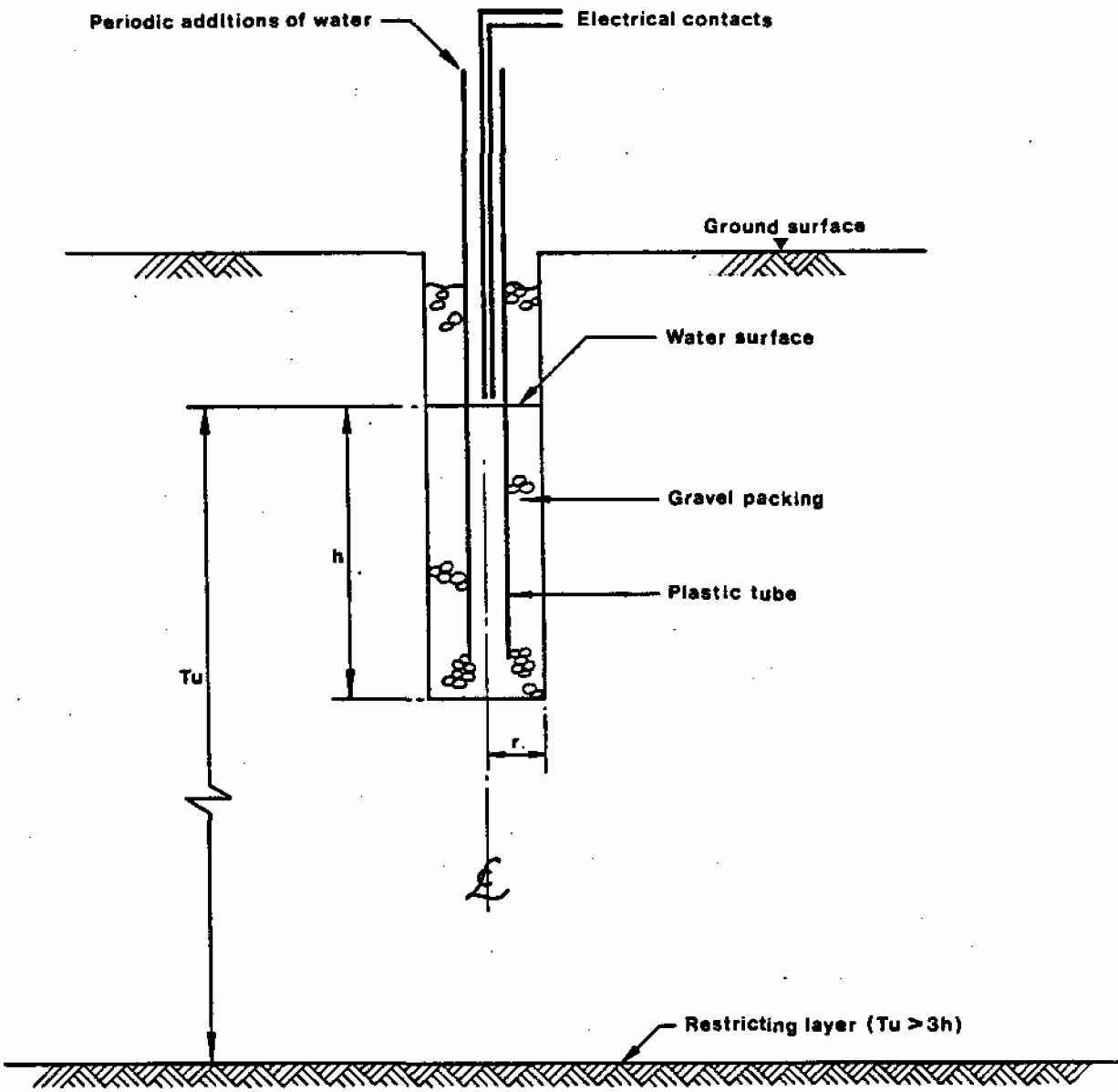


Cumulative infiltration rates

V.5



Hydraulic conductivity measurement



Hydraulic conductivity, K (mm/day) given by :

$$K = \frac{24Q\left[\log_e\left(\frac{h}{r} + \sqrt{\left(\frac{h}{r}\right)^2 - 1}\right) - 1\right]}{2\pi h^2}$$

V.2 Hydraulic Conductivity

Tests were carried out in order to estimate both horizontal and vertical hydraulic conductivity rates at a number of sites representative of the soil mapping units. Information provided by the former tests are required as variables in drainage equations used to calculate optimum drain spacings. Estimates of vertical hydraulic conductivity are required in cases where there may be a potential hazard from rising groundwater tables, as these estimates provide a measure of rates of downward percolation of undrained irrigation and leaching water.

V.2.1 Horizontal Hydraulic Conductivity

Measurements of this parameter were made using the single auger hole 'pour-in' test USBR, (1953) and theory suggested by Boersma (1965). Of the many available methods, this was selected as appropriate on consideration of the disposition, both spatially and vertically, of groundwater tables and highly impermeable soil horizons within the project area.

In this test, an auger hole of known dimensions was excavated to the required depth and stabilised as indicated in Figure V.6, care being taken to prevent excessive disturbance of soil within the test horizon.

A constant head of water was then maintained coincident with the soil horizon under test, by means of periodic additions of a fixed volume of water required to compensate for the essentially lateral flow from the auger hole.

Once equilibrium conditions had been achieved (normally after approximately 4 hours), measurements of time increments between the periodic additions of water enabled horizontal hydraulic conductivity rates to be calculated with reference to the appropriate equation (Figure V.9).

Preparatory saturation of the soil horizon under test was found to enhance the accuracy with which equilibrium conditions could be identified, especially when observations could only be made (for practical reasons) over a one-day period.

In most cases, it was decided to concentrate tests at or around probable drain depth (1 000 mm or greater) although several observations were made both above and below this depth. A total of 20 tests was carried out at representative sites, the results are presented in Table V.8.

V.2.2 Vertical Hydraulic Conductivity

Double ring infiltrometers provide an estimate of vertical hydraulic conductivity when installed in a suitably excavated cavity rather than at the soil surface, measurements of infiltration being recorded in a similar manner to those for surface tests.

A series of sub-surface tests was carried out at those sites where it was considered that rises in groundwater table could be potentially hazardous, triplicate tests being used in each case unless otherwise impracticable. In each case, the equipment was installed at or around probable drain depth, in order to provide estimates of percolation rates below this depth, and to provide an indication of the vertical flow component of radial flow normally associated with closed drains.

TABLE V.8

Hydraulic Conductivity Data

Test site	Soil mapping unit	Depth tested[1] (cm)	Textural groups within test depth[2]	Structural groups within test depth[2]	Hydraulic conductivity[3] (mm/d)
T008	Jb1	11 - 50	sicl(h) - cl	2m sbk - 2c pr	Extremely rapid
		50 - 150	c	1c pr - 1m sbk	39.0
T020	Jb1	80 - 140	c	2mw - 1f abk	3.0
T029	Jb1	150 - 200	c	2mw - 2m abk	4.3
T139	Jb1	75 - 125	c	2m sbk	2.0
G052	Jb2 - 3	100 - 200	c	1mw - 1f abk	10.0
T076	Jb3	150 - 200	sicl(h)	1m sbk	12.3
T027	Jl	130 - 200	c	2m sbk	39.0
T077	Jl	150 - 200	sic	2m abk - 2m pr	22.0
T078	Jl	70 - 135	sic - c	2m sbk - 2f sbk	2.1
T021	Jmxl	50 - 150	c -c(l) - sicl(h)	3f pr - 2f sbk - 1f sbk	84.1
T024	Jmxl	10 - 60	fscl	1f sbk	11 739.0
		60 - 110	fsl(h)	1f sbk	1 472.0
T135	Jmxl	65 - 100	sicl	2m cr	42.2
T081	Jdl	150 - 200	c	Massive	1.3
T032	BM	100 - 200	fscl	Massive - 1f sbk	33.0
		30 - 120	sl	Massive - 2f sbk	0.0
T136	Jmxd	60 - 200	vfsl - vfs	Massive	778.0
G137	Jmxd	60 - 160	c	1 mw	10.5
T028	MP	100 - 200	sic	Massive - 2m sbk	3.0

Notes: (1) Depths measured from surface:
(2) Stated in order of succession form surface.
(3) Refers to horizontal hydraulic conductivity, calculated after a variable time when equilibrium conditions assumed to have been reached.

Textures:

sicl	=	silt clay loam
cl	=	clay loam
c	=	clay
fscl	=	fine sandy clay loam
fsl	=	fine sandy loam
vfs(l)	=	very fine sand (loam)
sic	=	silt clay
(h)	=	heavy

Structures:

1	=	weak
2	=	moderate
3	=	strong
f	=	fine
m	=	medium
c	=	coarse
sbk	=	sub angular blocky
pr	=	prismatic
abk	=	angular blocky
w	=	wedge
cr	=	crumb

TABLE V.9

Comparison between Vertical and Horizontal Hydraulic Conductivities at Four Test Sites

		Vertical hydraulic conductivity[1]		Horizontal hydraulic conductivity	
Test site	Soil mapping units	Depth of surface under test (cm)	Vertical conductivity (mm/d)	Depth tested (cm)	Horizontal conductivity [3] (mm/d)
T139	Jb1	100	27.0	75 - 125	1.90
T020	Jb1	80	88.0	80 - 140	2.70
G052	Jb2-3	100	30.0	100 - 200	10.00
G141	Jb3	90	41.1[2]	80 - 180	11.20

Notes: (1) Values are means of triplicate tests except where otherwise stated.

(2) Mean of 2 sets of observations.

(3) Refer to separate tests carried out at site during vertical conductivity test.

TABLE V.10

Determination of Moisture Retention Properties

Profile Nr	Depth (cm)	Texture	Soil class	Hydraulic conductivity (mm/d) vertical	Hydraulic conductivity (mm/d) horizontal	Bulk density (g/cm^3)	Percentage moisture* 0	1/10 atm	1/3 atm	1 atm	15 atm	Available moisture % by wt	% by vol.	cm	per 120 cm profile
D012	0-22	C	Jb1	192	-	1.15	49	43	37	36	28	15	17.2	3.7	
	22-59	C		-	-	1.29	43	39	35	34	15	24	30.0	11.1	
	59-123	C		-	-	1.68	-	-	-	-	28	-	-	-	33.1
G052	0-15	C	Jb3	672	-	1.26	44	35	32	30	23	12	15.1	2.25	
	15-44	C		-	-	1.12	53	38	33	32	25	13	14.5	4.0	
	44-150	C		30	10.0	1.5	-	-	-	-	13	-	-	-	17.4
G141	0-27	CL	Jb1	-	-	1.5	49	34	29	28	18	16	24.0	6.4	
	27-90	C		-	-	1.4	32	28	26	25	18	10	14	8.8	
	90-135	SiL		41	11.2	1.7	-	-	-	-	20	-	-	-	19.4
T009	0-13	Cl	Jl	528	-	1.2	41	33	27	25	16	17	20.4	2.6	
	13-40	CL-C		-	-	1.2	41	34	30	28	20	14	16.8	4.3	
	40-116	SiC		-	-	1.8	-	-	-	-	19	-	-	-	17.9
T020	0-15	C	Jb1	96	-	1.3	38	31	27	26	-	-	-	-	
	15-40	C		-	-	1.6	-	-	-	-	-	-	-	-	
	40-140	C		88	2.7	1.2	45	40	34	33	22	18	21.6	21	25.9
T024	0-10	SiL	Jmxl	2 232	-	1.5	27	22	18	17	11	11	16.5	1.6	
	10-60	SCL		-	**	1.3	38	26	21	19	14	12	15.6	7.5	
	60-110	L		-	1 472.0	1.5	28	24	23	17	10	14	21.0	10.5	21.7
T076	0-30	C	Jb3	960	-	1.1	54	49	45	43	33	16	17.6	5.1	
	30-80	C		-	-	1.3	35	32	29	29	21	11	14.3	7.0	
	80-150	C		-	12.3	1.4	33	32	31	29	23	9	12.6	8.8	17.1
T077	0-20	L	Jl	264	-	1.2	42	34	28	21	15	19	22.8	4.4	
	20-76	CL		-	-	1.3	34	29	26	24	18	11	14.3	7.8	
	76-130	L		-	-	1.5	27	26	24	23	6	20	30	16.2	25.4
T078	0-25	L	Jl	1 320	-	1.2	40	34	31	29	17	17	20.4	5.0	
	25-70	L		-	-	1.4	31	28	27	26	-	-	-	-	
	70-135	C		-	2.1	1.5	35	33	30	29	25	8	12.0	7.8	16.4
T081	0-20	C	Jd1	144	-	1.4	-	-	-	-	24	-	-	-	N.A.
	20-50	C		-	-	1.7	-	-	-	-	21	-	-	-	N.A.
	50-145	C		-	1.3	1.6	-	-	-	-	22	-	-	-	N.A.
T136	0-30	CL	Jmxd	384	-	1.2	44	41	39	38	27	14	16.8	4.8	
	30-60	L-SCL		-	-	1.3	40	39	37	36	11	28	36.4	10.8	
	60-155	L-SCL		-	778	1.5	27	24	18	18	11	13	19.5	8.5	27.3
T139	0-15	C	Jb1	312	-	1.0	55	41	36	35	25	16	16.0	2.4	
	15-40	C		-	-	1.4	-	-	-	-	28	-	-	-	
	40-150	C		27	1.9	1.5	-	-	-	-	20	-	-	-	19.2

Note : * Where values are not available for soil moisture in the subsoil, the 120 cm calculation is based on available data for the upper horizons

** Extremely rapid

Observations were continued over a period of two days initially, although infiltration rates were found to stabilise after 6 or 7 hours in most cases. Results from these tests are summarised in Table V.9, and compared (in the same table) with horizontal hydraulic conductivities at a similar depth.

V.2.3 Available Moisture Capacity

The available moisture content of a soil is generally accepted as being the difference between the moisture content at field capacity and at permanent wilting point. These limits closely correspond to the moisture retained at tensions of 0.1 and 15 atmospheres, respectively. Farbrother (1972) suggests that for soils with pronounced vertisolic characteristics the former values can usually be replaced by that for saturation point at 0 atmosphere. However in the accompanying Table V.10 the conventional terminology has been applied. The difference between the two figures so calculated when multiplied by the bulk density gives the percentage available moisture by volume. This is divided by 100 and multiplied by the thickness of the soil horizon in centimetres to give the available water in the whole horizon. Summation of the values for each horizon gives the available water for the whole profile. The depth of the solum has been taken as 120 cm and values adjusted and interpolated where appropriate. Where moisture content figures are not available for one or more of the horizons making up the 120 cm depth of solum, values have been estimated from the other horizons. Thus we obtain a figure for the available moisture per 120 cm of profile. This figure in effect, represents the thickness of the sheet of water which is available to the crop after the soil has been brought to field capacity. The moisture actually easily available to the plant approximates to 50% of this value which often correlates well with the moisture available between the 0.1 and 1 bar tensions. The available moisture figure can be used to calculate the frequency of irrigation water application needed by a crop growing in that soil.