Jamhuuriyadda Dimoqraadiga Soomaliya
Heyadda Beelaha Danwadaagta Beeraleyda

Somali Democratic Republic
Settlement Development Agency

Homboy Irrigated Settlement Project
Volume I
Soils

Hunting Technical Services Limited
Elstree Way
Borehamwood
Herts WD6 1SB
England

HUNTING TECHNICAL SERVICES LIMITED
A DIVISION OF HUNTING SURVEYS AND CONSULTANTS LIMITED
ELSTREE WAY - BOREHAM WOOD - HERTS - WD6 1SB - ENGLAND
(Reg Office)
Telephone: 01-953 6161 Telex: 23517 Cables: HUNTECO BOREHAMWOOD

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CONSULTANTS IN LAND AND WATER RESOURCE AND ENVIRONMENTAL PLANNING

Our Ref: Somali/Homboy

September, 1979.

The General Manager,
Settlement Development Agency,
P.O. Box 1407,
Mogadishu,
Somali Democratic Republic.

Dear Sir,

Homboy Irrigated Settlement Project Area Phase II.

In accordance with your letter dated 31st July 1978 we have pleasure in submitting herewith the soils report for the Homboy Irrigated Settlement Project, Phase II, dealing with the potential for irrigated and rainfed development within the 15,000 hectares selected for semi detailed soil survey.

The report comprises one volume supported by four map sheets depicting Soil and Land Suitability respectively. In addition two further volumes are in preparation to complete the studies on agriculture and economics; and physical planning.

We would like to express our thanks to you and the staff of the Settlement Development Agency who have helped us in our studies.

Yours faithfully,

H. Piper
Regional Manager of Africa.

Homboy Irrigated Settlement Project Volume I Soils

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SPELLING OF SOMALI PLACE NAMES

There has been a great deal of inconsistency in the spelling of Somali place names in previous reports. The present report takes the spelling of place names from the most recent topographic maps, produced at 1:100,000 scale by Hogaanka Kartografiyada Wasaaradda Gaashaandhigga in 1967.

The one exception to this rule is Mogadishu, where the normal internationally accepted spelling has been used.

Towns and Villages:-

Mogadishu
Kismaayo
Bouale
Dujuuma
Sablaale
Kurtun Waarey
Afgooye
Mareerey
Saakow
Bardheere
Mudun
Janaale
Buulo Mareerta
Qalaaliyow
Mogaambo
Jilib
Kamsuuma
Fanoole
Alessandra
Barwaaqo
Bodboode
Helashiid
Balley
Nasriib
Mashemba
Madhooka
Limoole
Maanyagaabo
Cumar Abooke
Dhey Tubaako
Arbey Cabdi
Homboy
Aminow
Sheekh Cabdi Muudey
Burgaan
Maqdas
Kaytooy

Rivers and Depressions:-

Jubba
Shabeelle
Harar Naga
Kormajirto
Tukuule

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Ministry of Agriculture, Mogadishu
Ministry of Works, Mogadishu
Meteorological Office, Department of Civil Aviation, Mogadishu
LIBSOMA, Mogadishu
ONAT, Mogadishu, Jilib and Jamaame
Department of Agriculture, Jilib and Jamaame
ADC, Jilib
Veterinary Office, Jilib
Alessandria Research Station
Banana Board, Mogadishu
Kismaayo Water Board
Jubba Sugar Project, Mareerey
CARS, Afgooye
Dryland Research Station, Bonka, Baidoa
Mogambo Irrigation Project
Veterinary Project, Kismaayo.

Finally to our technical counterparts, Salaad Ahmed Ismail in Mogadishu and Mohamed Buwe Nur, Makamed Sheik, Muuse Yussud Muuse and Abdulahi Xaji Maxamed in the field, whose help was essential to the efficient completion of the Phase II studies.

Introduction

Early in 1978 the Settlement Development Agency (SDA) decided to translocate the Dujuuma Settlement Scheme to an area environmentally better suited to irrigated and rainfed agriculture. This decision was taken in the light of a previous, rather unfavourable account of the soils of Dujuuma area (HTS, 1977), the low total amount and poor distribution of rainfall at Dujuuma, and recent experience of disastrous floods during the Der rains of 1977.

In July 1978 the SDA requested Hunting Technical Services to carry out investications within the Fanoole command area aimed at identifying a suitable site for the translocation of Dujuuma Settlement. This study was financed by the Arab Fund, Kuwait. The terms of reference comprised three main components.

(1) A reconnaissance survey of 60,000 ha of land to identify 24,000 ha suitable for irrigated agricultural development.

(2) Studies of the 24,000 ha to include topo-survey, semi-detailed soil survey and agricultural, irrigation and villagisation studies.

(3) Detailed engineering design on a priority Phase 1 development area of 9,000 ha.

Fieldwork for the reconnaissance survey was carried out from July to October 1978 and the Reconnaissance Report was submitted in December. Only 15,500 hectares of land were identified as being suitable, both on soil and engineering grounds for irrigation development. The Phase II studies are confined to this area, which comprises the lower Shabeelle floodplain extending from the line of the new Jilib-Golweyn road to the northern limit of the banana plantations around Kamsuuma. This area is henceforth referred to as the Homboy Irrigated Settlement Project Area.

The present report describes the methods, findings and conclusions of the soil survey investigations, forming part of the Phase II studies which were carried out in the Homboy Irrigated Settlement Project Area. Chapter 1 gives an account of the general natural and human resources of the area and Chapter 2 describes the soils in more detail, drawing on information gained from the present survey and investigations. The principles and methods employed for arriving at the land suitability classification for the proposed development are described in Chapter 3, along with general guidelines as to suitability for rainfed agriculture. The findings, conclusions and recommendations of this study are presented in the 'Summary and Conclusions' at the beginning of the report.

Summary and Conclusions

The Reconnaissance Survey (HTS, 1978) recommended that the Homboy-Burgaan area was the only area within the Fanoole command suitable for large scale irrigation development. In the present Phase II study, this area was renamed the Homboy Irrigated Settlement Area. Detailed topographic survey, semi-detailed soil survey and agricultural investigations were carried out over the Homboy Irrigated Settlement Area in the Haggai season of 1979.

The topographic survey was carried out using trace lines 250 m apart. Final maps were plotted at 1:10,000 scale with a contour interval of 0.25 m.

The soil survey covered a total of 15,100 hectares, comprising the entire lower Shabeelle floodplain between the proposed new Jilib-Golweyn road and the line joining the villages of Kamsuuma and Burgaan. Soil survey traverses were carried out on trace lines at 1 km intervals. A total of 596 soil profile pits and auger borings were examined, giving a density of observation of one site per 25 hectares. Field tests were carried out to measure surface infiltration and soil permeability at selected representative sites and laboratory analyses of physical and chemical properties were carried out on selected samples. Soils and Land Suitability maps were prepared at 1:20,000 scale, based on the data from soil investigations, and utilising the 1:10,000 scale topographic maps as a base.

The soils are mainly fine textured, and clay content increases from the levees of the virtually abandoned Farta Tukuule, through the flat cover floodplains, to the depressional areas. Soils on the lower cover floodplain and in the depressions typically have a prismatic structure in the root zone and a massive/wedge structure in the subsoil. Levee soils are better structured, but appear more susceptible to erosion. Permeabilities are low in the subsoils of cover floodplain and depression soils, except where coarser layers occur. Salinities are generally high in the subsoil but chemical differences between soil units are not significant.

Variations in the soils of the lower Shabeelle floodplain are not the only factors influencing land suitability or choice of cropping pattern. Most of the deeper depressions in the proposed project are excluded on the basis of flood hazard, and the levee soils are downgraded on the basis of their topography and irregular shape. The high clay content and poor soil structure in the depressions, however, makes them more suited to rice cultivation, and the more irregular topography on the levees make them more suited to sprinkler irrigation. Table S.1 summarises the land classes in the Project Area.

TABLE S.1 DISTRIBUTION OF LAND CLASSES IN THE PROJECT AREA

Class	Suitability	Area (ha)	Area (%)
II	Suitable	6,456	42.7
III	Moderately suitable	5,702	37.8
IV	Very marginally suitable	776	5.2
VI	Unsuitable	2,151	14.3

Table S.1 shows that a total of 12,158 hectares gross of land in the Project Area are suitable for irrigation development. This figure is likely to be significantly reduced in the irrigation design stage.

1

The Study Area

1.1 LOCATION AND DESCRIPTION

The area covered by detailed topographic survey and semi-detailed soil survey was selected from the Reconnaissance Report as being the area most suitable for irrigation development. The location of this study area now termed the Homboy Irrigated Settlement Project Area, is shown in Figure 1.1. It comprises the entire floodplain of the lower Shabeelle River between the new Jilib-Golweyn road which is presently under construction, and the northern limit of the banana plantations around Kamsuuma. The area is bounded to the north west and south east by the extensive flat Marine Plain and associated 'Beach Remnants', to the north by fairly extensive swamps and to the south by the sandy Coastal Ridge and the banana plantations. The study area comprises 15,100 ha and lies between the geographical coordinates 0° 15' and 0° 30' and 42° 00' E.

The study area lies within the Lower Jubba region and is divided between Jilib and Jamaame administrative districts. Figure 1.1 illustrates the present pattern of settlements and communications within the adjacent to the study area.

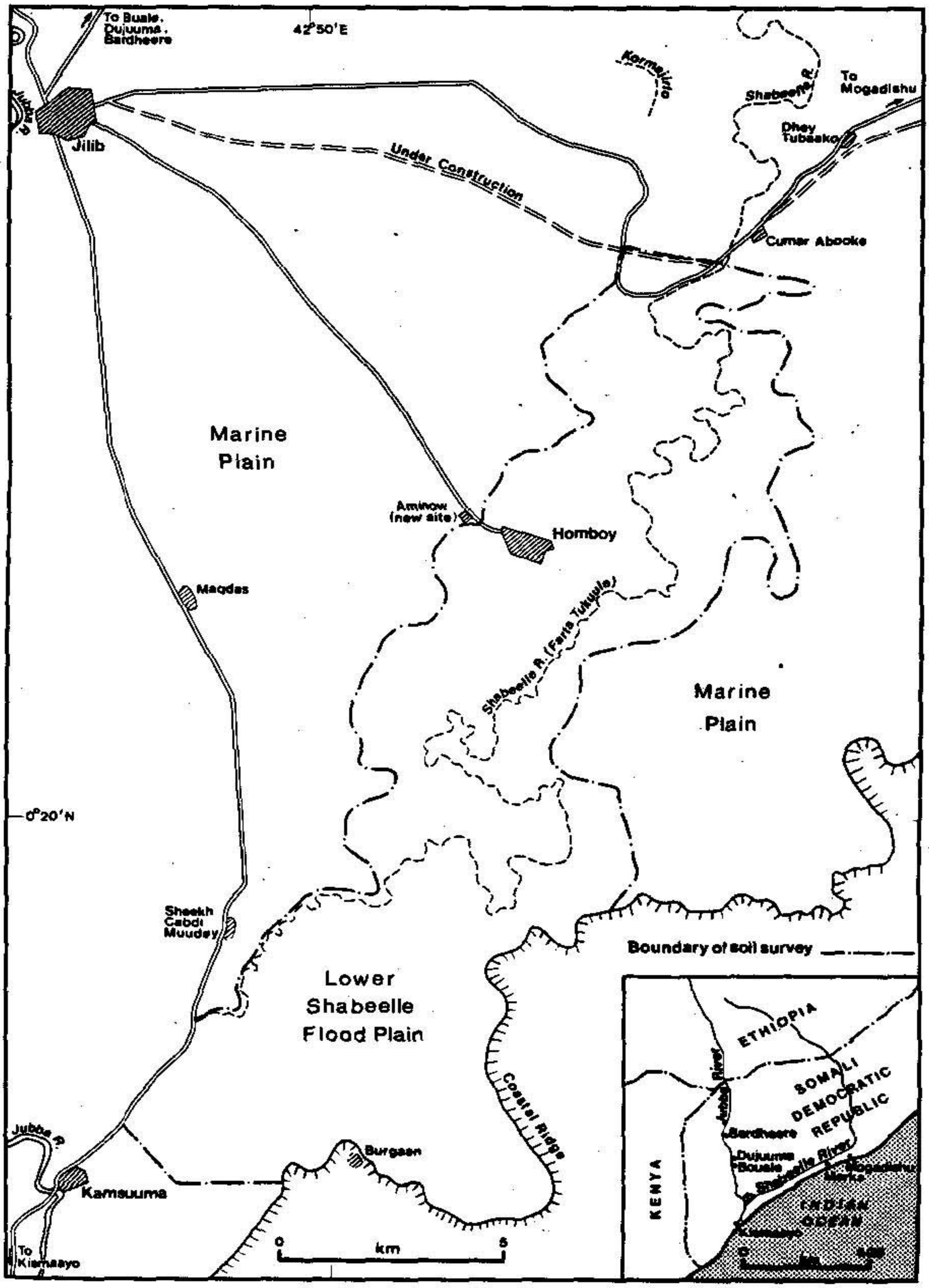
Settlement within the actual survey area is limited by flood hazard under the present situation in which no flood protection measures are employed. Homboy (population 3,734) is the only settlement of any size and is situated on an 'island' of Beach Remnant material about 3m above the surrounding floodplain. A few small villages, comprising less than ten families each are situated on higher level sites alongside the Farta Tukuule, and temporary camps are established on the floodplain by nomad graziers during the 'Haggai' and 'Gelal' seasons. A number of villages are situated around the perimeter of the floodplain, notably Burgaan (population 1,500) on the Coastal ridge, and Aminow (population 631) which has been recently resited on the Marine Plain, close to Homboy. Villagers from these settlements exclusively farm the alluvial lands within the survey area. The relationships between present settlers in the study area and their agricultural activities is discussed in Chapter 5.

Present communications to and from the study area are poor. Homboy is linked to Jilib by a relatively good dirt road, and to the Jilib-Golweyn and Jilib-Kismaayo roads by poor quality tracks. All these lines of communication are frequently cut in the rainy seasons. The track linking Burgaan to the Jilib-Mogadishu road at Kamsuuma is rarely passable in the rainy seasons and the track over the sand ridge to Jamaame is barely negotiable by four wheel drive vehicles even under dry conditions. The extreme south west of the study area has direct access to the metalled all weather Jilib-Kamsuuma road and the extreme north is accessible to the Jilib-Mogadishu road which is presently only seasonably passable. Within the survey area, a few tracks link smaller settlements to Homboy. These are normally motorable only in the dry seasons.

TABLE 1.1 CLIMATIC DATA FOR JILIB (ALESSANDRA)
00°30'00"N 40°46'00"E Altitude 24 m

Month	Period / Years Complete Data	Temp °C	Humidity %	Wind Run km/day	Sunshine hrs/day	Penman Eo mm/day	Rainfall mm
	Period	1923-63	1931-63	1953-59	1934-58	-	1922-60
	Years Complete Data	15	13	5	7	-	20
January		28.7	69	150	9.19	7.1	2.2
February		28.9	68	170	8.96	7.5	1.4
March		29.0	67	160	10.00	7.9	8.0
April		28.3	73	78	7.62	6.4	138.5
May		28.0	78	35	7.62	5.8	111.2
June		26.5	79	52	6.87	5.2	54.0
July		25.8	77	52	6.98	5.2	52.5
August		26.1	75	60	7.93	5.8	18.0
September		26.6	73	86	8.51	6.4	17.7
October		27.3	73	95	7.47	6.3	74.6
November		28.0	76	78	6.72	5.9	59.7
December		28.1	74	95	8.21	6.3	48.3
Year		27.6	74	93	8.01	6.3	585.9

1.1 Homboy Irrigated Settlement Area
Location, settlements and communications



Following completion of the Jilib-Golweyn road, the Jilib area will have assurred communication with Mogadishu and with the port of Kismaayo. In the planning and implementation of the proposed project, the network of roads within the project area must be adequate to ensure easy access of required inputs and to allow efficient transport of agricultural produce to these trunk routes.

1.2 CLIMATE

The climate of the project area is classified as tropical semi arid. Rainfall is bimodally distributed with maxima occurring in the 'Gu' (April to May) and 'Der' (October to December) seasons respectively. The 'Gelal' season (January to March) is generally hot and dry, but showery weather is common in the 'Haggai' season (June to September). Jilib (Alessandra Research Station) is the closest meteorological station to the project area with reasonably continuous records extending over a period of time. Table 1.1 summarises climatic data for Jilib, together with Penman evapotranspiration estimates based on HTS (1977).

1.2.1 Rainfall: Seasonal and Geographical Distribution

Although less critical than under a rainfed system, the seasonal distribution of rainfall is, nevertheless, important under irrigation in determining water requirements and the timing of cultivation and harvesting operations.

Available rainfall data from Jilib (Alessandra) was analysed in the Inter-Riverine Study (HTS, 1977). Table 1.2 illustrates major characteristics of the Gu and Der rainy seasons.

TABLE 1.2 CHARACTERISTICS OF 'GU' AND 'DER' RAINY SEASONS AT JILIB (ALESSANDRA)

	Gu Season	Der Season
Average Rainfall (mm)	356	183
Start[1]:		
1 year in 4	By 9th April	By 17th October
Average	14th April	26th October
3 years in 4	By 18th April	By 3rd November
Duration[2]:		
1 year in 4	95 days	50 days
Average	77 days	49 days
3 years in 4	59 days	40 days

[1] *The average rainfall in the Gu season includes the 'Haggai' rains falling in June to July.*

[2] *Start and finish of rainy seasons has been taken as the first and last falls of 10mm or more. Isolated raindays separated by 10-15 days from other raindays have been excluded from the main season.*

The geographical distribution of rainfall is important when applying meteorological data from Alessandra or other stations to the project area. According to the isohyetal map in the Inter-Riverine Report (HTS, 1977) total annual rainfall tends to decrease from Jilib towards the coast. However, data is insufficient to state that total annual rainfall varies significantly between Jilib and the project area or within the project area itself. Of greater significance is the local nature of most of the falls and the resulting variation in daily, monthly and annual total rainfall between stations located in fairly close proximity

TABLE 1.3 VARIATION IN MONTHLY RAINFALL IN 1978 AT THREE STATIONS CLOSE TO THE PROJECT AREA

	Alessandra 0°30'N 42°46'E 24m		Jilib State Farms		Jubba Sugar Project 0°25'N 42°42'E 20[1] m	
	Rainfall (mm)	No. of Rainy Days	Rainfall (mm)	No. of Rainy Days	Rainfall (mm)	No. of Rainy Days
January	0	0	0	0	0	0
February	0	0	0	0	1.1	1
March	84.7	6	103	7	35.4	5
April	153.7	16	390	16	198.2	16
May	228.9	19	203	12	222.3	21
June	38.8	14	57	6	39.6	14
July	32.1	11	56	9	32.5	13
August	3.2	4	8	1	4.3	4
September	0.2	1	0	0	0.0	0
October	37.1	5	39	3	101.4	10
November	225.6	17	273	13	163.5	15
December	83.4	11	141	8	174.1	11
Total	887.7	104	1,270	75	972.4	110

[1] *This is the geographical reference of the 'Permanent Meteorological Station'. From January to July, readings were taken from the 'Temporary Office Site'.*

to one another. Table 1.3 illustrates the variation in monthly rainfall totals and the number of rainy days between three meteorological stations during 1978. These stations were situated not more than 12 km apart and lying to the north west and west of the project area. Figures are calculated from daily rainfall totals collected during the present study. Daily rainfall figures are presented in Appendix F.

Table 1.3 shows that 1978 was wetter than the average year. In particular, the rainfall at the Jilib State Farms amounts to more than twice the annual average. Variation between stations occurs during both the 'Gu' and 'Der' rainy seasons. Diurnal variations are particularly significant (see Appendix G).

Evidence suggests that most of the flooding which occurs in the project area under present conditions results from rainfall and, apart from imposing high demands on the surface drainage system, the very local nature of the precipitation hampers accurate prediction and application of irrigation water requirements. There is a clear need, therefore, for an efficient surface drainage system of adequate capacity and a certain amount of flexibility in the management of irrigation applications. A full meteorological station should be established as soon as possible during project implementation and, as development proceeds, a number of rain gauges should be established in different parts of the irrigated area.

1.3 GEOMORPHOLOGY

The study area is confined to the alluvial floodplain of the lower Shabeelle River which merges into the more active Jubba floodplain in the south. Presently there appears to be little throughflow of water along the Shabeelle channel (Farta Tukuule) into the Jubba River, but the regular distribution of sediments around the channel suggests that the Shabeelle was more active in historic times. The present landscape of the Shabeelle floodplain results mainly from this semi recent activity, although fragments of terraces and meander complex are indicative of still older phases of deposition. In the extreme south of the area back flooding from the Jubba has resulted in a more complex distribution of landforms.

Within the study area the Shabeelle Floodplain varies from around 5 km to 8 km in width. The topography is very subdued except in the vicinity of channels or *fartas* and most of the area appears virtually flat to the naked eye. Figure 2.2, however, which illustrates a typical cross section of the floodplain in the vicinity of Homboy, shows a distinct topographic sequence typical of an aggrading river, with a central channel surrounded by elevated levees sloping onto flat areas of 'cover floodplain' and with backswamp depressions along the floodplain perimeters. In fact, the river was aggraded to such an extent that the Farta Tukuule is now effectively blocked and most of the water resulting from high flow further up the Shabeelle flows along more recent channels into the peripheral depression areas.

Alluvial areas can be readily subdivided into component landform units on the basis of air photo interpretation and field observations. In the present study area eleven units were recognised during the course of the soil survey. They are listed in Table 1.4.

Of the landforms listed in Table 1.4, those developed from semi recent and recent alluvium are by far the most extensive and account for over 85 per cent of the study area. The remaining landforms are relatively less important and, in general, give rise to soils or topographic conditions which are less suited to development of irrigated agriculture.

TABLE 1.4 ALLUVIAL LANDFORM UNITS

Unit	Origin
Levee Cover Floodplain Depression Depressional Lake Farta (Channel)	Semi recent and recent Alluvium
Terrace (higher) Terrace (lower) Meander Complex Oxbow Lake	Old Alluvium
Jubba-Shabeelle Floodplain Complex	Mixed Jubba and Shabeelle Alluvium
Slopes of adjacent Marine Plain	Alluvium and Marine clay

Because alluvial landforms and constituent soils are products of the same depositional processes, the alluvial landforms listed in Table 1.4, are used as the basis of the soil classification adopted in the study area which is described in Section 2.3. Derived soil mapping units have distinct topographic as well as soil properties and this facilitates assessment of their suitability for irrigation development.

Further details of alluvial landforms and related soil mapping units are presented in Appendix B.

The floodplain landscape is still evolving in response to present day geomorphological processes although the time scale over which these occur is too long to significantly affect development of an irrigation project. Currently the area receives sediments in periods of flood from the Shabeelle river and its associated highly seasonal tributaries the Harar Naga and Kormajirto, and from runoff resulting from local rainfall on the surrounding Marine Plain. Flood water collects in the wet seasons in the depressions on the eastern and western sides of the floodplain where most of it evaporates. Periodically, the southern part of the study area is subject to flooding and more active deposition of sediments from the Jubba river. Control of flood water from these sources forms an essential part of project planning.

1.4 NATURAL VEGETATION

Natural vegetation within the study area is primarily dependent on the duration of flooding under the current hydrological regime. As flood duration is primarily dependent on relative elevation, vegetation associations are strongly related to the landform units listed in Section 1.3. The existing vegetation pattern has been affected by cultivation in some areas and this has resulted in changes in species distribution.

Figure 2.2 illustrates typical vegetation associations on the most common landforms in the study area. In the predominantly flooded deeper depression areas, swamp grasses and sedges predominate with relatively few emergent trees. The shallower depressions are characterised by dense growth of *Acacia nilotica* while the cover floodplains support a mixed *Acacia* and non thorny shrubland in which such species as *A. nilotica*, *A. zanzibarica*, *A. bussei, Dobera glabra* and *Thespesia darlis* are well represented. On the higher levee areas, non thorny species tend to dominate and often give rise to a more open cover. In the areas that have been under fallow for one or two years or more regrowth is dominated by such species as *Ficus populifolia, Dalbergia* spp. and *Therpesia darlis.*

Vegetation associations on individual landforms and soil mapping units are given in Appendix B.

1.5 POPULATION

The present section identifies population groups currently associated with the project area and gives some indication of how these groups may react to development of the proposed settlement project.

Although no accurate population statistics exist for the project area it is possible, on the basis of observation and local discussion, to classify the population with an agricultural or livestock interest in the project area into four groups:-

(i) Settled population
(ii) Settled and semi settled nomads
(iii) Pure nomads
(iv) Town people, primarily from Jilib and Kamsuuma, who use parts of the area for agricultural purposes.

The decision on whether to offer the present population places as settlers in the proposed scheme is the responsibility of the Settlement Development Agency. Discussions with village chiefs revealed that most of the settled population and settled and semi-settled nomads (Groups i and ii) wished to participate in the scheme. The distribution of population in these groups in the villages either within or adjacent to the project area is given in Tables 1.5 and 1.6.

TABLE 1.5 DISTRIBUTION OF PRESENT SETTLED POPULATION IN THE PROJECT AREA

Village	Families	Total Population	Remarks
Homboy:			
Iftin	150	945	All amalgamated with Homboy village complex
Kulmix	190	1,104	
Barka	160	904	
Holwadaq	155	775	
Aminow	95	574	
Bula Gedud	22	85	
	772	4,387	
Dayax	22	250	Moved to Gedgoy
Goorka	60	300	
Cumar Muuse	1	12	
Sheek Cabdey Muudey	40	200	
Gedgoy	see Dayax		Not a true village, scattered residence in cultivated area
Burgaan	288	1,497	
Olhari	20	104	
Burtaquma	18	93	
Totals	1,221	6,843	

TABLE 1.6 DISTRIBUTION OF SETTLED AND SEMI-SETTLED NOMADS IN THE PROJECT AREA

Village	Families	Total Population	Remarks
Ged Subag	30	150	These figures can be regarded as the base population who remain in the area but at times these villages are much enlarged.
Cabdi Maama	25	140	
Demasera	8	40	
Cumar Abooke	80	400	
Gedgoy	80	400	
Totals	**223**	**1,130**	

Although permanent, in that this group cultivate land annually, they still retain much livestock and have close links with their related nomadic population.

Although a few of the truly nomadic population, which amounts to around 2,000 people during the 'Gelal' season, may be attracted to settle on the proposed scheme, we consider that settlement would not be attractive to the town people in Group (iv). Local settlers would, therefore, be drawn mainly from Group (i) and (ii) which are quantified in Table 1.5 and 1.6. This would amount to a maximum of around 1,400 families. If the proposed 9,000 hectare area is to be divided on the basis of 1 hectare of irrigated land per family, this leaves sufficient land to accommodate 7,600 families from Dujuuma.

1.6 AGRICULTURAL LAND USE

Present agricultural land use practices are well adapted to the environmental conditions of the lower Shabeelle floodplain.

Figure 2.2 illustrates two types of agricultural land use which are typically found in the study area. These are:

(a) Cropping of cereals (sorghum and maize) on the cover floodplain and levees, and

(b) Cropping of sesame, maize, sorghum and pulses in the depressions and channels.

Cropping on the levees and cover floodplain relies primarily on rainfall although some residual moisture is probably utilised from the relatively infrequent floods which cover these areas. The soils on these landforms generally have silty clay and silty clay loam surface horizons which made them more easily workable than the clays of the depressions. Crops frequently show uneven growth which may be due to moisture stress. Planting generally coincides with the onset of the 'Gu' and 'Der' rains and frequently two crops are grown in one year on each piece of cultivated land.

Cropping in the depressions, however, takes place mainly by utilising residual flood waters. The lower areas are progressively planted as the water recedes. Sesame is typically planted in the wetter sites. Cultivation is limited to preparation of small basins with a hand hoe or 'yambo'.

Crop husbandry is based on traditional practices with low levels of inputs and consequently low yields. Local varieties are grown and fertilisers are not used. Apart from 'seed dressing' pesticides are not used. More recently, however, villagers at Homboy have cooperated and hired ONAT tractors for primary cultivation operations. In the 'Der' season of 1978 a large area in the vicinity of Homboy was ploughed and subsequently planted to sorghum intercropped with green gram. These relatively progressive measures, together with the high rainfall in 1978, help to account for the sale of surplus crops amounting to 929 quintals of sesame, 560 quintals of maize and 854 quintals of sorghum to ADC, Jilib. The Homboy area is at least self sufficient in grain in most years and surplus crops, not sold to ADC, are normally stored in pits. Government assistance was, however, required in the severe drought of 1973-4.

Although the Ministry of Agriculture provides an extension service staffed by a District Agricultural Officer with a team of 35 extension workers based on Jilib, private farmers such as those resident in the project area, are amongst the lowest priority group and receive little attention. The efforts of the extension service are directed mainly towards participants in 'Crash Programmes' and Producer Cooperative Groups. The extension staff comprise specialists in training and plant protection, cooperative advisers and surveyors.

Because pressure of population is not severe in the study area the overall density of agricultural land use in not high. Most of the existing cultivation is concentrated around the main centres of population such as Homboy and Burgaan. During the soil survey, observations of current land use were made at sites of soil profile pits and auger borings. As soil survey was carried out on a grid basis and bores were spaced to give an even density over the survey area, analysis of these point observations gives an accurate estimate of current land use in the area. The results are presented in Table 1.7.

TABLE 1.7 HOMBOY IRRIGATED SETTLEMENT AREA: PRESENT LAND USE ANALYSIS

Land Use Class		No. of Observations	%
U	No evidence of cultivation	329	59
F2	Long term fallow (> 2 years)	72	13
F1	Recently fallowed land	37	7
C	Presently cropped or harvested during current season (Gelal)	118	21
		556	**100**

21 per cent of land in the study area, amounting to approximately 3,200 hectares is presently cultivated and a further 20 per cent shows signs of previous cultivation. Of the cultivated land, 26 per cent is farmed mainly on residual flood water around the larger depressions, the other 74 per cent is mainly sorghum (Der season crop) grown on cover floodplain and levee areas.

1.7 LIVESTOCK

The lower Shabeelle floodplain is an important grazing area for livestock. Cattle products, live animals, meat and hides are a major Somali export and a large proportion of the nation's cattle are concentrated in the lower Jubba region. Local sources estimate the resident cattle population in the Dhey Tubaako-Homboy area as 5,000.

An aerial livestock survey census was carried out by FAO in the 'Gelal' season of 1975 and 1976, when the resident population is greatly increased by an influx of nomad graziers. The resulting statistics, however, are organised by districts and do not account for the much higher livestock concentrations on the alluvial floodplains at this time of year, when grazing on the marine plain is minimal. Field observations in the 'Gelal' season made during the present study suggested a cattle population far in excess of the 5,000 resident population, together with large numbers of camels, goats and sheep.

Livestock are owned by both 'settled nomads', who also cultivate crops (Section 1.5), and by semi nomads, who return to the villages of their settled kinsman on a bi-annual cycle, which coincides with the dry season harvesting of arable crops and the availability of crop residues. A proportion of livestock is retained in the villages to provide a source of meat and milk, and a very active trade is carried on with the resident agricultural population. This trade, together with the relatively high level of agricultural production has resulted in a balanced nutritive diet enjoyed by the population. According to the World Food Programme, residents of the Lower-Middle Jubba Regions currently have the highest standard of nutrition in Somalia.

Irrigation development of the project area will undoubtedly have a major impact on the livestock population and on the local economy of the resident population. In a broader context, the planned development of the Jubba and Shabeelle floodplains could have a serious adverse effect on the regional livestock population and hence affect the volume of livestock exports, unless livestock are integrated into schemes or adequate provision is made for alternative grazing. The latter alternative would be difficult to realise, as the marine plain surrounding the floodplain area has a comparatively low carrying capacity due to poor soils and relative absence of flooding. Serious consideration should be given, therefore, to integrating livestock into the proposed irrigation scheme. Crop residues could be fed to livestock and the possibility of fodder production should be examined. With the present situation of cooperation between farmer and graziers within the project area, and the nomadic background of the Dujuuma settlers, integration of livestock into the scheme should have many socioeconomic advantages.

1.8 OTHER ACTIVITIES: FISHING AND WOOD GATHERING

Fishing is currently practiced in the depressional lakes and deeper depressions in the project area, particularly in the Far Sitay lake, which rarely completely dries out. Fish is sold either fresh or dried, and forms an addition to the protein content of the local diet. It is unlikely that the deeper depressions will be utilised for cropping under the proposed irrigation system, and fishing activities could be continued or perhaps extended following project implementation.

The remaining woodland and shrubland in the project area is used as a source of timber for building poles and firewood. Most of this resource will disappear on project implementation. The ability of the surrounding marine plain to furnish alternative supplies is not known at present.

1.9 WILD LIFE

The Lower Jubba region harbours a rich and varied assemblage of wildlife and a number of mammal species such as elephant, hippopotamus, greater kudu, gerenuk, waterbuck, wart hog, caracal, civet, dik-dik and baboons, along with numerous bird species, were observed during the course of the survey. Under present circumstances these animals compete for food and water with the resident farming population and with domestic livestock. We recognise that wild game will inevitably be excluded from the proposed irrigation area but efforts should be made to ensure minimum disturbance of surrounding areas such as the Shabeelle swamps upstream of the Jilib-Mogadishu road. This recommendation does not preclude the use of this area as flood storage area, as flooding would only be temporary during periods of high flow in the Shabeelle River or the Harar

Naga. The Somali government's policy is laudable in preserving a rich wild life resource which could have future potential for tourist exploitation, and current and future development of the region should take account of all its productive resources.

1.10 THE DUJUUMA SETTLERS

Although not yet a component of the study area, the Dujuuma settlers are the raison d'etre of the present study and their numbers and agricultural activities are outlined below.

Table 1.8 shows the present and former population numbers on the three SDA settlements, and shows the distribution of settlers by age and sex in June 1978. Largely due to the partial failure of agricultural production, the population has declined in all three settlements but Dujuuma, as the least successful, has suffered the greatest loss. Since the beginning of 1979, the number of families leaving the settlements has declined.

Agricultural production does not provide subsistence for the settlers and there is continued dependence upon the World Food Programme to provide food. Agricultural activities are confined to 100 hectares of irrigated vegetable production and 485 hectares of rainfed crops. Cultivations on the irrigated land are mechanised whilst traditional methods of cultivating and planting are maintained on the rainfed area. No fertilisers are used and yields are consequently low. Table 1.9 gives the yields obtained from rainfed crops during the 1977/78 'Der' season.

TABLE 1.9 DUJUUMA YIELDS FROM RAINFED CROP PRODUCTION 1977/78 'DER' SEASON

Crop	Yield Quintals/Ha	Remarks
Sorghum	2.0	Bird damage severe
Sesame	0.8	
Maize	4.5	
Groundnuts	10.0	
Cowpea	2.0	

Although 4,000 adults are available to provide labour on the schemes, the average daily turn out is around 1,450 persons who receive payments ranging between 2/- and 5/- per day depending on the type of work. The remainder of the available work force are unemployed or underemployed. Resettlement in Homboy will mean that a much greater level of physical commitment to working on the scheme will be required.

TABLE 1.8 SETTLEMENT POPULATIONS

(i) Changes in Population

Year	Dujuuma	Sablale	Kurtun Warey	Total
1975	47,896	29,486	26,295	103,677
1978	27,646	19,431	17,990	65,067
1979	25,078	16,831	16,811	58,720

(ii) Breakdown by sex and age grouping as at 30.6.78

	0 - 5			6 - 14			15 - 60			61 and over			Grand
Settlement	M	F	Total	M	F	Total	M	F	Total	M	F	Total	Total
Dujuuma	1,683	1,559	3,242	7,172	5,689	12,861	4,191	6,698	10,889	292	362	654	27,646
Sablale	1,300	1,400	2,700	4,300	4,387	8,687	2,735	4,165	6,900	420	724	1,144	19,431
Kurtun Warey	1,329	1,314	2,643	3,686	2,866	6,552	3,489	5,111	8,600	86	109	195	17,990

2

Soils

2.1 METHODS OF STUDY

The Homboy Irrigated Settlement Project area was subjected to soil survey at semi detailed level as required by the Terms of Reference. The total area covered by the soil survey amounts to 15,100 ha and the average density of observations is one site per 25 hectares.

2.1.1 Soil Survey

The boundary of the area covered by the soil survey was taken as the boundary of the lower Shabeelle floodplain as indicated on the Reconnaissance Study maps. This boundary was amended in a few areas as more soils and topographic information became available.

The entire area is covered by aerial photographs (1:33,000 scale flown by Aero Exploration, Frankfurt in 1963). These are rather old and the small scale limited their use for detailed soil mapping. The contact prints were however, useful for location purposes in the field. Soil survey fieldwork was preceded by interpretation of these aerial photographs.

Soil survey traverses were carried out along the trace lines cut for the topographic survey. The network of cut lines traversed during the soil survey is shown in Figure 2.1. Lines at one kilometre intervals were normally traversed and borings to two metre depth were made at 250 m intervals using a two inch Jarrett auger. Soil profile pits, excavated to two metres, were sited representatively throughout the survey area. Pits and bores were described according to FAO guidelines and such features as topography, microrelief, surface characteristics, vegetation and land use were recorded at each site. A total of 596 sites were examined; 23 of these were soil profile pits which are described in Appendix C. In addition a further 23 borings and two pits excavated during the reconnaissance survey fall within the present survey area. Auger borings were extended to five metres at 20 sites to study subsoil drainage characteristics. A sample area of 100 ha was surveyed at a density of one bore per 5 ha to investigate variation in soil type within mapped units.

Soil samples were collected at alternate bore sites for routine chemical analysis. Standard sampling depths were 0-25 cm, 25-50 cm and 50-100 cm. In addition, at every tenth bore site samples were collected from 100-150 cm and from 150-200 cm. The analytical results from these deeper layers could be of significance if water table rise occurs during the irrigation project bringing harmful salts into the root zone. Eleven representative soil profile pit sites were sampled by horizon for more detailed analysis. Undisturbed core samples were also taken from these sites for determination of bulk density and moisture retention characteristics.

2.1.2 *Field Soil Tests*

Double ring infiltrometer tests were carried out at 11 representative sites adjacent to soil profile pits in order to assess surface infiltration characteristics. Measurements of horizontal saturated hydraulic conductivity were made at a total of 20 sites using the pour in auger hole method. At three sites attempts were made to measure vertical hydraulic conductivity by siting an infiltration ring at the bottom of a soil pit.

The results of these soil physical tests are summarised and discussed in Section 2.6 and the experimental methods and detailed results are presented in Appendix E.

2.1.3 Laboratory Analysis

The soil samples were analysed at the laboratories of Hunting Technical Services in Borehamwood, England. Routine bore samples were tested for pH, salinity (electrical conductivity of saturation extract), cation exchange capacity, and exchangeable sodium. The exchangeable sodium percentage (ESP) which is a standard measure of soil sodicity or alkalinity was calculated as a percentage of the measured cation exchange capacity. In addition to the above, the soil pit samples were submitted to particle size analysis and to testing for exchangeable cations, soluble anions and cations, soluble boron and total carbonate. Surface horizons were also tested for organic carbon, total nitrogen and total and available phosphorus. Bulk density measurements were carried out on undisturbed samples and soil cores were also subjected to moisture retention determinations at suctions of 0, 0.1, 0.3, 1 and 15 bars. Laboratory analytical methods are described in Appendix F. The results are presented in Appendices C and D, and are summarised and discussed in Sections 2.5-2.7.

2.1.4 Mapping

The detailed topographic maps produced at 1:10,000 scale by Hunting Surveys Limited concurrently with the present study were used as a base for the 1:20,000 scale soil maps enclosed with the present report. Sites of soil profile pits and auger borings, including relevant sites from the reconnaissance survey, were plotted on overlays to the 1:10,000 scale maps. Soil mapping units, initially based on those defined in the Reconnaissance Report, were subdivided and redefined with reference to the more detailed soil and topographic information now available (Section 2.3). Boundaries between units were interpreted mainly from the detailed contour information on the base maps, although interpretation of airphotos was also found useful in some areas.

Land Suitability maps were produced from the soil maps, suitability classes for irrigation being interpreted from soil mapping units on the basis of specific land and soil limitations significant under proposed project conditions which are discussed in Chapter 3. Boundaries between land suitability classes generally follow soil boundaries.

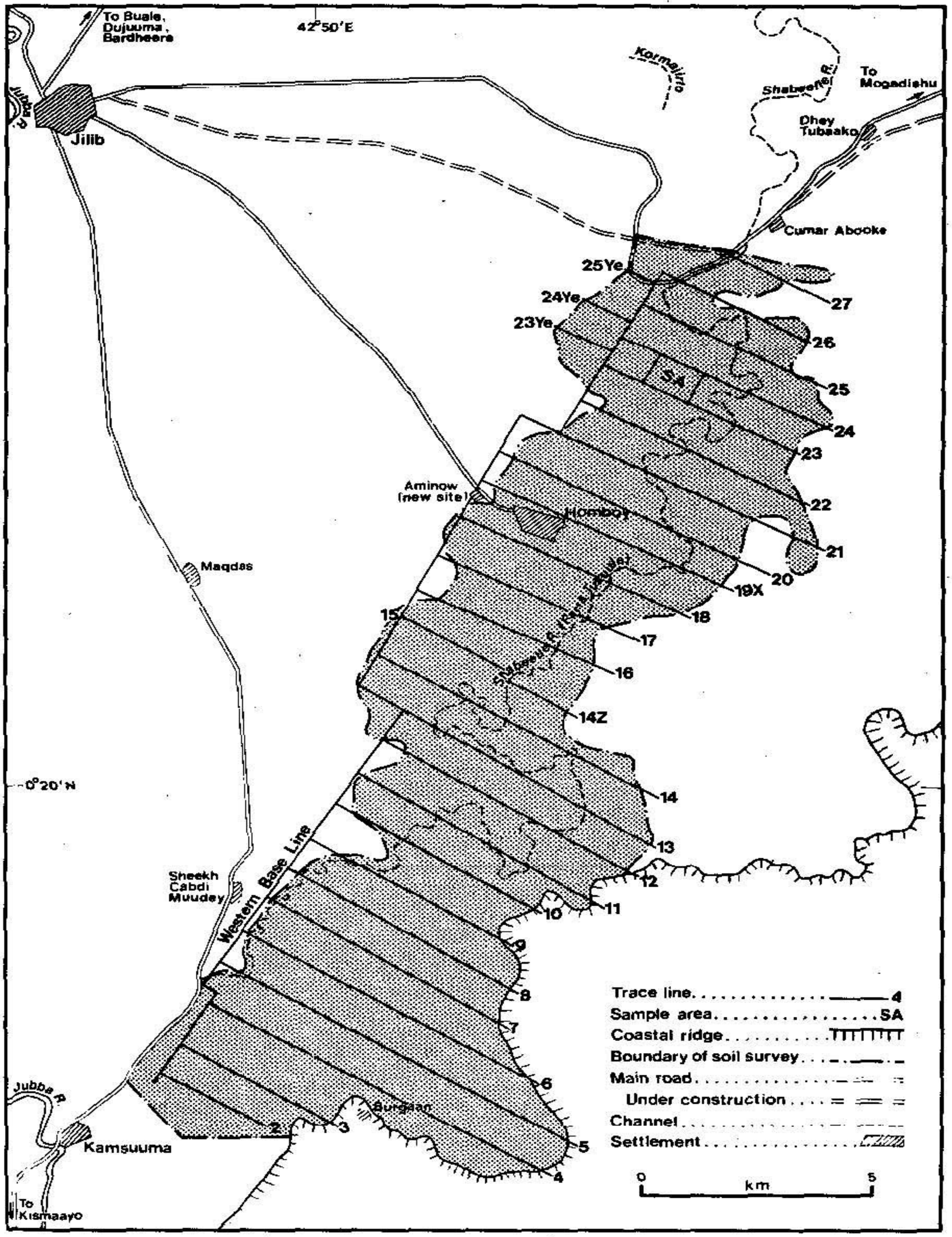
2.2 SOIL FORMATION

All the soils within the Homboy Irrigated Settlement Project Area are alluvial, having developed in parent materials deposited by fluvial processes. Soil properties are primarily determined by the mode of deposition of the parent material, by the resulting topography and associated duration of flooding and by the length of time, subsequent to parent material deposition, available for processes of soil formation to occur.

2.2.1 Formation of Soil Parent Materials

The aggrading regime of the lower Shabeelle River and the resulting deposition of sediments to form the type of floodplain landscape illustrated in Figure 2.2 is mentioned in Section 1.3. A number of landform units are identified and classified according to the

2.1 Soil survey traverses



origin of their parent alluvium, age and present topography.

These landform units give rise to characteristic soil parent material which due to the mature to senescent regime of the depositing river are predominantly fine textured. However, textural variations do occur over the floodplain, and these are related to the type of deposition. On the dominant semi-recent to recent alluvium a typical sequence is observed with relatively coarser deposits on the levees, finer deposits on the cover flood-plain areas and the finest deposits in the depressions. The complexity of fluvial depositions within the Project Area increases the difficulty of assembling relative ages to the soil parent materials. Because relatively coarse textured sediments accumulate more quickly, the youngest deposits normally occur as the levees of an active channel. However, the central Farta Tukuule is currently inactive and present day depositions result, mainly from flooding through discontinuous channels in the depression areas or by run off direct from the surrounding Marine Plain. Levees around these channels are either very poorly defined or absent and there is virtually no evidence of differentation in textural deposition resulting from current flooding. Evidence suggests that the Shabeelle River was more active in the period when the Farta Tukuule formed its primary channel and we therefore ascribe a semi recent origin to most of the soil parent materials of the Project Area, deposits resulting from current flooding being largely confined to the surface layers of some depressional soils.

The older Shabeelle alluvium, represented by at least two levels of terrace and a well defined meander complex in the south east of the Project Area also gives rise to dominantly fine textured parent materials, and fine textures also predominate in the area of mixed Jubba and Shabeelle alluvium in the south west. Around the perimeter of the floodplain colluvial wash from the adjacent Marine Plain or transitional Beach Remnant soil contributes to the dominantly alluvial soil parent material.

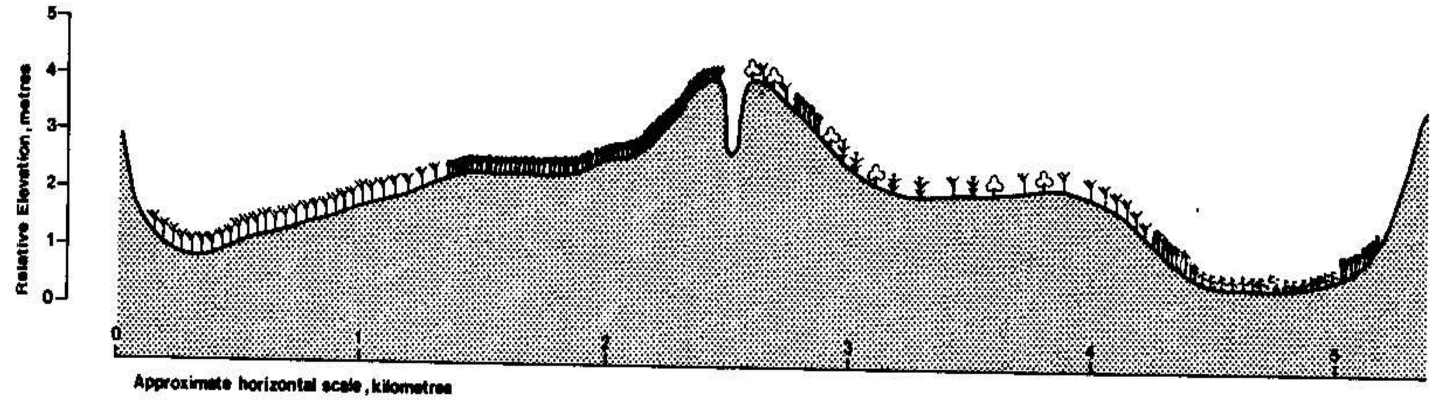
2.2.2 Pedogenesis

Soil profile development or 'pedogenesis' on the alluvial soils of the Project Area is determined primarily by the nature of the parent material, the length of time over which processes of soil formation have taken place and the soil moisture regime over the same period. Young (1976) describes the two major processes of initial soil formation as 'ripening' and 'homogenisation'. Ripening particularly affects clays and involves their consolidation, partial oxidation and development of cracks and relatively stable structural aggregates on drying. Homogenisation is the gradual breakdown of the layered structure associated with sedimentary deposition. Plant roots and faunal activity are the major contributors to this change and cultivation accelerates the process. Following these initial stages of soil formation further changes may occur over a period of time. Of particular significance to the subsequent management of some of the soils of the Project Area under irrigated conditions is the development of 'vertisolic' properties in the depressions and, to a lesser but still significant extent, on the cover floodplain. The processes leading to soil profile development on the landforms listed in Table 1.1 are outlined below. Figure 2.3 illustrates typical profile types.

(a) Levees

Soils developed on the levee landform unit adjacent to the currently inactive Farta Tukuule Channel are somewhat variable in texture and related properties. The typical profile, however, has a silty clay loam surface and passes into silty clay and finally into clay at depth. Although there is usually an overall increase in clay content with depth this increase is often irregular and there is little evidence of downward clay movement and the formation of argillic horizons (USDA, 1975). There is little

2.2 Lower Shabeelle floodplain: idealised cross section



Landform	Marine Plain	Depression	Cover Floodplain	Levee	Channel	Levee	Cover Floodplain	Depression Sideslope	Depression	Marine Plain
Soil Mapping Unit*	SMP	Sd2, Sd1	Sb2, Sb1	Sl2	Sf, Sh	Sl2	Sb1, Sb2	Sd1	Sd3	MP
Natural Vegetation	Acacia/non-thorny shrubland	Dominated by dense *Acacia nilotica* thicket	Mixed shrubland, including *Acacia nilotica* *Acacia zanzibarica* *Dobera glabra* *Thespesia danis*	Mixed shrubland More non-thorny species	Dense shrubland	Mixed shrubland More non-thorny species	Mixed shrubland, including *Acacia nilotica* *Acacia zanzibarica* *Dobera glabra* *Thespesia danis* and others	Dense *Acacia nilotica* thicket	Mainly swamp grasses and sedges. Few small *Acacia nilotica* and 'Eerib'	Mixed *Acacia*/ non-thorny shrubland
Current Land Use	Uncultivated		Cropped with Sorghum (Der season)		Sesame	Uncultivated; Sorghum Plot	Fallow, with remnant trees (mainly *Dobera glabra*) and low regrowth dominated by *Thespesia danis* and *Dalbergia spp.*	Uncultivated	Sesame, Maize, Sorghum, grown on receding flood water	Uncultivated

*See Section 2·3

sign of stratification, indicating that the soils are sufficiently old to have undergone the 'homogenisation' described above, and moderate structures are usually developed in the surface and subsurface horizons. Fine semi-hard calcium carbonate concretions are common throughout the profile and at apparently older sites larger discrete nodules have formed. The high content of calcium carbonate is a result of high levels of calcium in the flood water and the semi-arid climate and fairly impermeable subsoil which favour an accumulation of salts in the profile. Some of the concretions and nodules have subsequently become coated with iron and manganese oxides. Land snails are common in the Project Area and the large number of small fragments found in most of the floodplain soils probably significantly contribute to total soil calcium carbonate content. Where levee deposits overlay the heavier layers of an older depressional land surface (e.g. Profile Pit A302 - Appendix C) there is a marked concentration of fossil shell fragments at the interface.

(b) Cover Floodplain

Cover floodplain soils typically consist of a thin blocky surface horizon overlying prismatic clay which passes into weakly structured clay at depth. Lighter textured horizons are commonly encountered in the subsoil. Following ripening and homogenisation, many of the soils, particularly in the lower areas, have developed 'vertisolic' soil properties. Such properties are characteristic of soil having a high clay content and containing a significant proportion of swelling clay minerals such as montmorillonite which lead to soil expansion and contraction on wetting and drying. Cracks develop on soil drying giving rise to the typical coarse prismatic structure in the subsurface horizon, material is washed down the cracks and expansion on subsequent flooding results in shearing across pressure faces or 'slickensides' in the subsurface and subsoil horizons. Stresses due to soil expansion and contraction also give rise to a characteristic 'gilgai' microrelief at the land surface, consisting of rounded mounds, depressions and sinkholes, although this is not obvious in cultivated areas. The development of these vertisolic properties on the cover floodplain soils is less marked than on the depressional soils which are generally heavier textured. However, most of the cover floodplain soils justify grouping in the vertisol order according to the soil classification system of FAO/UNESCO (1974).

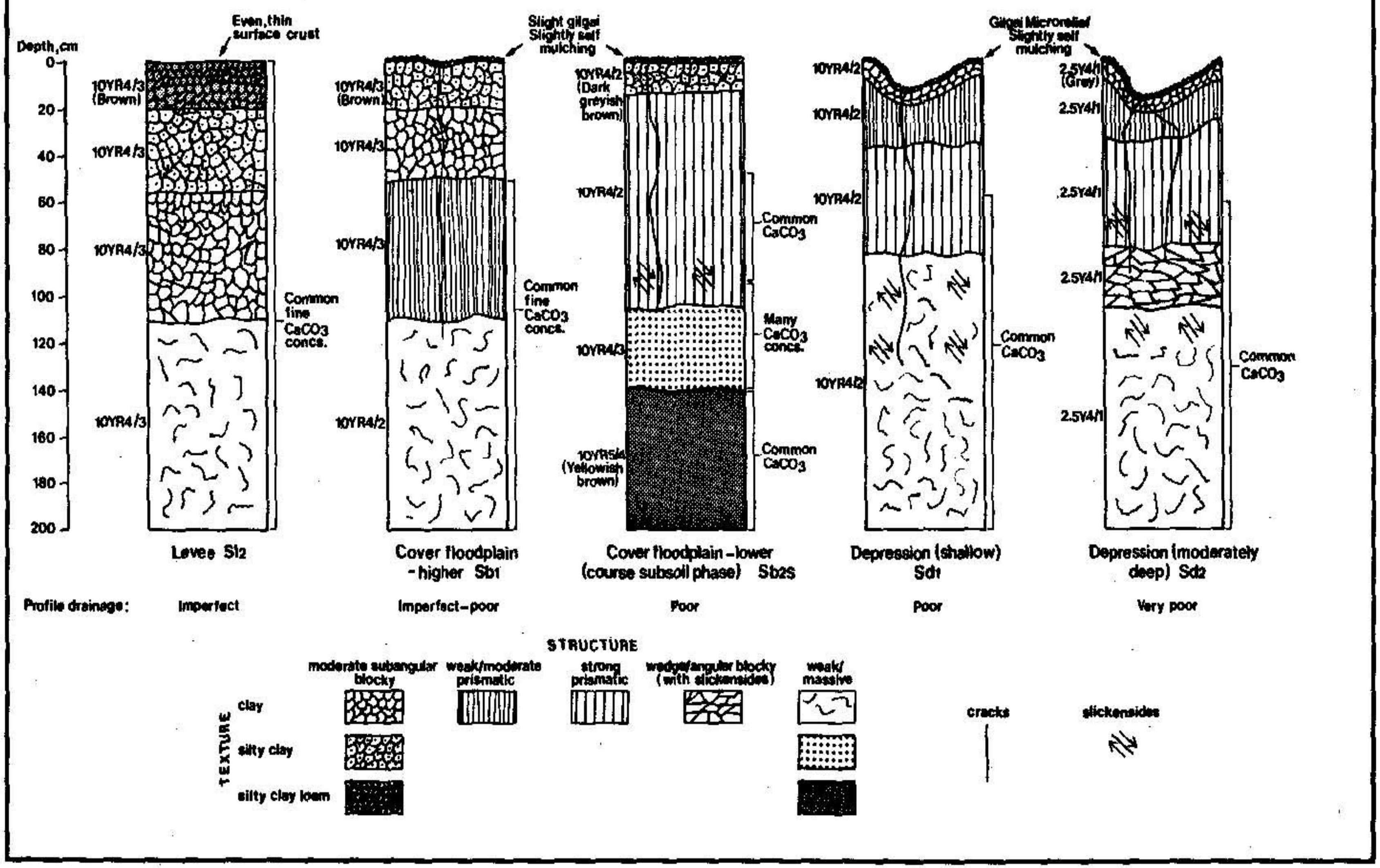
The lighter textured soil horizons which commonly occur in the cover floodplain subsoil are considered to be remnants of channels and levees formed during a previous, probably more active, cycle of deposition. They have a yellowish brown colour and texture ranges from light silty clay to loamy fine sand.

Fine calcium carbonate concretions and shell fragments occur in cover floodplain profiles. The former generally increase with depth and this may be due to illuviation. Accumulations of concretions commonly occur just above the boundary of lighter subsoil horizons. Occasionally weakly developed cutans were observed in the subsurface horizon, indicating possible downward clay movement.

(c) Depressions

Soils of the shallow to deep depressions and backswamps are typically clay textured throughout and typically have a blocky structured surface, a prismatic subsurface horizon and a weakly structured subsoil commonly containing wedge shaped aggregates and well developed slickensides on the ped surfaces. It is in the depressions that vertisol properties are most strongly developed. The gilgai microrelief is particularly severe in some of the depressions in the south west of the area which are flooded from both the Jubba and Shabeelle systems. The development of a self mulching

2.3 Common soil mapping units: typical profile types



surface is also a feature of soil expansion and contraction. On drying, the top one or two centimetres of soil often break into discrete subangular blocky aggregates. This improves the soil handling properties during present cultivation practices.

Small shell fragments are particularly common in the soil surface in depressional sites. Calcium carbonate concretions and amorphous or crystalline deposits are present and generally increase in amount with depth.

(d) Depressional Lakes

The depressional lakes are underlain by soils which are inherently similar to those in the depressions. However, a comparatively long duration of flooding (between 6 and 12 months per year) has limited soil development. Soils rarely dry out sufficiently for significant cracking to occur and the resulting soils consist of only semi-ripened clays. The soil surface is generally even, but slight gilgai is sometimes present around the lake margins. If these areas dried out the soils would probably develop vertisolic properties similar to soils of the relatively dryer depressions.

(e) Older Shabeelle Alluvial Landforms

The soils of the older Shabeelle alluvium are also dominantly heavy textured and are generally fairly compact. In general, they contain a greater proportion of hard nodular calcium carbonate than the more recent alluvium, particularly on the higher terrace where nodular gravel is often dominant below one metre depth. There is often some clay depletion in the topsoil which may be partially due to clay illuviation. The soils in the meander complex area in the south east contain significant amounts of fine sand and originate from more active fluvial deposition than the more uniform terrace areas. It is possible that the meander complex may be a remnant of the Jubba rather than the Shabeelle floodplain system.

2.3 SOIL CLASSIFICATION

2.3.1 *Definition of Soil Mapping Units*

The physiographic system of soil classification adopted in the Reconnaissance study (HTS, 1978) forms the basis for the soil classification used in the present study. Because of the greater availability of topographic and soil data resulting from the field studies carried out in early 1979, further subdivisions are recognised and new limits identified on the lower Shabeelle floodplain comprising the survey area. Figure 2.2 shows the breakdown of the floodplain into constituent 'landform units' using this data and airphoto interpretation, and resulting 'soil mapping units' are defined based on landform units and associated soils. Table 2.1 illustrates the derivation and important properties of the soil mapping units, and Table 2.2 shows their relationship to mapping units used in the Reconnaissance Study. Soil Mapping Units are systematically defined in Appendix B. It is significant that properties of the land surface as well as the soil are included in the mapping unit definition and this ensures a direct relationship with land suitability classes for irrigation development.

Figure 2.2 illustrates the relationship between soil mapping units, topography and associated vegetation and land use; Figure 2.3 illustrates typical soil profiles in the more common soil mapping units. Complete profile descriptions and analytical data are given in Appendix C.

The soil mapping units listed in Table 2.1 are the basis of the legend of the 1:20,000 scale soil maps attached to the present report. In one or two cases, it was impossible to map

TABLE 2.1 SOIL MAPPING UNITS

Major Grouping	Parent Material	Unit Description	Symbols Landform Unit	Soil Unit	Phase	Physiography	Soils	Profile Drainage	Surface Microrelief (Gilgai) Class†
Lower Shabeelle Floodplain Units.	Semi-Recent and Recent Alliuvium	Shabeelle Levee - coarse type	Sl	Sl1		Slightly raised areas alongside existing and abandoned channels. The Sl1 unit tends to occur on crests and steeper slopes of the more strongly developed levees.	Brown silty clay loams/light silty clays dominant to 2m depth. Usually well structured.	Imperfect - Mod. Well	MO
		- finer type		Sl2			Brown silty clay loam or light silty clay at surface, usually passing into brown clay at around 1 m depth.	Imperfect	MO-M1
		Shabeelle Cover Floodplain - higher	Sb	Sb1		Almost flat area extending between levees and the lower depression and backswamp areas.	Brown silty clay loam on light silty clay at surface. Passing into, often prismatic, clay at c.50 cm and into more massive clay at depth.	Imperfect - Poor	M1
					Sb1s		As above, but having lighter textured layers (silty clay loam, silt loam) in the subsoil.		
		- lower		Sb2			Thin silty clay - clay surface overlying greyish brown prismatic clays, passing into wedge struc- clay at c.1m depth.	Poor	M1-M2
					Sb2s		As above, but having lighter textured layers (silty clay loam, silt loam) in the subsoil.		
		Shabeelle Depressions - shallow	Sd	Sd1		Flat floored or concave depressional or backswamp areas, usually concentrated around floodplain edges. Subject to seasonal flooding.	Dominantly greyish brown clay; subangular blocky surface, passing to prismatic and to weak subangular blocky/wedge with depth.	Poor	M1-M2
		- moderately deep		Sd2			As above, only dominantly grey Clay.	Very Poor	M2
					Sd2g		As above, some disturbance of profile.		M3+

TABLE 2.1 SOIL MAPPING UNITS (continued)

Major Grouping	Parent Material	Unit Description	Symbols Landform Unit	Soil Unit	Phase	Physiography	Soils	Profile Drainage	Surface Microrelief (Gilgai) Class†
		- Deep		Sd3			Dominantly grey clay, may be very moist at depth.	Very Poor	M2-M1
		Shabeelle Depressional Lakes.	Sdw			Broad, flat floored depressionary inundated in all but driest months of year.	Grey clays, dominantly prismatic in top metre, becoming massive. Relatively moist.	Very Poor	M1-M0
		Shabeelle Fartas (Channels)	Sf			Existing and abandoned flood channels.	Variable commonly clay over lighter subsoil.	Imperfect - very poor	M2-M1
	Older Alluvium	Shabeelle Terrace	Sot			Slightly raised areas, usually near floodplain edge.			
		- higher		Sot1			Silt loams - clays overlying hard calcareous nodules at C.lm depth.	Imperfect	MO
		- lower		Sot2			Dominantly brown-greyish loam clays. Calcareous nodules present. Fairly compact.	Poor	M1
		Shabeelle Meander Complex	Som			Raised, very slightly undulating plain dissected by shallow channels.	Greyish brown-olive brown fine sandy clay loams and sandy clays passing into clay at c.1m. depth.	Poor - Imperfect	MO
		Shabeelle Oxbow Lakes.	Sox			Oxbow shaped depression associated with old meander complex.	Dominantly grey clay	Very Poor	M1
Complex Units	Jubba and Shabeelle	Jubba-Shabeelle Floodplain complex	JSfx			Gently undulating plain dissected by small channels	Variable, from levee type to depression type.	Imperfect - Poor	M2-M1
		Jubba Shabeelle Fartas (channels)	JSf			Overflow channels, fed from either the Jubba or Shabeelle.	Variable	Poor - Very Poor	M1-M2
		Jubba - Shabeelle Depressions (Moderately deep)	JSd2		JSd2g	Flat floored or concave	Dominantly grey clays	Very Poor	M3+
	Shabeelle Alluvium and Marine Clays.	Shabeelle Alluvium over Marine plain clays	SMP			Sloping areas at Marine Plain/ Shabeelle Floodplain Interface.	Alluvial clay, passing into marine clay within 150 cm depth.	Poor	M1

† Gilgai Microrelief Classes MO No perceptable Gilgai M1 Slight Gilgai Amplitude 10-25 cm M2 Moderate Gilgai Amplitude 25-50 cm M3 Severe Gilgai Amplitude more than 50 cm

some units separately due to soil variation. This situation occurs on some of the levees where coarser and finer soil types units Sl_1 and Sl_2 respectively, are not separately mappable on the information available, and on some cover floodplain areas where the coarse textured subsoil phases, Sb_1s and Sb_2s occur in irregular association with the modal Sb_1 and Sb_2 units. In these comparatively few areas (4.7 per cent of the project area) the soils were mapped as complexes of the constituent units.

TABLE 2.2 SOIL MAPPING UNITS ON THE LOWER SHABEELLE FLOODPLAIN: COMPARISON BETWEEN PRESENT (SEMI DETAILED) AND RECONNAISSANCE STUDIES

Landform/Soil Unit	Mapping Symbol: Present	Mapping Symbol: Reconnaissance
Levee		
- coarser type	Sl_1	Sl
- finer type	Sl_2	
Cover floodplain		
- higher	Sb_1	Sb
- lower	Sb_2	
- coarse subsoil phase	Sb_2s	
Depression		
- shallow	Sd_1	Sd_1
Depression		
- moderately deep	Sd_2	
- moderately deep gilgai phase	Sdg	Sd_2
- deep	Sd_3	
Depressional lakes	Sdw	w
Fartas (channels)	Sf	Not mapped
Terrace		
- higher	Sot_1	Not
- lower	Sot_2	recognised
Meander complex	Som	Sm
Oxbow lake	Sox	w
Jubba - Shabeelle complex	JSfx	
Units	JSd_2g	Sd_1/Jd_1
	JSf	
Alluvium over Marine Clays	SMP	Not mapped

In addition to the soil mapping units listed in Table 2.2, *soils are also mapped around* the periphery of the survey area in case subsequent decisions are taken to undertake irrigated or rainfed agriculture on a trial basis in surrounding areas. Some of these mapping units also occur as outliers within the floodplain. Peripheral units are listed in Table 2.3 and described in Appendix B. Marine Plain and Beach Remnant Units are described in more detail in the Reconnaissance Report.

TABLE 2.3 PERIPHERAL MAPPING UNITS

Unit	Symbol
Marine Plain	MP
Marine Plain depression	MPd
Beach Remnant	BR
Transitional Beach Remnant	BM
Coastal Ridge	CR

2.3.2 *Comparison with International Systems of Soil Classification*

The recognised international soil classification systems of FAO/UNESCO (1974) and USDA (1975) *are of limited use as a basis for the detailed classification and mapping* of an alluvial area such as the present project area, mainly because they are insufficiently detailed and fail to emphasise many of the properties relevant to land suitability for irrigation. However, for purposes of correlation to these accepted international systems of soil classification, mapping units described are compared in Table. 2.4.

TABLE 2.4 COMPARISON OF SOIL MAPPING UNITS WITH INTERNATIONAL SYSTEMS OF CLASSIFICATION

Soil Mapping Unit Symbol*	FAO/UNESCO System (1974)	USDA System (1975)
Sl_1	Calcaric Fluvisols	Ustifluvents
Sl_2		
Sb_1	Calcaric Fluvisols/ Chromic Vertisols	Ustifluvents (vertic)
Sb_2	Chromic Vertisols	Chromusterts
Sd_1		
Sd_2		
Sd_3	Pellic Vertisols	Pellusterts
Sdw		
Sf	Calcaric Fluvisols	Ustifluvents
Sot_1		
Sot_2	Calcaric Regosols	
Som		
Sox	Pellic Vertisols	Pellusterts
JSfx	Chromic Vertisols and	Chromusterts and Ustifluvents
JSd_2	Pellic Vertisols	Pellusterts
JSf	Calcaric Fluvisols	Ustifluvents
SMP	Chromic Vertisols	Chromusterts

**Phases of soil units are not significant and are excluded.*

2.4 SOIL DISTRIBUTION

The distribution of soil mapping units in the Homboy Irrigated Settlement Project Area is shown on the 1:20,000 maps accompanying this volume. Table 2.5 shows the relative proportions of soil mapping units in the Project Area.

TABLE 2.5 PROPORTIONS OF SOIL MAPPING UNITS IN THE PROJECT AREA

Soil Mapping Unit	Symbol	Area (ha)	Area (%)
Levee			
- complex of finer and coarser types	Sl_{1-2}	713	4.7
- finer type	Sl_2	1,060	7.0
Cover floodplain			
- higher	Sb_1	2,645	17.5
- higher - coarse subsoil phase	$Sb_1(s)$	623	4.1
- lower	Sb_2	2,398	15.9
- lower - coarse subsoil phase	$Sb_2(s)$	790	5.2
Depression			
- shallow	Sd_1	2,774	18.5
- moderately deep	Sd_2	564	3.7
- moderately deep; gilgai phase	Sd_2g	260	1.7
- deep	Sd_3	340	2.3
Depressional lake	Sdw	388	2.6
Farta	Sf	259	1.7
Terrace			
- higher	Sot_1	139	0.9
- lower	Sot_2	514	3.4
Meander Complex	Som	417	2.8
Oxbow Lake	Sox	232	1.5
Jubba-Shabeelle			
- floodplain complex	JSfx	641	4.2
- depression; gilgai phase	JSd_2g	159	1.1
- Farta	JSf	29	0.2
Alluvium over marine clays	SMP	100	0.7
Coastal Ridge outlier	CR	40	0.3
Total		**15,085**	**100,0**

Footnote: The 15,085 hectares covered in the Phase II soil survey is slightly less than the area of the Homboy-Burgaan block delineated in the reconnaissance study, due to the ommission of some predominantly swampy areas in the extreme north east of the block.

2.5 SOIL MORPHOLOGY AND PHYSICAL PROPERTIES

In the following discussion emphasis is placed on the more recent alluvial soils which account for 85 per cent of the project area, and which include the soils most suitable for irrigation development. However, the particular properties limiting irrigation suitability in the older units are also mentioned. Physical properties of the surface and root zone are both important in determining land suitability for irrigation development. Subsoil properties are primarily important in their effect on soil drainage, and they are therefore discussed in Section 2.6.3.

2.5.1 Surface Features and Microrelief

The surface features characteristic of land in the Project Area comprise the following:

(a) Features associated with expansion and contraction of soil clays, and

(b) surface crusting.

Features associated with expansion and contraction of soil clays on wetting and drying are best developed in the vertisols of the depressional areas (excepting the deep depressional 'lakes') but also extend over most of the cover floodplain. The most obvious feature reflecting clay expansion and contraction is the development of 'gilgai' microrelief. This gilgai consists of rounded micro-depressions and few mounds separated by flat shelf areas. 'Sink-holes' commonly occur in the micro-depressions. The average 'amplitude' of the gilgai, usually taken as the difference in elevation between the bottom of the micro-depression and the overall land surface is about 20 cm on the cover floodplain and shallower depressions (Units Sb_1, Sb_2, Sd_2) but sometimes exceeds 50 cm in some moderately deep depressions in the south west of the area (Units Sd_2g, JSd_2g). Cultivation tends to obscure gilgai microrelief and its occurrence on the cover floodplain was underestimated in the Reconnaissance Study when survey was limited to the more accessible and hence more cultivated areas of floodplain.

The formation of surface cracks is another feature associated with soil contraction on drying. In some of the heavier clay soils of the depressional areas a polygonal cracking pattern has developed but cracks are more usually discontinuous and concentrated in sink-holes and micro-depressions. The surface cracks are commonly obscured by a surface mulch composed of a layer of subangular blocky or granular aggregates about 2 cm thick coating the surface. Mulching occurs most commonly on the shallower depression soils (Unit Sd), although it is also common on the cover floodplain. The surface mulch is important, both in pedogenesis, because aggregates falling into cracks cause build up of pressures in the soil profile on subsequent wetting, resulting in development of shear faces, and in determining land use, because it renders an otherwise very hard clay surface cultivable with hand tools.

Surface crusting is best developed on soils which are insufficiently fine textured at the surface to give rise to surface mulching. Weakly developed crusts are normally found on the levees and also on the older terrace and meander complex units, although they also occur on the cover floodplain. The large amount of finely divided calcium carbonate in the surface soil (Section 2.7) may facilitate crust formation (Massoud, 1973) or it may be straightforward mechanical dispersion due to impact of rain drops. Since calcium carbonate is practically insoluble, the crusting would only occur by binding due to precipitation of calcium carbonate from river water. The crusts are generally silty clay loam in texture and are soft and friable. They do not pose problems to cultivation but the presence of fine sandy wash and rills on sloping areas (more than one per cent slope) indicates considerable erosion susceptibility in areas subject to crusting.

The surface aggregates constituting the mulch, and the surface crusts are easily dispersed on wetting, although the results of infiltration tests (Section 2.6.1) show that the surface does not seal completely.

Accumulations of fragments of gastropod snail shells are common throughout the project area and are particularly abundant in the depressions. The dark ferromanganese coated calcium carbonate concretions, which are a common feature of the surface of the Marine Plain, are rarely present at the surface in the alluvial soils although they are occasionally encountered in the soil profile.

2.5.2 The Root Zone

The physical properties of the root zone* are of prime importance in forming the environment for seed germination and crop growth and are fundamental in determining land suitability for either irrigated or rainfed agriculture.

Figure 2.3 illustrates the textural and structural properties of the most commonly occurring soil mapping units in the project area. The relatively lighter textured, moderately structured soils of the levees and higher cover floodplain areas are most easily penetrated by roots, and physical penetration becomes progressively more difficult over the range from lower cover floodplain to deep depression soils. During the course of the soil survey, root penetration to more than one metre depth was noted in all the profiles examined, but the best rooted profiles were usually those occurring on the levees or cover floodplain.

'Vertisolic' properties associated with expansion and contraction are best developed in the heavier soils of the depressions and lower cover floodplain. Such properties include the development of medium to wide cracks on soil drying, the presence of a coarse prismatic subsurface horizon and the formation of shear faces or 'slickensides' and associated wedge shaped aggregates near the base of the root zone. Soil structure in these vertisols (Section 2.3.2) is largely dependent on moisture content and the soils become virtually structureless when wet. Consistence is very hard when dry, very firm when moist and very sticky and plastic when wet. Such properties make these soils difficult to manage under irrigated conditions and restrict the time available for carrying out any mechanised operations.

Soils of the older terraces and meander complex are generally lighter in texture but are poorly structured and compact. On the higher terrace, effective rooting depth is sometimes limited by a layer of hard calcium carbonate nodules.

2.5.3 Bulk Density and Porosity

Bulk density determinations were carried out on undisturbed core samples collected from profile pit sites. Initially, eleven sites were sampled, but samples from seven sites were lost in transit and the onset of the Gu rains prevented further sampling. Bulk density figures for the remaining four sites, and for two sites sampled during the reconnaissance study, are summarised according to soil mapping units in Table 2.6. Full bulk density results are given in Table C.1. (Appendix C).

*The present discussion refers to the root zone of the deepest rooting crop proposed for development under project conditions. This is cotton, for which a rooting depth of 1 m has been described elsewhere on the Shabeelle floodplain (MMP/HTS, 1978).

TABLE 2.6 BULK DENSITY

Soil Units	Depth Range (cm)	Texture	No. of Samples	Mean Bulk Density (g/cc)
Sl_2	25-50	SiCL	1	1.27
	50-75	SiC	1	1.41
Sb_1, Sb_2	0-25	SiC, C	2	1.30
	25-50	C	2	1.33
	50-75	C	2	1.48
Sd_1, Sdw	0-25	C	2	1.40
	25-50	C	2	1.43

The figures in Table 2.6 show an increase in bulk density with depth in the profile, and an increase in bulk density going down the alluvial toposequence from the levees, through the cover floodplain to the depressions. The variations in bulk density reflect an increase in clay content, but none of the bulk densities recorded are high enough to indicate excessive soil compaction problems. Bulk densities recorded on the Shabeelle floodplain are significantly lower than those recorded on the adjacent Marine Plain soils, which were considered less suitable for irrigation during the reconnaissance study.

Bulk density measurements in vertisolic soils vary significantly according to moisture content. Farbrother (1972) recorded bulk density variations of up to twelve per cent of the maximum recorded in the vertisols of Sudan. Vertisols on the Shabeelle alluvium are generally less well developed than those on the Sudan Gezira, but MMP/HTS (1978) suggest that increasing the standard bulk density figures of Farbrother (recorded over different depth ranges at different moisture contents) by ten per cent shows a fair approximation to recorded bulk densities on Shabeelle alluvial soils in the Jowhar and Janaale areas. These modified standard bulk density values are presented in Table 2.7.

These standard bulk density values are also comparable with those recorded in the vertisolic depression and cover floodplain soils in the present study, and may therefore provide a useful guideline for predicting bulk densities in these units. Highest bulk densities are recorded when soils are in a dry state, and bulk densities should therefore improve on irrigation.

TABLE 2.7 BULK DENSITY VALUES FOR VERTISOLS (values in g/cc)

% Moisture	Depth of Sample (cm)				
w/w	0-40	40-60	60-80	80-100	100-200
50	1.22	1.24	-	-	-
40	1.27	1.31	1.38	1.42	1.43
30	1.31	1.39	1.45	1.52	1.54
20	1.35	1.45	1.61	1.68	1.69
10	1.38	1.49	1.68	-	-
0	1.38	-	-	-	-

Source:- Farbrother (1972) data for Sudan Gezira, increased by a factor of 10% for use in Shabeelle Vertisols (MMP/HTS, 1978).

Soil porosity is estimated visually in the field and pore size distribution can be assessed from the moisture retention figures tabulated in Table 2.10 (Section 2.6.2). The total porosity, estimated from the moisture content at saturation is normally between 50 and 60 per cent, and the aeration porosity, measured between saturation and 0.1 bar tension varies between less than one and ten per cent (Table C.1, Appendix C). Most of these aeration porosities are low, but this may be due to incomplete saturation of the core samples. The fact that the tension holding water in the soil is dependent on the radius of the pore in which the water is held, enables pore size distribution to be assessed from standard moisture retention measurements. Table C.1 and Figure 2.4 show that more than 50 per cent of available soil water is usually held in the least readily available fraction, between 1 bar and 15 bars tension, indicating a predominance of very fine pores, particularly in the soils of the depression. This dominance of very fine pores is confirmed by field observations and accounts for the low permeability measurements discussed in Section 6.2.3.

Soil porosity, like bulk density, however, varies widely in vertisolic soils according to moisture content. Soil drying results in contraction and effective reduction in porosity, although the cracks which develop play an important role in the movement of soil, air and water. The importance of this shrinkage and cracking in affecting water intake, retention and storage in the vertisolic soils of the depressions and cover floodplain is discussed in the following section.

2.6 SOIL-WATER RELATIONSHIPS

An understanding of the factors governing soil water interactions is crucial in initial land evaluation for irrigation development and in subsequent irrigation scheduling and planning of drainage requirements. A soil should satisfy the following three criteria for successful irrigation:-

(a) Infiltration capacity should be sufficient to accept proposed irrigation applications but the rate should not be sufficiently high to produce irregular distribution and inefficient use of irrigation water.

(b) Water storage, as indicated by available water capacity, should be sufficient to meet crop water requirements between irrigation applications.

(c) Subsoil permeability should be sufficient to satisfy drainage and leaching requirements but insufficiently high to lead to excessive percolation losses.

Soil water requirements are therefore described under three headings relating to infiltration, retention and permeability.

2.6.1 Surface Infiltration

A total of eleven infiltration tests were carried out at representative sites in the Project Area. A further two tests were carried out during the reconnaissance survey on the lower Shabeelle floodplain. The experimental method is described in Appendix E and the results are summarised in Table 2.8. Curves of cumulative infiltration are illustrated in Figure 2.4.

Table 2.9 shows the mean initial and final rates and cumulative infiltration for levee soils (Units Sl_1, Sl_2) cover floodplain soils (Sb_1, Sb_2, Sb_2s) and depression soils (Sd_1, Sd_2, Sd_3, Sdw).

TABLE 2.8 SURFACE INFILTRATION

Test Site[1]	Soil Mapping Unit	Surface Texture	Initial Rate (mm/hr)[2,3]	Cumulative Infiltration (mm)[2,4]	Final Rate (mm/hr)[2,4,5]
A301	Sl_1	Silty clay loam	118	738	21
B035[6]	Sl_2	Silty clay loam	54	364	9
C239	Sl_2	Heavy silty clay loam	204	693	22
A364	Sb_1	Silty clay	135	424	17
C038	Sb_1	Silty clay loam	108	519	16
A058[6]	Sb_2	Silty clay	136	508	14
A379	Sb_2	Silty clay	147	479	10
A300	Sb_2s	Silty clay	109	260	7
C009	Sd_1	Clay	116	545	17
A377	Sd_1	Clay	60	278	7
C238	Sd_2	Clay	94	507	14
C178	Sd_3	Clay	38	223	3
C263	Sdw	Clay	88	358	9

[1] *Refers to Profile Pit Number.*

[2] *Figures are means of triplicate values.*

[3] *Refers to 15 or 20 minutes after start of test.*

[4] *Corrected for evaporation using Class A pan readings recorded at Jilib (Alessandria) during the test. In general, cumulative values reduced by 9 mm/day of test and final rates by 1 mm/hour. Initial rates are not significantly affected by evaporation.*

[5] *Final rate calculated from mean of readings once steady state obtained (i.e. no further decrease).*

[6] *Reconnaissance Study test site. Cumulative infiltration and final rate computed after two days.*

2.4 Cumulative infiltration curves

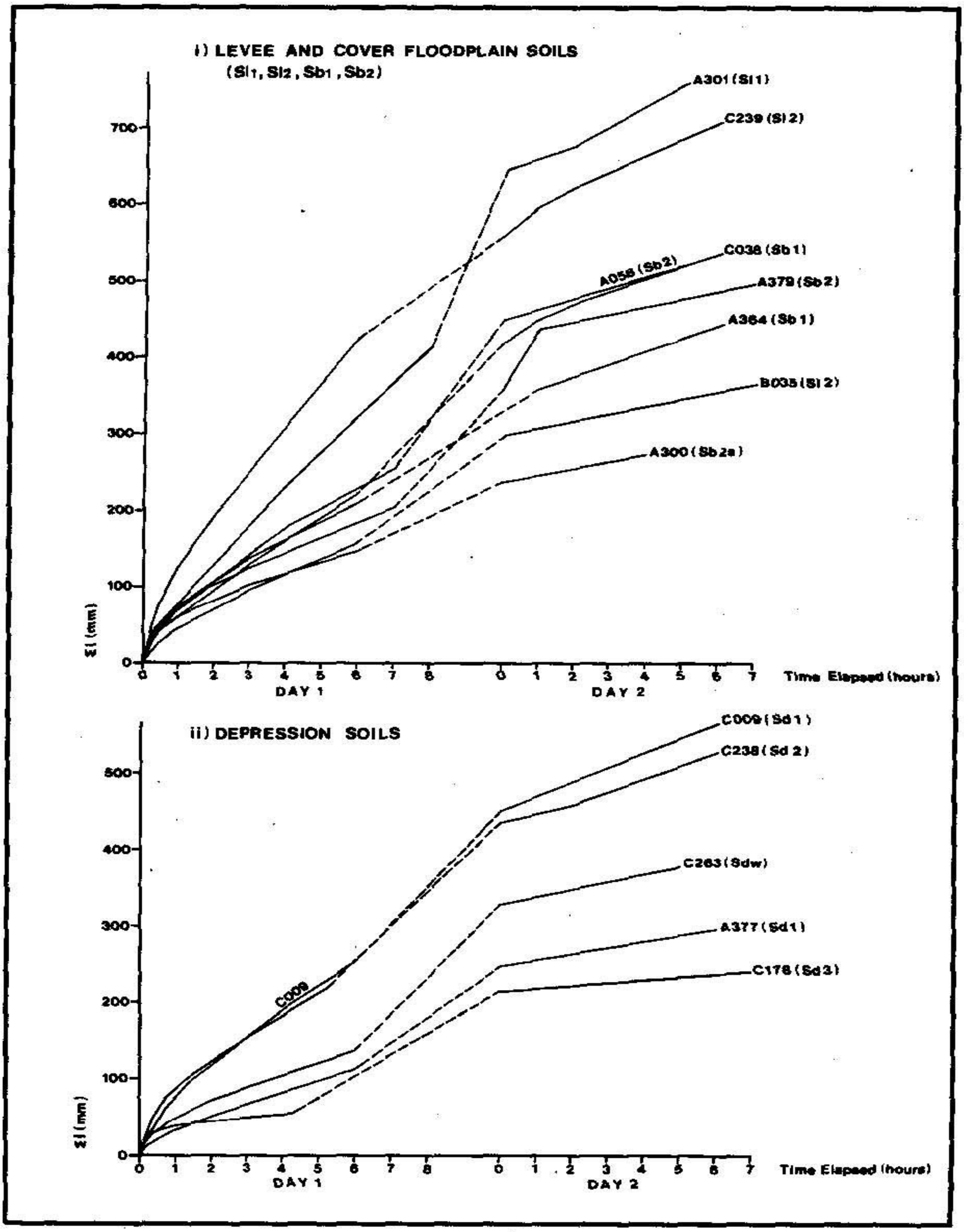


TABLE 2.9 AVERAGE INFILTRATION PROPERTIES OF LEVEE, COVER FLOODPLAIN AND DEPRESSION SOILS

Landform/Soil Type	Initial Rate (mm/hr)	Cumulative Infiltration (mm)	Final Rate (mm/hr)
Levee	125	598	17
Cover floodplain	127	438	13
Depression	79	382	10

All the soils show acceptable final rates and infiltration capacities for either surface or sprinkler irrigation and there is a fairly predictable variation in the soils of the Project Area. Levee soils, with their relatively lighter textured surface horizons tend to accept more water and have higher final rates, while the lowest infiltration rates were recorded in the clay soils of the depressions.

The infiltration tests were, however, commenced when the soils were in a dry state and under irrigated conditions the soil will not dry out completely between irrigations and cumulative values may be somewhat less than those indicated in Tables 2.8 and 2.9. Taking the final infiltration rate as an indication of the poorest condition, the maximum time required to infiltrate a 'normal' irrigation application of 80 mm varies from 4.5 hours in levee soils to 8 hours in depression soils. These figures are acceptable in a surface irrigation system. The latter figure may be considerably increased in the soil has dried sufficiently for surface cracks to develop between irrigation applications, although recent evidence from the Janaale area suggests that this does not occur (MMP, 1978).

It is possible that the long term effects of irrigation on these soils may produce a decline in their infiltration capacity due to breakdown of soil structure particularly in the vertisolic clay soils of the lower cover floodplain and depressions. Careful soil management is required to minimise this effect and infiltration rates should be monitored during the course of the project. Cropping these areas with rice might be a solution if problems are encountered.

2.6.2 Moisture Retention and Available Water

Undisturbed core samples collected from four soil profile pit sites (samples from a further seven sites were lost in transit) were saturated and equilibrated under varying suctions to determine moisture retention characteristics. The available water capacity (AWC) defined as the proportion of soil water available to roots to sustain plant life, is calculated as the water held between 0.1 and 15 bar suctions. As the degree of availability decreases with increasing suction a second parameter, the easily available water capacity (EAWC) is defined as the water held between 0.1 and 1.0 bar suctions. AWC and EAWC values, calculated in the top 80 cm of soil (which is the approximate rooting depth of maize) are summarised according to soil mapping units in Table 2.10. Results from two Shabeelle alluvial sites sampled during the Reconnaissance Study are also included. Moisture retention curves are plotted in Figure 2.5 and full results of moisture retention and bulk density measurements are included in Table C.1 (Appendix C).

2.5 Moisture retention curves

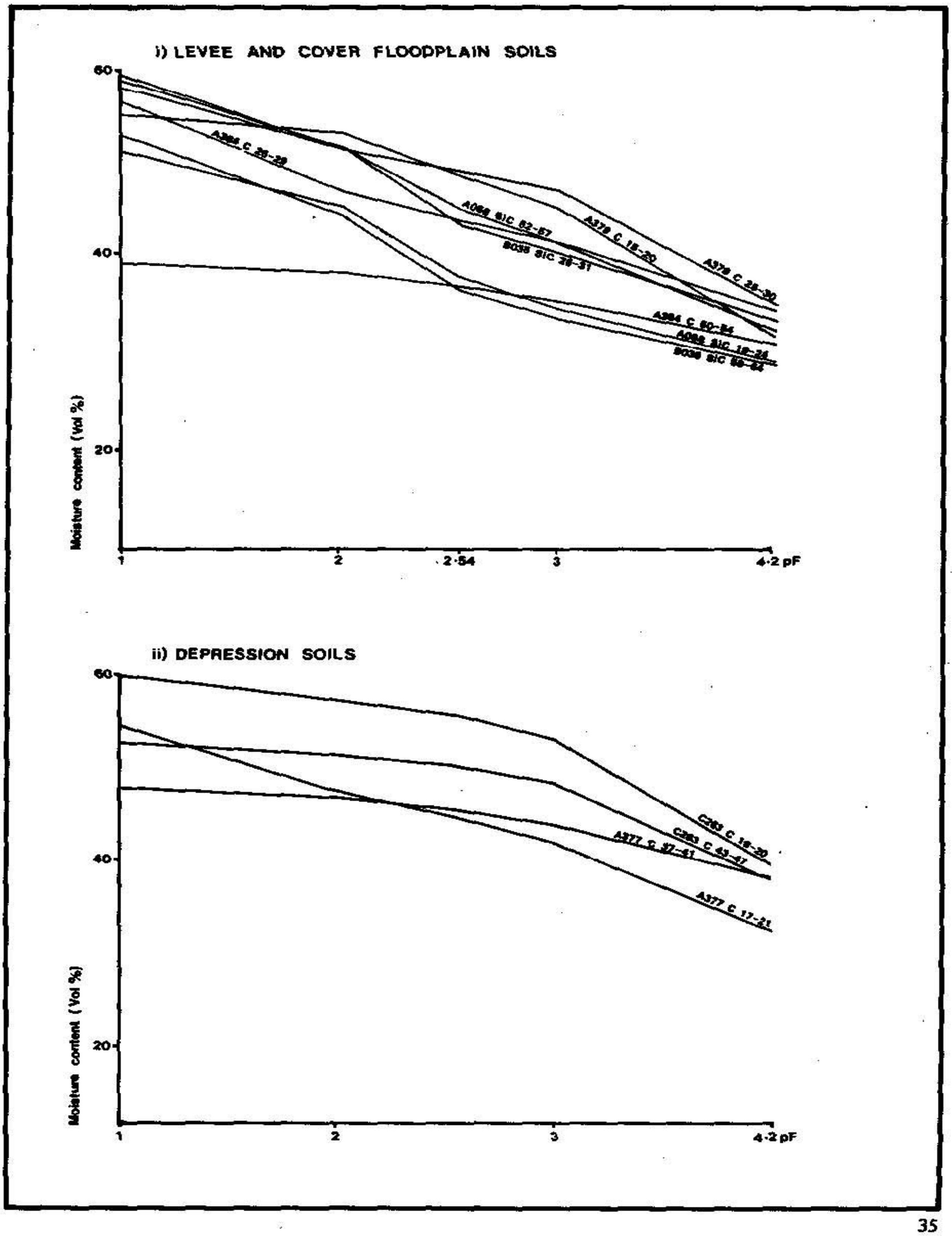


TABLE 2.10 SOIL AVAILABLE WATER

Soil Mapping Units	Sites (Profile Pit No.)	AWC (mm/0.8 m soil)	EAWC (mm/0.8 m soil)	EAWC (% AWC)
Sl_2	B035*	135	88	65
Sb_1, Sb_2	A058*	133	82	62
	A364	90	34	38
	A379	140	40	29
	Mean	125	61	48
Sd_1	A377	96	33	34
Sdw	C263	143	28	20

**Reconnaissance Survey Profile Pit*

It is unfortunate that, owing to the loss of samples in transit, only a relatively small amount of data is available. The low moisture contents recorded in at least two samples (A364/W2 and A377/W2) at 0.0 tension are very low for clays and suggest that the samples were not fully saturated and true AWC and EAWC estimates may be slightly higher than suggested by the figures in Table 2.10. In addition, some workers (e.g. Farbrother, 1972; MMP/HTS, 1978) regard the water held between 0.0 and 0.1 bar tensions as forming part of the available water in vertisolic soils, where the concept of 'field capacity' becomes meaningless due to volume alteration on wetting and drying. Addition of this macropore water (corresponding to the 'aeration porosity' in Table C.1) further slightly inflates the AWC values in cover floodplain and depression soils, although this water is not judged to be easily available because of anaerobic effects on plant roots (Crawford, 1977). From this rather complex picture, and bearing in mind the limited data, the following conclusions can be drawn:-

(a) Although total available water capacities are fair, most of the water is held in the less readily available fraction, between 1 and 15 bar suctions and EAWC's are generally low. Exceptions are the levee soils and one of the cover floodplain soils in which EAWC's are adequate.

(b) The EAWC accounts for less of the AWC going down the alluvial toposequence. Table C.1 also indicates a decrease in both AWC and EAWC with depth in the profile. There is a decrease in EAWC with increasing clay content.

The low values of EAWC in the depressional soils are of reduced importance if cropping with paddy rice is implemented. The low amount of easily available water on some of the cover floodplain soils could limit the optimum irrigation interval. More detailed work on soils in the Janaale area, further up the Shabeelle valley, by MMP/HTS in 1978 yielded similar results and an irrigation interval calculated on the basis of 60-65 per cent depletion of total available soil water (between 0.1 and 15 bars) was recommended. Applying these recommendations to a crop of maize and assuming a crop consumptive use of 5 mm/day and no losses due to percolation, cover floodplain soils in the Homboy Irrigated Settlement area would have a maximum interval between irrigations of 15 days. The maximum interval for shallower rooting crops would be less.

2.6.3 Subsoil Permeability

Tests to determine the hydraulic conductivity or permeability of subsurface and subsoil layers were carried out at twenty two representative soil profile pit sites in the Project

TABLE 2.11 PERMEABILITY OF SOIL MAPPING UNITS

Soil Mapping Units	Landform	Depth Range (cm)	No. of Tests	Textural Range[1]	Hydraulic Conductivity (mm/day) Range	Mean
Sl_1, Sl_2	Levee	0-50	1	C	-	37.0
		50-100	4	SiC(l)-C	20-98	46.0
		100-150	3	SiC(l)-C	9-71	34.0
		150-200	3	SiC-C	4-24	13.0
Sb_1, Sb_2, Sb_2s	Cover floodplain	50-100	8	C(l)-C	3-12.5	8.0
		100-150	1	SiC	-	14.0
		150-200	7	C	3-9	5.6
		150-200(s)	1	SiCL(l)	-	220.0
Sd_1	Depression (Shallow)	50-100	2	C	3-4	3.2
		100-150	1	C	-	4.3
		150-200	3	C	0.6-3.2	1.6
Sd_3, Sds, Sdw	Depressions (Mod. deep-Deep) + Depressional lakes	50-100	4	C	3-17	6.9
		100-150	0	-	-	-
		150-200	4	C	0-2.9	1.9

[1] SiCL = Silty clay loam
SiC = Silty clay
C = Clay
(l) = light

Footnote: The above results include two tests carried out in the reconnaissance survey.

Area. The 'pour in' auger hole technique was employed and the experimental method and full results are presented in Appendix E. This test measures horizontal hydraulic conductivity. At three sites attempts were made to measure vertical hydraulic conductivity using single infiltration rings in the subsoil, but the results were disregarded due to excessive lateral seepage losses. The results of the auger hole hydraulic conductivity measurements are summarised in Table 2.11, according to soil mapping unit, depth and texture.

Table 2.11 shows that permeabilities are generally very low. All the values recorded fall into the very slow class of USDA (1951). Within the range recorded, however, there is considerable variation and the highest permeabilities predictably occur in the lighter textured horizons of the levee soils and, notably, in the lighter horizons occuring in the coarse subsoil phase of the cover floodplain soils. The lowest permeabilities occur in the clay subsoils of the depressions. In horizons of similar texture, permeability tends to decrease with depth in the profile of the cover floodplain soils.

The overall low permeability of the Project Area is a contributory factor to the ease with which flooding occurs during periods of heavy rainfall. The flooding problem is most serious in the depressions where run off accumulates and where subsoil permeability rates are lowest. Field observations suggest that water enters the soil through cracks and a saturated front builds up because subsoil permeability is insufficient to transmit the excess water. As the saturated front rises to the soil surface, the cracks seal, preventing any further water intake. Under irrigated conditions, low permeabilities could lead to excessive waterlogging, especially when rainfall adds to normal irrigation applications. This problem should be at least partially alleviated by inclusion of an efficient system of field drainage ditches in the irrigation design. In the shallow depressions (Unit Sd_1), where permeabilities are particularly low and run off accumulates due to topographic position, serious consideration should be given to continuous rice cultivation. Subsoil permeabilities are generally sufficient to at least meet the theoretical leaching requirement for irrigation with Jubba river water (less than 1 mm/day for irrigated rice - Reconnaissance Report - Appendix G). It may be possible to cultivate some of the deeper depressions with rice, but most are best allocated as storage or disposal areas for excess water from cultivated areas.

Permeabilities are also sufficiently low to cause problems in the cover floodplain soils. Subsoil drainage should be much improved in the areas where the coarse textured subsoil phase occurs, but those were only encountered in less than twenty per cent of cover floodplain sites examined.

If soil cracking occurs to a significant extent between irrigation applications, the effective field permeability of the upper layers of depression and cover floodplain soil (corresponding approximately to the root zone) may be considerably greater than that suggested by the auger hole test results. Giprodovhoz (1973) recorded seepage losses of 1,150 mm/day into deep surface drains in the top one metre of alluvial soils on the Jubba floodplain, which are similar although not identical to those of the Project Area. This figure may not, however, represent permeability under saturated conditions. There is also some doubt as to whether cracking occurs under irrigated conditions (MMP, 1978).

Soil permeability and associated drainage problems of the root zone and immediate subsoil layers is an obvious limitation to irrigation development over most of the Project Area. Some attempt is made to describe the extent of this limitation in Chapter 3, but a detailed assessment of the problem can only be made after field trials which should be undertaken during the early stages of project implementation. We believe the problem will be surmountable in most cases, given careful irrigation management.

In order to assess the drainage characteristics of the deeper subsoil layers a total of 22 borings were extended to five metres depth at representative profile pit sites. Figure 2.6 illustrates the composition of the deep subsoil layers.

Most (64 per cent) of the deep bores consist either wholly or dominantly of clay to five metres depth. As permeability tends to decrease with depth in horizons of similar texture (Table 2.11), many of these deeper subsoil layers may be virtually impermeable. However, given the fairly low deep percolation requirement for leaching, irrigated cropping is still possible provided surface drainage is adequate. The drainage problem is most severe in the depressions, where five out of six profiles examined consisted completely of clay from the soil surface to five metres.

No water tables were encountered during the deep boring, and previous work by Soviet specialists indicates a groundwater level of approximately 20 m. This estimate was confirmed by observations of existing wells during the present study. Assuming the subsoil layers are not completely impermeable, the increase in percolating water under an irrigated system will eventually lead to a rise in groundwater, probably accompanied by harmful salts. This is a potential problem which may develop in the long term, possibly after a period normally regarded as the economic life of the project. It's effect cannot be accurately gauged at this stage, but groundwater levels should be monitored during the life of the project.

2.7 SOIL CHEMICAL PROPERTIES

In a semi arid environment the major chemical factors limiting agricultural land use are usually associated with the accumulation of salts in the profile. In the chemical analysis, therefore, attention is primarily focussed on assessing the type and total amount of soluble salts and the amount of exchangeable sodium associated with the soil clay. Consequently, a large number of samples were analysed purely to assess soil salinity and sodicity and detailed chemical analysis was limited to a smaller number of samples collected from soil profile pits. The analytical results are discussed below and presented in full in Appendices C and D.

2.7.1 Routine Samples

(a) Soil pH

Soil pH (acidity/alkalinity) was measured in 1:2½ soil to water suspension in the laboratory. In table 2.12 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 ECe value. pH values for samples in the deeper subsoil show no appreciable increase.

TABLE 2.12 RANGE OF pH VALUES BY MAIN SOIL GROUPS FROM ROUTINE ANALYSES

Soil Grouping	% of samples in pH range, 7.1 - 7.5	7.6 - 8.0	8.1 - 8.5	8.6 - 9.0	>9.0
Levees Sl	0	9	59	31	1
Cover flood plain Sb	0	7	60	32	1
Depressions Sd	0.5	3.5	57	38	1
Terraces Sot	0	0	47	53	0
Fartah Sf	0	20	80	0	0
Meander complex Som	0	10	35	45	0
Beach remnant Bm	0	17	75	8	0
Marine Plain MP	0	0	52	48	0

(b) 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 of 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 initial level of salt varies in importance 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 have 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 ECe 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 for the Jubbariver is very high, some values are given in Table 2.13.

A guide to the equilibrium salinity which can be maintained in the root zone can be obtained from the consideration of the fraction of the applied drainage water which must pass through the root zone to maintain the salinity equilibrium at some desirable level. This leaching requirement will depend on the salt concentration of the irrigation water applied, and the maximum level which can be permitted in the root zone. The leaching requirement can be calculated from the formula where

LR = leaching requirement

$$LR = \frac{ECi}{f \times ECd}$$

2.6 Subsoil textures

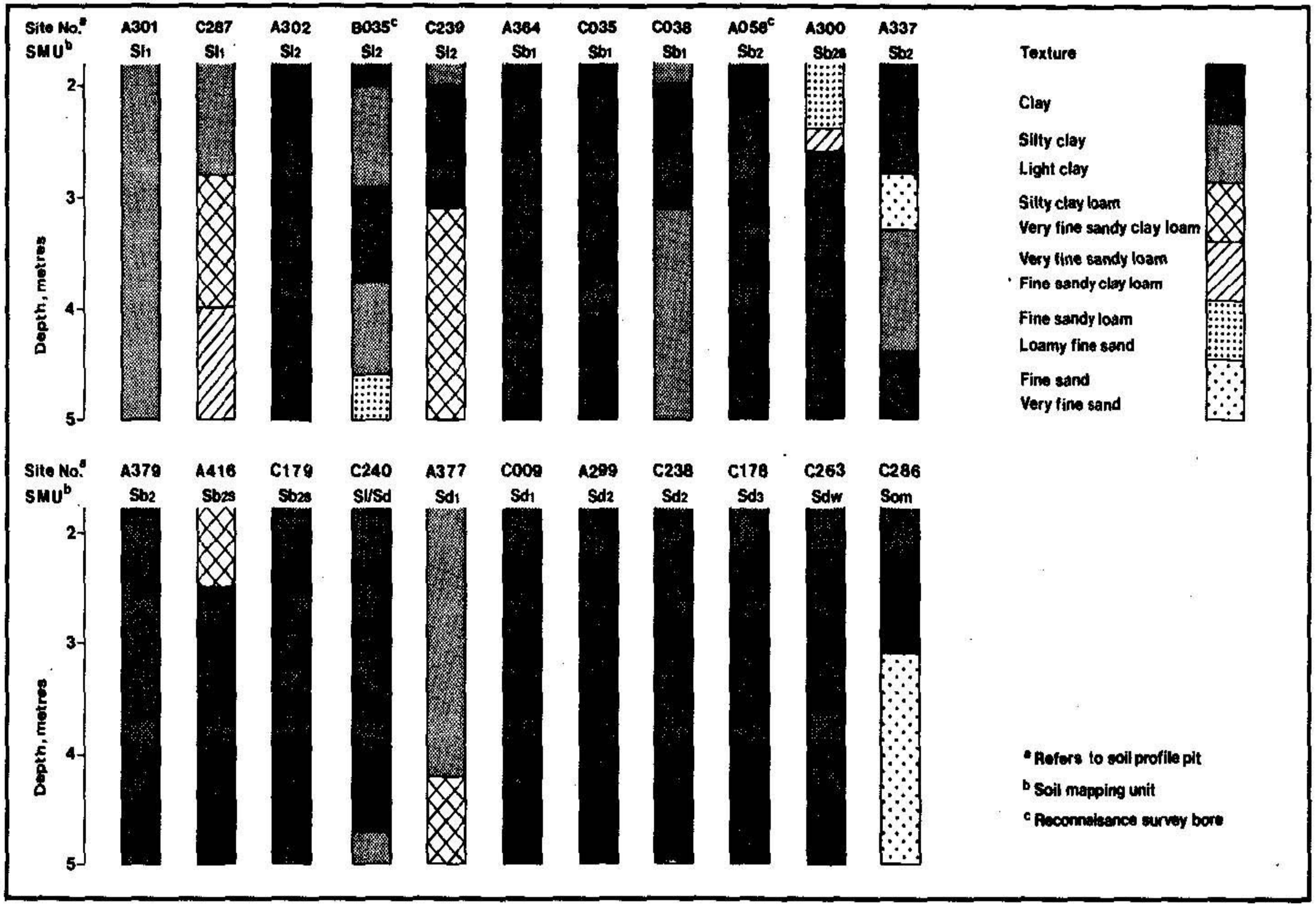


TABLE 2.13 CHEMICAL ANALYSES OF SOME JUBBA RIVER WATER SAMPLES AND ONE GROUNDWATER SAMPLE

				Milliequivalents per Litre									ppm		
Date Sampled	EC x 10^3	pH	TDS ppm	Ca	Mg	Na	K	CO_3	HCO_3	SO_3	Cl	Total Hardness ppm	Sol Fe	B	SAR
31.1.79	0.53	7.58	328	2.70	1.18	2.12	0.09	Nil	2.40	1.20	2.40	225	0.38	0.53	1.52
28.2.79	0.47	7.64	284	2.52	0.73	1.44	0.08	Nil	2.20	0.86	2.30	156	0.30	0.51	1.13
7.3.79	0.37	7.53	222	2.22	0.69	0.70	0.05	Nil	2.20	0.78	1.20	145	2.28	0.58	1.19
7.3.79	1.59	8.03	1,084	3.04	6.68	8.00	0.04	Nil	8.30	3.79	6.00	486	0.38	0.89	0.32
Homboy Well	1.95	7.66	1,338	9.46	5.70	5.00	0.35	Nil	6.0	4.92	8.50	758	0.42	0.59	1.82

where LR = leaching requirement
Eci = conductivity of the irrigation water mmhos/cm
Ecd = conductivity of the percolating drainage water
f = leaching efficiency factor

Assuming that some increase in the salinity of the irrigation water will occur during its transport from the intake point to actual field outlet, the value of ECi of the irrigation water is taken as 0.6 for this area. The value of the root zone ECe is set at 4 mmhos/cm as the highest permissible level to allow optimum yields of a full range of crops. The leaching efficiency factor relates to the fact that only part of the applied leaching water is effective in salt removal because water is transported mainly through the larger pores, in which structure tends to consist of rather large aggregates and in which water movement is much influenced by cracking. This will allow rapid leaching along the cracks bordering the structural aggregates but will have little effect in removing salt from the large volume of soil dominated by fine capillary pores. Therefore the factor 'f' for the clay soils of the area will be low. No experimental determinations of this factor have been carried out for the area but within clay soils of this type generally the adopted value is 0.3. However, on wetting considerable saturation and structural disintegration does take place in these soils suggesting that leaching factor might be more effective than 0.3. Also in practice in vertisols salt transfer occurs laterally. After drying and cracking salts move laterally to the face of peds where they accumulate to be washed downward during subsequent irrigation.

ECd in and above equation can be roughly calculated from the relationship that ECe = 0.5 ECd, because ECe moisture content is roughly twice that of the soil *in situ* at field capacity. The ECe so obtained is that at the base of the root zone. Values for ECe at the base of the root zone are usually higher by a factor of 1.5. Therefore the ECe at the base of the root zone may be 6 mmhos/cm the ECd 12 mmhos/cm. Substituting these values in the equation yields:-

$$LR = \frac{0.6 \times 100}{0.3 \times 12} = 16 \text{ per cent}$$

The actual deep percolation losses that can be expected through these soils estimated from the subsoil permeability experiments would suggest that this value can be exceeded throughout the area.

Salinity values for the routine samples analysed during the current study have been summarised in Table 2.14. Salinity classes have been adopted from FAO standards. 60 per cent of the samples have a negligeable salinity class with a values of 2.4 mmhos/cm or less, 25 per cent of samples fall in the low salinity class with values of less than 4.9 mmhos/cm only a small percentage of samples have moderate and high salinity values. Figure 2.7 indicates the average salinity values for the different sample depths examined in the study. It is significant that although there is a steady increase in salinity with depth, average values above 1.0 metre do not exceed 4 mmhos/cm which is accepted as a critical level affecting crop growth in the land classification. Average values below 1.0 metre from a smaller percentage of samples show a significant increase but are not regarded as severely limiting.

TABLE 2.14 SUMMARY OF ECe (MMHOS/CM) VALUES FOR ROUTINE ANALYSES BY SALINITY CLASSES AND MAIN SOIL GROUPS

Salinity Class (after FAO)	Maximum ECe Value	Survey Area	Per Cent Total Observations Sl	Sb	Sd	Sot	Sf	Sm	BM	MP
I Negligible	2.4	60	64	65	79	89	64	80	78	37
II Low	4.9	25	22	22	16	0	36	15	22	21
III Moderate	7.4	9	5	9	4	6	0	5	0	10
IV High	9.9	4	5	3	1	5	0	0	0	10
V Very high	+9.9	2	4	1	0	0	0	0	0	22

Investigations within the Jubba valley (Booker 1973) have shown that material brought to the surface by termites to produce termitaria contains a considerable salt content derived from the subsoil horizons. Values obtained for ECe determinations in this study are shown in table 2.15 and are significantly higher than on average at the soil surface. 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; and termitaria are not widely distributed except in small areas of levee soils

TABLE 2.15 CHEMICAL ANALYSES OF TERMITE HILL SAMPLES

Sample Number	Depth cm	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex Na	CEC Me/100g	ESP
C239/T1	0-30	8.2	3.30	0.39	24.7	2
C239/T2	30-60	8.4	3.80	0.31	25.8	1
C287/T1	0-30	8.6	5.20	0.21	21.3	1
C287/T2	30-60	8.2	3.40	0.09	21.8	0

(c) 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 alkali when the ESP exceeds 15. This is also generally accepted as the limit beyond which deterioration in the soils physical properties will excessively affect crop performance and cultivation. However, evidence from the Sudan and elsewhere 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 depends 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 effects 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 to progressively 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 Jubba river for the samples listed in table 2.13 are all low indicating the high quality of the water for irrigation requirements. The very 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. Table 2.16 summarises the main ESP values obtained from the routine samples. Most of the values (97%) fall below 15 per cent and most of the upper horizons have values of less than 5 per cent, Figure 2.7. 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. (section 2.7.2 following).

TABLE 2.16 SUMMARY OF ESP VALUES BY MAIN SOIL GROUPS FROM ROUTINE ANALYSES

Soil grouping	% of samples within ESP ranges					
	< 5	5 - 10	10 - 15	15 - 20	20 - 25	>25
Levees Sl	79	11	7	2	0	
Cover floodplain Sb	83	13	3	1	0	0
Depressions Sd	86	12	1	1	0	0
Terraces Sot	85	5	0	0	5	5
Fartah Sf	100	0	0	0	0	0
Meander Complex Sm	70	25	0	5	0	0
Beach Remnant BM	100	0	0	0	0	0
Marine plain MP	31	17	19	7	14	12
All soils	77	16	4	1	1	1

2.7.2. Profile Pit Sample Analyses

(a) Nature of Soluble Salts

The nature and distribution of soluble anions and cations accounting for soil salinity is important in assessing soil behaviour under irrigation. Analysis of soluble cations and anions was carried out on profile pit samples; the results are presented in Appendix C, and are averaged over standard depth ranges for the major soil units in Table 2.17. Data from the two reconnaissance survey pit sites falling within the proposed irrigation area is included in Table 2.17.

Concentrations of individual cations and anions varied widely between samples from similar sites, and not too much significance should be attached to the averaged figures in Table 2.17. Some consistent overall trends are, however, worthy of comment:-

- There is an increase in total cations and anions with depth. This increase agrees with measured ECe's (Section 2.7.1).

- Calcium is normally the dominant cation in the upper soil layers. Magnesium and sodium become increasingly important with depth. The observed poor structure in the subsoil suggests the dominance of sodium or magnesium cations.

- The sodium adsorption ratio (SAR) increases with depth, but is rarely high enough to suggest a significant sodic hazard (Section 2.7.1). SAR values do not appear related to exchangeable sodium percentage values discussed in Section 2.7.2(c).

- Sulphate is usually the dominant anion although chloride is also present in significant amounts. Some sulphate may be released by a solution of gypsum.

- Levels of soluble boron are appreciable and close watch should be kept for symptons of boron toxicity in crops. Wilcox (1960) states that 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 perennials are more susceptible. Although the levee soils have the highest average boron level, high levels were recorded on all the major mapping units.

(b) pH

pH was measured on samples from soil profile pit sites in a soil/water paste. The results are summarised in Table 2.17.

pH values generally lie within the range 7.7 to 8.0, indicating mildly alkaline conditions. There is little significant variation in pH with depth and differences between soil mapping units are only minor. pH's within this range are unlikely to cause significant problems to cultivation although deficiencies of phosphorus and certain trace elements such as iron may occur due to fixation.

(c) Exchangeable Bases and Cation Exchange Capacity

Although analysis of exchangeable sodium was carried out on all samples because of the special significance of ESP as a factor in soil evaluation, analysis of the other exchangeable bases (calcium, magnesium and potassium) was limited to the samples collected from soil profile pits. The results, summarised for levee, cover floodplain and depression soils, are presented in Table 2.18.

The following conclusions can be drawn from the data in Table 2.18.

- Values of total exchangeable bases (TEB) generally exceed measured cation exchange capacity (CEC). This effect is due to release of calcium from calcium carbonate concretions and possibly from gypsum and is particularly marked in levee soils. The soils can be regarded as 100 per cent base saturated.

- Calcium is the dominant cation, even allowing for release by breakdown of calcium carbonate. Magnesium contents are also appreciable.

TABLE 2.17 SOLUBLE SALTS AND pH

Horizon[1] Depth (cm)	No. of Samples	pH Paste	ECe	Soluble Cations (Me/l) Ca	Mg	Na	K	Soluble Anions (me/l) Cl	SO_4	HCO_3	B in Sat^n Extract (ppm)	SAR
(a) Levee Soils (Units Sl_1, Sl_2)												
Topsoil	3	7.8	2.5[2]	19.6	6.0	4.8	2.1	8.0	22.7	3.8	2.6	1.2
10-50	4	7.8	2.3	22.6	6.3	5.2	1.4	17.5	21.4	2.7	2.3	1.4
50-100	2	7.7	3.9	28.1	10.3	9.8	0.9	13.5	37.2	2.5	2.1	2.1
100-200	5	7.8	4.9	31.1	27.0	25.5	1.2	31.2	48.4	2.8	3.4	4.6
(b) Cover Floodplain Soils (Units Sb_1, Sb_2, Sb_2s)												
Topsoil	5	7.9	1.3	9.3	3.6	4.0	0.3	7.4	7.1	2.9	1.0	1.6
10-50	5	8.0	1.7	7.2	4.1	6.0	0.2	9.4	12.6	3.0	1.1	2.5
50-100	3	8.0	4.2[3]	19.4	15.7	20.8	0.3	15.2	33.3	2.4	2.0	4.9
100-200	9	7.9	4.1	14.1	10.9	17.2	0.3	15.6	36.6	3.1	2.8	4.6
(c) Depression Soils (Units Sd_1, Sd_2, Sd_3, Sdw)												
Topsoil	5	7.7	1.6[4]	10.4	4.6	5.0	0.5	5.8	9.7	3.6	1.5	1.7
10-50	5	7.9	1.7	9.9	5.9	5.6	0.3	6.0	13.0	2.9	1.2	1.6
50-100	6	8.0	2.6	10.4	8.0	13.6	0.2	12.3	14.0	3.3	1.6	3.9
100-200	7	7.8	5.1	25.4	17.4	22.8	0.4	20.6	45.0	2.4	2.6	4.8

[1] *Pits were sampled by horizon and horizons were grouped into depth ranges for comparison. Figures are mean values.*
[2] *Includes one ECe of 4.2.*
[3] *Includes one ECe of 8.3.*
[4] *Includes one ECe of 4.3.*

TABLE 2.18 EXCHANGEABLE BASES, CEC and ESP

Horizon Depth (cm)	No. of Samples	Exchangeable Cations (me/110g) Ca	Mg	Na	K	TEB (me/100g)	CEC (me/100g)	ESP (%)	Texture Range
(a) Levee Soils (Sl_1, Sl_2)									
Topsoil	3	50.4[1]	3.7	0.6	2.0	56.7[1]	26.8	2	SiCL-L
10-50	4	42.7[1]	4.6	0.5	1.4	49.2[1]	25.5	2	FSCL-SiCL-SiC
50-100	2	57.8[1]	6.7	0.3	0.9	65.6[1]	25.2	1	SiC
100-200	5	27.2[1]	5.8	0.3	1.1	34.5[1]	24.7	1	SiL-SiC
(b) Cover Floodplain Soils (Sb_1, Sb_2, Sb_2s)									
Topsoil	5	23.1	8.2	0.5	1.4	33.1[1]	29.9	2	SiCL-C
10-50	5	15.5	6.5	0.5	0.8	23.3	29.6	2	SiC-C
50-100	3	26.8	6.5	0.8	0.9	35.1[1]	28.5	3	SiC-C
100-200	9	25.4	7.8	1.2	0.9	35.2[1]	23.6	5	FSL-C
(c) Depression Soils (Sd_1, Sd_2, Sd_3, Sdw)									
Topsoil	5	25.8	7.8	0.4	1.7	35.7[1]	30.9	1	C
10-50	5	22.0	9.2	0.7	1.1	33.1[1]	30.3	2	C
50-100	6	20.3	12.2	1.8	1.1	35.4[1]	31.4	5	C
100-200	7	31.7[1]	8.5	1.1	0.9	42.4[1]	31.4	4	C

[1] *Inflated due to Ca or Mg release from breakdown of calcium/magnesium carbonate concretions.*

Footnote: Figures refer to means over stated depth ranges. TEB, CEC and ESP are measured from data in Appendix C.

- Exchangeable sodium is low in most cases and no problems should be encountered due to high ESP. There is a slight increase in ESP with depth in cover floodplain and depression soils.

- Levels of exchangeable potassium are fairly high, particularly in levee soils, and potassium tends to decrease with depth. K:Mg ratios are adequate and there should be no requirement, at least initially, for potassium fertilisers.

- CEC values are only moderately high, and lower than expected given the vertisolic characteristics of the depression and cover floodplain soils. Given an average clay content of approximately 50 per cent, CEC's in these units are around 60 me/100 g. This suggests a mixed clay mineral assemblage which includes some montmorillonite clay minerals but also includes significant amounts of illite. Soils with similar CEC's in the Janaale-Buulo Mareenta area were found to have a mixed montmorillonite/illite clay mineral assemblage (MMP/HTS, 1978).

- Apart from the increasing CEC with increasing clay content from the levees through the cover floodplain to the depressions, there is little difference in the cation exchange properties between the three units in Table 2.18.

(d) Carbonate and Gypsum

The results of carbonate and gypsum analysis from different profile pit sites in the Project Area show little variation with soil mapping unit. The results of all the sampled profiles are presented in Table 2.19.

TABLE 2.19 TOTAL CARBONATE AND GYPSUM

Depth (cm)	No. of Samples	Total Carbonate (%)	Gypsum (%)
Topsoil	13	21	0.05
10-50	14	22	0.05
50-100	11	22	0.31
100-200	21	23	0.69

Carbonate levels are high, accounting for over 20 per cent of the total soil mass. The results in Table 2.19 have been calculated assuming all the carbonate is in the calcareous form, and figures have to be increased slightly if magnesium carbonate is also present. This high carbonate content confirms field observations and although calcium carbonate concretions were most concentrated in the subsoil, the most vigorous reaction to hydrochloric acid was often given by the topsoil where the carbonate is in a more finely divided state. Table 2.19 shows a slight, but barely significant, increase in total carbonate with depth.

These carbonate levels are unlikely to have direct harmful effects on soil conditions or crops, but due to their low solubility, carbonates act as diluents, thereby reducing the effective volume of soil that can be exploited by plant roots for water or nutrient resources. The available water capacity, discussed in Section 2.6.2, measured without the removal of carbonate, is generally adequate in the soils proposed for irrigation development.

The content of gypsum in the soils of the Project Area is low in the upper rooting zone but increases in the subsoil. Gypsum is generally regarded as a beneficial soil constituent at these levels of concentration as it contributes to the soil exchangeable calcium and therefore offsets the harmful effects of sodium and magnesium on soil structure. Gypsum can, however, cause corrosion problems in engineering structures due to release of sulphate in the soil solution.

(e) Carbon, Nitrogen and Phosphorus

Results of analysis of organic carbon, total nitrogen, and total and available phosphorus are summarised for all the soils of the Project Area in Table 2.20. With the exception of one site in a depressional lake (Unit Sdw) which showed a relatively high organic carbon content (1.7) and a very high carbon:nitrogen ratio (20) indicating poor mineralisation of organic matter due to predominant anaerobic conditions there is little variation in carbon, nitrogen and phosphorus content between different soil units. The depressional lake sample is omitted from Table 2.20.

TABLE 2.20 ORGANIC CARBON, NITROGEN AND PHOSPHORUS (all soils)

Horizon	No. of Samples	Organic Carbon (%)	Total Nitrogen (%)	C:N Ratio	Phosphorus Total (ppm)	Phosphorus Available (ppm)
Topsoil	12	1.0	0.09	11	776	1.9
Subsurface	12	0.7	0.06	11	718	1.2

Levels of organic carbon and total nitrogen are fairly low and nitrogen fertilisers will be necessary to maintain yields under an intensive cropping system. With the exception of the depressional lake site noted previously, C:N ratios indicate an adequate rate of mineralisation and problems of poor nitrogen availability should not be encountered. Practices of organic matter conservation, such as ploughing in crop residues, growing green manure crops or incorporation of grazing animals in the rotation system should be investigated and encouraged following implementation of the project.

Total phosphate levels are fairly high but only a small amount of phosphorus is in the available fraction. At the moderately high pH values recorded in the soils of the Project Area, this phosphate fixation is due mainly to formation of poorly soluble calcium phosphates. Under the proposed, relatively intensive system of cultivation, crops should respond to phosphate fertiliser applications, and trials should be undertaken to determine optimum application rates.

3

Land Suitability for Irrigation Development

3.1 INTRODUCTION

Evaluation of the possible effects of soil and land properties on development costs and crop yields is one of the most critical stages in assessing the feasibility of an area for agricultural development. In order to make evaluation as objective and accurate as possible soil and land properties are interpreted strictly in relation to the proposed land use or uses, and constraints are identified. Studies of the problems and limitations of any existing similar schemes should be taken into account in the final assessment of land suitability.

In the present study, evaluation of the land of the Homboy Irrigated Settlement Project area is carried out in four stages:-

(a) Definition of the proposed agricultural land use under project conditions.

(b) Selection of a system of land classification.

(c) Recognition of land and soil constraints to development and maintenance of the proposed land use. Discussion of the effects of these constraints and definition of their levels of limitation.

(d) Allocation of land suitability classes to soil mapping units, based on their number and degree of limitations.

Following completion of these stages, land suitability classes and sub-classes are mapped at 1:20,000 scale. These maps accompany the present report.

3.2 PROPOSED LAND USE

The prime aim of the present study is the identification of an area suitable for irrigated agricultural development. A net area of 9,000 ha of irrigable land is required.

The engineering field studies forming part of the present phase of investigations have not yet been completed but preliminary observations suggest that either a basin or a furrow irrigation system would be most suitable over most of the project area. However, on the levee alongside the Farta Tukuule, topographic constraints warrant consideration of sprinkler irrigation, and the rather specialised topographic and soil conditions in the depressions make basin irrigation of paddy rice a possible alternative.

Under the proposed irrigation development the SDA propose to divide the land into 100 hectare irrigation units. Each of these units would be subdivided into four 25 hectare blocks which would be run as separate farms. We assume that some mechanisation would be employed in the initial land preparation and possibly in the subsequent planting and harvesting of these blocks.

Crop rotations are discussed in Chapters 4 and 5 and would initially include maize, upland rice or groundnuts in the 'Gu' season and cotton, groundnuts, sesame or paddy, or upland rice in the 'Der' season. Following construction of the Bardheere dam and the removal of the constraints imposed by the low flow period of the Jubba river, green gram may be incorporated into the rotation in the 'Gu' season.

Possibilities for rainfed agriculture areas outside the proposed 9,000 hectare scheme are discussed in Section 3.6.

3.3 THE LAND CLASSIFICATION SYSTEM

The land classification system for irrigated cropping, based on USBR (1953), has been used on most previous studies in the Jubba Valley (ICA, 1961; Selchozpromexport, 1965; Technital, 1975; HTS, 1977, 1977a, 1978) and is employed in the present study. In this system, land classes are defined on the basis of the number and degree of limitations to irrigation development. The payment capacity, reflecting the yield levels of crops under the proposed cropping patterns, or substantial differences in land development costs, is related qualitatively to the land and soil limitations. Six land classes are recognised in the USBR system, three of which are suitable for arable cropping and one which is definitely unsuitable for irrigation development.

USBR classes are adapted to local Somali conditions in the present study. In particular, Land Class IV, which is regarded as a 'special use' class by USBR, has been redefined as a very marginal class in the present study to correlate with previous studies in the Jubba Valley. The limiting values of some of the various constraints to land use have also been modified from the USBR standards, which were developed with reference to American conditions. Classes I-III can be regarded as suitable for development in the present study. The economics of developing Class IV land may be highly questionable and it should be avoided as far as possible in the scheme layout.

This modified USBR system forms a framework for evaluating the suitability of the land of the project area for the proposed land use described in Section 3.2. In addition to ordering land suitability for furrow irrigation under the proposed cropping patterns, suitability classes are also allocated for sprinkler irrigation and for basin irrigation of paddy rice in soil mapping units where these forms of land use may be more appropriate.

3.4 LIMITATIONS

The limiting criteria on which land suitability class definition is based are generally stable inherent properties of the soil or land surface which are not easily correctable without significant economic inputs. For successful agriculture the soil must provide a favourable physical and chemical environment for seed germination and crop growth and the land surface should not hinder any cultivation practices or watercourses required by the proposed land use or present unacceptable erosion hazards.

In the present project area, the following soil and land properties are considered limiting to irrigation development:-

Physical properties of the root zone
Subsoil permeability and soil drainage
Susceptibility to flooding

TABLE 3.1 USBR LAND CLASSES FOR IRRIGATION

Class	Rating	Modified USBR
I	Very good	Lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of climatically adapted crops at reasonable cost. These lands have potentially a relatively high payment capacity.
II	Good	Lands that have a moderate suitability for irrigation. These are usually either adaptable to a narrower range of crops, more expensive to develop for irrigation or less productive than Class I. Potentially these lands have an intermediate payment capacity.
III	Fair	Lands that have a marginal suitability for irrigation. They are less suitable than Class II lands and usually have either a serious single deficiency or a combination of several moderate deficiences in soil, topography or drainage properties. Although greater risk may be involved in farming these lands than those of Classes I and II, under proper management they are expected to have adequate payment capacity.
IV	Very Marginal	Land with at least one severe deficiency, correctible only at high cost or likely to seriously limit crop yields or pose severe risks. The payment capacity of this land can be regarded as questionable.
V	Questionable	Not used in present study.
VI	Unsuitable	Land that is non-arable under the existing or projected economic conditions associated with the proposed project development and fails to meet the minimum requirements for the other classes of land. The lands do not have sufficient payment capacity to warrant consideration for irrigation.

TABLE 3.2 Physical Properties of the Root Zone

Property	Levee and higher cover floodplain (Sl_1, Sl_2)	Lower cover floodplain, Shallow Depressions (Sb_2, Sd_2)	Depressions (Sd_2, Sd_3, Sdw)
Texture	Moderately heavy (silty clay loams/silty clays/ clays)	Heavy (silty clays/ clays)	Very heavy (clays)
Structure	Fairly good Moderate medium subangular blocky dominant.	Fairly average - Dominately coarse prismatic with weak substructure. Subangular blocky at surface.	Poor, Dominantly coarse-very coarse prismatic with weak substructure.
Consistence	Fair Hard when dry. Firm-friable when moist.	Fairly poor Hard when dry Firm-very firm when moist. Sticky and plastic when wet. Timing of operations critical.	Poor Very hard when dry. Very sticky and plastic when wet. Timing of operations critical.
Bulk Density		Not Limiting	
Porosity	Adequate	Fairly Poor. High proportion of very fine pores.	Poor. High proportion of very fine pores.
Available Water	Adequate AWC and EAWC both fairly high (EAWC sometimes low in Sb_1).	Adequate AWC fairly high EAWC fairly low	Marginally adequate AWC fairly high EAWC low.
Surface	Slight tendency to form crusts.	Usually self mulching	Usually self mulching
Degree of Limitation	None	Minor (s)	Major (S)
Comment	Also suited to sprinkler irrigation.	Also suited to paddy rice cultivation (particularly Sd_1).	Physical properties more favourable for paddy rice cultivation.

Topography
Microrelief
Erosion hazard
Salinity

These properties are continuous variables, and in view of the limited information on crop performance under similar environmental conditions, limits are not precisely defined between land classes except in the case of the soil salinity and sodicity limitations which are easily quantifiable. Instead, two levels of limitation are selected for each property; a minor level at which the deficiency is either easily correctable or at which crop yields are only slightly depressed, and a major level which requires significant economic inputs for deficiency correction or at which crop yields are significantly reduced.

The individual limiting criteria and their significance to the development of the Fanoole-Kamsuuma area are discussed below.

3.4.1 Physical Properties of the Root Zone

For successful irrigation the soil in the crop rooting zone must have physical properties favourable for seed germination and crop growth, and be sufficiently stable to withstand planned cultivation operations. Effective soil volume, texture, structure, consistence, porosity and available water holding capacity are all important in determining suitability for irrigated cropping and these properties are assessed in the soils of the project area in Sections 2.5 - 2.6.

Table 3.2 summarises the physical properties relevant to irrigation development in the three major groups of soil units, and evaluates constraints under the proposed forms of land use.

3.4.2 Subsoil Permeability and Soil Drainage

In a successful irrigation agricultural system, soil drainage must be adequate to dispose of any excess water in the root zone, to transmit the necessary 'leaching requirement', to limit the accumulation of soluble salts in the root zone and to maintain the soil water table at an acceptable level.

Section 2.6.3 concluded that soil permeabilities are generally very low. Results of hydraulic conductivity tests showed values generally lower than the limit of 24 mm per day set for normal irrigation by FAO (1974) except in the levee soils (down to 150 cm) and in the coarser subsoils of some cover floodplain soils. The lowest permeabilities are in the depression soils where mean readings varied from 1.5 to 7 mm per day (Table 2.8). However, because of the expanding nature of the clays in the project area and the resulting cracks which form on drying the effective field permeability may be greater than that suggested by the test figures. The trials conducted by Giprodovhoz(1973) and recent experience on the Jubba sugar project support this view. However, work on Shabeelle alluvial soils in the Janaale area (MMP, 1978) suggests that the soils stay sufficiently moist between irrigation applications to prevent significant cracking.

Relating the above somewhat conflicting evidence to the basic drainage requirements of a soil under irrigated conditions, the following conclusions can be drawn:-

(a) Except in the lighter textured levee soils, the permeability may well not be sufficient to dispose of excess water in the root zone resulting from rainfall or surplus irrigation. Soil waterlogging for periods of more than 48 hours is harmful to some of the proposed crops (particularly maize). An efficient surface drainage system must be installed to minimise waterlogging.

(b) Except in one case (the subsoil of a depressional lake) permeabilities are adequate to meet the theoretical leaching requirement of Jubba river water, which is less than 1 mm/day (Reconnaissance Report - Appendix G).

(c) The vast majority of soils in the project area have low salinities in the root zone (ECe less than 4.0 mmhos/cm - see Section 2.7.2). However, ECe's usually increase sharply below 1.0 m depth and if perched saturated layers develop there is a strong possibility of increased salinity in the root zone.

(d) The permanent groundwater table is presently around 20 m deep and subsoil drainage is unlikely to be required for at least the first 20 years of the project.

On the basis of current evidence, we conclude that low permeabilities pose a significant constraint to irrigation in the project area, and that the magnitude of the constraint increases from the levees, through the cover floodplain to the depressions. Surface drainage is required to minimise waterlogging and this aspect will be studied in more detail in the current engineering investigations. Field trials should be established early in the life of the project to monitor water applications and losses.

In the shallow and moderately deep depressions (Units Sd_1, Sd_2) consideration could be given to substituting basin irrigation of paddy rice in place of the proposed cropping patterns. Provided permeabilities are sufficient to meet the leaching requirement, this crop could be expected to thrive under these conditions.

3.4.3 Susceptibility to Flooding

Under present conditions, various parts of the project area suffer periods of severe flooding resulting from either discharge from the Shabeelle River or Harar Naga or Kormajirto depressions, local rainfall and run off from the Marine Plain, overflow from the River Jubba or from a combination of these sources. Following construction of the proposed project the risk of flooding from sources outside the project area will be much reduced by the construction of bunds and flood relief channels. However, local surplus water from rainfall and excess irrigation will tend to accumulate in the lower areas within the project boundary and these areas will, therefore, be susceptible to flooding during the course of the project. The flood problem is increased by the low permeability of the depression soils.

The risk of flooding increases in severity from the shallow depressions, through the moderately deep depressions to the depressional and oxbow lakes. The shallow depressions (Sd_1 unit) are regarded as suffering a minor limitation, but the risk is considered major on the other depressional areas, which are probably uneconomic to drain and protect from further flooding. Better returns could probably be realised by stocking the deeper depressional areas with fish.

3.4.4 Topography

The project area is generally topographically well suited to surface irrigation with slopes on the dominant cover floodplain generally in the region of 0.1 - 0.3 per cent. However, the increasing costs of land levelling make topography an increasingly stringent factor in irrigation and suitability classification, and the slopes of 0.5 - 2 per cent on the levees (Units Sl, Sl_2) together with the irregular shape of the mapped units are sufficient to impose a minor but significant limitation to development of a furrow or basin irrigation system. Similar constraints exist on the upper terrace (Sot_1) and meander complex (Som) units, and topography is a major limitation to developing the 'fartas' or channels. These problems could be overcome by the use of sprinklers and we recommend that, in spite of increased costs, the feasibility of this method of irrigation should be considered, particularly on the levees, where soil conditions are relatively favourable.

3.4.5 Microrelief

'Gilgai' microrelief (Section 2.5.1) formed by expansion and contraction of clay rich soils on wetting and drying is present, to a greater or less extent over most of the project area except for the levees, upper terrace and meander complex. On the cover floodplain and in the shallow depressions (Sd_1) it is only slightly developed and is unlikely to cause any significant problems, as irregularities will probably be removed in the initial land planning. It is unlikely to reappear during the course of the project because of the more stable soil moisture conditions prevailing under irrigation.

Gilgai development is more marked in the moderately deep depressions (Sd_2 unit). In a few areas (Sd_2g, JSd_2g units) a hummocky microrelief of amplitude around one metre occurs. Land levelling requirements would be very high in these areas, but the poor physical properties of the soil, very low permeability and flood risk preclude any justification of expensive levelling operations.

3.4.6 Erosion Susceptibility

Slopes in the project area are generally too gradual for erosion to be a serious problem. However, the soils are structurally fairly unstable and erosion runnelling was observed on some of the steeper slopes on the levees, terraces and meander complex. If these areas are irrigated erosion may be enhanced unless adequate conservation measures are taken. However, it appears unlikely that these areas will be irrigated, at least by surface methods. A more significant problem could be erosion on the banks of canals and drains, which is a current problem on the Jubba alluvial soils of the Jilib State Farm Project. The unstable nature of the soils of the project area should be borne in mind when watercourses are designed for the proposed project.

A certain amount of wind erosion was noted on cleared areas of soil within the project area. Tree windbreaks would minimise this problem, in addition to providing shade for the agricultural labour force.

3.5 ALLOCATION OF LAND SUITABILITY CLASSES TO SOIL MAPPING UNITS

Land suitability classes for irrigation are assigned to each of the soil mapping units defined in Table 2.1 (Section 2.3.1) based on the number and degree of limitations described above. Land classes are based on the system of USBR and reflect the payment capacity of the land under the proposed irrigated land use and level of management. Table 3.3 illustrates allocation of land suitability classes on the basis of limitation to all the soil mapping units for the major proposed land utilisation type which is assumed to be irrigated mixed cropping (maize, cotton, sesame, rice and vegetables and pulses) under either a basin or furrow irrigation system. Alternative land classes for sprinkler irrigation of mixed crops and for rice monoculture are given in units where we consider these proposed uses may be appropriate.

Land classes were allocated according to the following guidelines:-

Class I land has no significant limitations.

TABLE 3.3 LIMITATIONS AND IRRIGATION SUITABILITY OF SOIL MAPPING UNITS

Soil Mapping Unit	Limitations: Physical props. of Root Zone	Permeability/ Drainage	Flood Susceptibility	Topography	Microrelief	Erosion Hazard	Salinity	Land Class and Subclass[3]: Basin/Furrow Irrigation of Mixed Crops[2] (Suffix[1])	Sprinkler Irrigation of Mixed Crops	Rice Monoculture
	Ss	Ww	Ff	Tt	M	e	x			
Sl_{1-2}				x		x	x	III tex	II	
Sl_2		x		x			x	III wtx	II	
Sb_1		x						II w		
$Sb_{1(s)}$		x						II w		
Sb_2	x	x						II sw		I
$Sb_{2(s)}$	x	x						II sw		I - III[4]
Sd_1	x	xx	x					III Wsf		I
Sd_2	xx	xx	xx					VI SWF		II - VI[5]
Sd_{2g}	xx	xx	xx		xx			VI SWFM		
Sd_3	xx	xx	xx					VI SWF		II - VI[5]
Sd_w	xx	xx	xx					VI SWF		
Sf	x	x	x	xx				IV Tswf		
Sot_1	xx	x		xx		x		VI STex		
Sot_2	x	xx					x	III Wsx		II
Som	xx	x		x		x		IV Swte		
Sox	xx	xx	xx					VI SWF		
JSd_{2g}	xx	xx	xx		xx			VI SWFM		
JSf	xx	xx	xx	xx				VI SWFT		
JSfx	x	x	x	x				III swft		
SMP	x	xx		x			x	IV Wstx		

[1] *A capital letter denotes limitation at major level; lower case, at a minor level.*
[2] *Including Maize, Cotton, Rice, Sesame, Pulses and Vegetables.*
[3] *Subclass (limitations) only given for proposed major land use.*
[4] *Downgrade to III where coarse subsoil phase occurs.*
[5] *Depends on flood status of depressions after implementation of irrigation project.*

x = Limitation at minor level.
xx = Limitation at major level.

TABLE 3.4 DISTRIBUTION OF IRRIGATION LAND SUITABILITY CLASSES

Land Class	Subclass	Area ha	%
II	II w	3,268	21.6
Suitable	II sw	3,188	21.1
	Total	6,456	42.7
III	III tex	713	4.7
Moderately Suitable	III wtx	1,060	7.0
	III Wsf	2,774	18.5
	III Wsx	514	3.4
	III swft	641	4.2
	Total	5,702	37.8
IV	IV Tswf	259	1.7
Very Marginal	IV Swte	417	2.8
	IV Wstx	100	0.7
	Total	776	5.2
VI	VI SWF	1,524	10.1
Unsuitable	VI SWFM	419	2.8
	VI SWFT	29	0.2
	VI STex	139	0.9
	VI unspecified *	40	0.3
	Total	2,151	14.3
Totals		15,085	100.0

* Coastal Ridge Outlier.

Class II land has up to two minor limitations and no major limitations.

Class III land has either one major limitation and a maximum of two minor limitations, or three or four minor limitations.

Class IV land has one major and three minor limitations.

Class VI land has two or more major limitations.

The derivation of irrigation suitability classes for the major soil mapping units are discussed below:-

(a) Levee Unit (Sl_{1-2}, Sl_2)
The levees soils are physically the best suited to irrigation in the Project Area. Their topographic position, significant slopes, and irregular pattern, following the meandering Farta Tukuule, poses problems of irrigation design and introduce land levelling requirements in the proposed basin or furrow irrigation system. These problems could be largely overcome by the use of sprinklers. Salinities in the levees are commonly significantly high in the upper subsoil (50 - 100 cm) and usually increase markedly below one metre depth. This salinity hazard could be increased if land levelling is carried out. Additional minor limitations due to erosion hazard (Sl_{1-2}) or subsoil permeability (Sl_2) justify the inclusion of levee soils in Land Class III for a furrow or basin system, and Class II for sprinkler irrigation.

(b) Cover Floodplain Units (Sb_1, Sb_1(s), Sb_2, Sb_2(s))
The cover floodplain is the best irrigation land in the project area. Present evidence suggests that the only significant limitation throughout the cover floodplain is the low subsoil permeability which hampers disposal of excess water. Even where coarse textured subsoils occur they are usually overlain by a compact clay layer of low permeability, and cover floodplain land is downgraded to Class II for this reason. Soils of the lower cover floodplain (Sb_2, Sb_2s) also suffer a minor constraint due to poor soil physical properties in the root zone. Rice monoculture could be considered as an alternative land use on the Sb_2 unit, but trials should be undertaken to measure percolation losses in areas where the coarse subsoil phase occurs.

(c) Shallow Depressions (Sd_1)
The generally very low permeability in the subsoils in the shallow depressions is sufficient to downgrade this unit to Land Class III. In addition it suffers minor limitations due to poor physical properties in the root zone and susceptibility to flooding. Provided this latter hazard can be controlled, the shallow depression areas are well suited to continuous paddy rice cultivation.

(d) Deeper Depressions (Sd_2, Sd_3, Sdw)
The combination of difficult drainage, high susceptibility to uncontrolled flooding, and poor soil physical properties made the deeper depressions unsuitable for development under the proposed irrigation system. If some control of flooding can be achieved, rice could be grown in the Sd_2 areas, but the deeper depressions are probably best allocated as flood relief areas. Some depressions could be stocked with fish; local fishing already thrives in the Far Sitay depressional lake in the south of the area.

Land classes and subclasses are plotted on the 1:20,000 map accompanying this report. In addition to the alluvial land forming the Project Area, land classes are also plotted on the adjacent Marine Plain, 'transitional Beach Remnant' and 'Coastal Ridge'. Land classes for the two former units are taken from the Reconnaissance Report (HTS, 1978). The Coastal Ridge is allocated to Class VI due to rolling topography and sandy soils.

3.6 DISTRIBUTION OF LAND CLASSES IN THE PROJECT AREA

The distribution of land classes and subclasses in the Project Area is shown on the 'Land Suitability for Irrigation Development' map accompanying this report. Boundaries between classes and subclasses are based on the soils map. Areas of the various classes and subclasses were measured by planimetry. The results are presented in Table 3.4 . Land classes refer to those for the major proposed land use (i.e. basin/furrow irrigation of various crops).

Table 3.4 shows that a total of 12,160 hectares gross of land (80.5 per cent of the area surveyed) is suitable for irrigation development under the proposed basin or furrow system using the crops recommended. This is slightly less than the 14,190 ha estimated in the Reconnaissance Report. Incuded in this total are 6,480 hectares which could alternatively be used for continuous cultivation of rice and 1,770 hectares which are more suited to sprinkler irrigation. A further 900 hectares (maximum) of Class VI land could be developed for rice monoculture provided sufficient control of flood water could be achieved under the irrigation regime proposed.

The best irrigation land occurs on the cover floodplains which form strips of varying width on either side of the central Farta Tukuule, and extend between the channel levees and the peripheral depressions along the north western and south eastern margins of the lower Shabeelle floodplain. The proportion of suitable land is less in the extreme south of the Project Area which suffers more marked topographic variation, a more complex soil pattern and greater flood risk due to the influence of the Jubba River.

3.7 LAND SUITABILITY FOR RAINFED CROPPING

Although the proposed project is directed specifically towards irrigation development, opportunities for rainfed cropping may exist in areas of land excluded in the irrigation design. In particular, the possibilities of small scale rainfed gardening on the house lots should be considered if villages are situated on the alluvial areas. Rainfed agriculture should augment the subsistence crop output under the proposed scheme.

The factors limiting rainfed agriculture on both the Shabeelle alluvium and the adjacent Marine Plain and Beach Remnant areas are discussed in the Reconnaissance Report (HTS, 1978). The most important physical factors limiting improvement in rainfed agriculture are the distribution and reliability of rainfall and the physical properties of the soil surface and root zone. Future cropping should be based largely on traditional cropping practices, supplemented if possible by fertiliser and other inputs.

Section 1.6 describes two major types of present agriculture practiced on the Shabeelle floodplain. These comprise the predominantly rainfed cropping concentrated on the levees and cover floodplain around areas of existing settlement and 'depression farming', utilising residual moisture from flooding in the depressions and fartas. Table 3.5 ascribes land classes for these two non irrigated land uses to soil mapping units in the Project Area.

TABLE 3.5 LAND SUITABILITY FOR NON IRRIGATED CROPPING

Soil Mapping Unit	Land Class	
	Normal 'Rainfed' Cropping	Depression Farming*
Sl_{1-2}	II	
Sl_2	II	
Sb_1	II	
Sb_1(s)	II	
Sb_2	III	
Sb_2(s)	III	
Sd_1	III	II - IV
Sd_2	VI	II - VI
Sd_{2g}	VI	II - VI
Sd_3	VI	II - VI
Sd_w	VI	II - VI
Sf	III	II - VI
Sot_1	IV	
Sot_2	III	
Som	III	
Sox	VI	II - VI
JSd_{2g}	VI	II - VI
JSfx	II	
JSf	VI	
SMP	III	

* Suitability class depends on flood status of depressions after implementation of irrigation project.

The levees and upper cover floodplain are most suitable for 'normal rainfed cropping'. If villages are situated on the levees, rainfed crop production on the house lots could augment subsistence needs.

Suitability of the depressions for cropping is entirely dependent on their flood status following implementation of the proposed irrigation scheme. It is likely that the deeper depressions will be permanently flooded.

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A

Terms of Reference

The complete original terms of reference for the resettlement study are as follows:

Since the completion of the Inter Riverine Agricultural Study, Phase 1, it has been proposed by the Settlement Development Agency that the settlement at Dujuma should be translocated to an alternative area within the Fanole-Gelib-Kamsuma road. Prior to relocation it is necessary that thorough investigations should be carried out to prove that the new area has a potential for the development of irrigated agriculture.

The following specific tasks will be undertaken:

(i) Reconnaissance Survey of some 60,000 hectares, to include soils, hydrological, engineering and agricultural investigations, to identify 24,000 hectares of irrigable land.

(ii) Study of 24,000 hectares, involving soils investigations and topographic survey Priority will be given to the survey of the Phase I 9,000 hectare development area. Preliminary engineering investigations will be made within the Phase I area to collect sufficient data for the final engineering design. Villagisation studies and relocation planning to facilitate the early transfer of settlers from Dujuma to the new site will be carried out concurrently.

(iii) Final Engineering Design of the 9,000 hectares priority Phase I development area.

The present report describes the methods, results and conclusions of the soils studies for the area outlined in (ii) above. The detailed terms of reference for these studies are as presented below. Because only 15,000 hectares of land was identified as being suitable for irrigation development in Phase I, some amendments (as described in the letter from H.Piper to Mr. Abdilleh on 15.11.78) are incorporated in these terms of reference.

(i) Semi-detailed Soil Survey and Land Classification

(a) Carry out semi-detailed soil survey over a gross area of approximately 15,000 hectares of land in the Homboy/Burgaan area, identified as suitable during the Reconnaissance Studies and as indicated on the land Suitability Map.

(b) The overall examination density will be one site per 25 hectares. At twenty two (22) the examination will be by pitting to 2 metres, the pits being extended by boring to five (5) metres.

(c) At every alternative auger site the soils will be sampled at depths of 0-25, 25-50, and 50-100 cms (this is intended to increase the data on the soils in the rooting zone).

(d) Samples will also be collected from eleven (11) selected pits for detailed analysis.

(e) Ten (10) core samples will be taken from pits and analysed for bulk density aeration porosity, available water capacity (against tensions of 0,0,1, 0.3, 1.0, 15.)

(f) Infiltration tests will be carried out at eleven (11) pit sites.

(g) Hydraulic conductivity tests will be carried out at some twenty (20) sites.

(h) Analyses of river water would be made on samples collected at monthly intervals to assess its suitability for irrigation. Since it is possible that well water may be used to supplement river water, well water samples will be collected and analysed: a total of 20 samples would be analysed.

(i) The findings of the study would be presented in the form of a report which would include soil survey methods, the basis of the soil and land classification, description of the representative soil units, interpretation of the survey data, results of the soil analyses and recommendations for agricultural practices. Apart from appropriate test figures, the report would be accompanied by semi-detail maps at a scale of 1:20,000 comprising:

A taxonomic soil classification map, showing boundaries of the irrigable areas.

A land capability classification map for irrigated cultivation classifying on broad lines according to US Bureau of Reclamation standards, but adjusted where necessary for satisfactory application to Somali conditions, using land classes Nos. 1, 2, 3, 4 and 6, and showing the boundaries of the irrigable areas.

(ii) Agriculture

The range of crops considered in the preliminary phase would be further refined and crop rotations would be developed to suit the selected project area. Where required, new crop water requirements and irrigation frequencies would be calculated for the selected crop rotation or rotations.

Agronomic and management practices would be studied to select those most suited to the chosen cropping patterns.

A determination of field layout and optimum size of holdings would be made in conjunction with the Irrigation Engineer and Agriculturalist. The SDA income targets for the settlers would be an important criteria in selecting optimum farm sizes.

B

Soil Mapping Units

SOIL MAPPING UNITS

	Airphoto Interpretation (API) Unit	Soil Unit	Phase
Floodplain Units:			
Semi-recent and Recent Alluvium			
Shabeelle Levee	Sl		
- coarser type		Sl_1	
- finer type		Sl_2	
Shabeelle Cover Floodplain	Sb		
- higher		Sb_1	
- higher (coarse subsoil phase)			Sb_{1s}
- lower		Sb_2	
- lower (coarse subsoil phase)			Sb_{2s}
Shabeelle Depression	Sd		
- shallow		Sd_1	
- moderately deep		Sd_2	
- moderately deep (extreme gilgai phase)			Sd_{2g}
- deep		Sd_3	
Shabeelle Depressional Lake	Sdw		
Shabeelle Farta (Channel)	Sf		
Old Alluvium			
Shabeelle Terrace	Sot		
- higher		Sot_1	
- lower		Sot_2	
Shabeelle Meander Complex	Som		
Shabeelle Oxbow Lake	Sox		
Complex Units:			
Jubba - Shabeelle Floodplain Complex	JSfx		
Shabeelle Alluvium over Marine Plain Clays	SMP		
Peripheral Units:			
Marine Plain	MP		
Marine Plain depression	MPd		
Beach Remnant	BR		
Transitional Beach Remnant	BM		
Coastal Ridge	CR		

Gilgai Microrelief Classes

MO	No perceptable Gilgai	
M1	Slight Gilgai	Amplitude 10-25cm
M2	Moderate Gilgai	Amplitude 25-50cm
M3	Severe Gilgai	Amplitude more than 50cm

UNIT:	Sl_1 - Shabeelle levee (coarser type).
FAO/UNESCO Classification:	Calcaric Fluvisols.
Physiography:	Crests and steeper slopes (towards channel) of the more strongly developed levees of existing and abandoned channels.
Extent of Occurrence:	Local - throughout survey area. Mapped as complex with finer type.
Elevation:	18.5-13.5 m.a.d.
Slope (est.):	2 per cent average, 10 per cent maximum.
Microrelief:	Even, except for occasional erosion rills and termite mounds.
Surface:	Brown, usually with slight surface crust. Surface wash on steeper slopes.
Soils:	Brown dominantly subangular blocky silty clay loams passing into light silty clays. Some lighter (SiL) layers present near surface in some profiles. Common soft $CaCO_3$, often irregularly distributed through profile.
Diagnostic Features:	Texture (Dominantly SiCL, light silty clay, on courser to 100 cm). Colour (7.5-10 YR, Chromas >4) Topographic Position.
Profile Drainage:	Imperfect - moderately well.
Natural Vegetation:	Dominantly relatively open shrubland dominated by non thorny species such as *Dobera glabra, Combretum hereroense* and *Thespesia darlis* with some *Acacia* present.
Land Use:	Occasionally cropped with sorghum (Der season). Growth is usually poor (moisture stress).
Development Limitations:	Topography. Erosion risk Salinity.
Irrigation Land Class:	III tex (Class II for Sprinklers)
Representative Pits:	A301, C287.
Total No. of Observations:	19

UNIT:	Sl_2 - Shabeelle levee (finer type).
FAO/UNESCO Classification:	Calcaric Fluvisols.
Physiography:	Slightly raised areas alongside existing and abandoned channels, when not occupied by Sl_1 unit.
Extent of Occurrence:	Widespread around channel courses throughout survey area. Also occurs around depressional lakes. (1060 ha). Also mapped as complex with Sl_1.
Elevation:	18.5-13.5 m.a.d.
Slopes (est.):	0.5-1 per cent average, 5 per cent maximum.
Microrelief:	Generally even (MO), except for occasional erosion rills (on steeper slopes) and termite mounds.
Surface:	Brown - greyish brown. Often granular. Slight surface crusting sometimes present. Surface wash on steeper slopes.
Soils:	Dominantly silty clay loam - light silty clay at surface, passing into silty clay and clay at depth. Lighter textured structure (SiCL) layers occasionally encountered in subsoil. Structure dominantly moderate subangular - angular blocky. Common powdery - crystalline calcium carbonate concretions in all but the surface horizons. Cracks appear on profile drying. Dominant colours are 10YR - 7.5YR 4/3.
Diagnostic Features:	Topographic position (lower than Sl_1, higher than Sb_1). Soil texture and structure (heavier than Sl_1). Soil colour.
Profile Drainage:	Imperfect.
Natural Vegetation:	As Sl_1. The levees around depressional lakes support a much denser vegetative growth of varied species composition.
Land Use:	Occasionally cropped with sorghum during Der season. Crop is usually poor, probably due to moisture stress.
Development Limitations:	Slight, due to topography, drainage and salinity.
Irrigation Land Class:	III wtx (Class II for Sprinklers).
Representative Pits:	BO35, A302.
Total No. of Observations:	48

UNIT:	Sb_1 - Shabeelle cover, floodplain - higher.
FAO/UNESCO Classification:	Calcaric Fluvisols/Chromic Vertisols.
Physiography:	The cover floodplain is an almost flat area extending between levees and lower depressions and backswamps. The Sb_1 units refer to the slightly higher, better drained areas usually adjoining the levees.
Extent of Occurence:	Widespread throughout survey area (3268 ha total).
Elevation:	18.0-13.5 m.a.d.
Slopes (est.):	Average 0-0.1 per cent. Rarely $>$ 0.5 per cent.
Microrelief:	Slight gilgai microrelief (M1) usually present. Often not apparent in cultivated areas.
Surface:	Brown - greyish brown. Sometimes weakly developed surface crust. Few - common cracks.
Soils:	Dominantly brown (around 10YR 4/3) silty clay loam - light silty clay at surface, passing into clay - silty clay within 50 cm depth. Structure dominantly moderate medium subangular - angular blocky in surface and subsoil horizons, although there may be some development of prismatic structure from 25-100 cm (approx.). Clay subsoil has weak - moderate subangular - angular blocky structure and is very firm - extremely firm when moist.
Distinguishing Features:	Soil colour (10YR 4/3 or browner dominant in top 1m). Soil texture (usually has a lighter surface horizon). Topographic position (intermediate between Sl and Sb_2).
Profile Drainage:	Imperfect - poor.
Natural Vegetation:	Dominantly *Acacia*/non thorny mixed wooded shrub. Grassland with some thicket. Typical species are *Acacia bussei*, *A. zanzibarica* and *Dobera glabra*..
Land Use:	Commonly cultivated with maize (Gu season) and sorghum (Der season).
Development Limitations:	Subsoil drainability.
Irrigation Land Class:	II w
Representative Pits:	CO35, CO38, A364.
Total No. of Observations:	109

Coarse Subsoil Phase (Sb_{1s}) has a lighter textured (light silty clay, silty clay loam, silt loam or more rarely sandy loam) subsoil layer, more than 10cm thick occuring from 1 to 2m depth in the profile. Subsoil drainability is considered less limiting in this phase. Sb_{1s} is only mapped as a complex with the typical Sb_1 soil unit. (Total number of observations: 19).

UNIT:	Sb_2 - Shabeelle cover, floodplain - lower.
FAO/UNESCO Classification:	Chromic Vertisols.
Physiography:	The Sb_2 unit refers to the lower, more poorly drained areas of the cover floodplain either adjoining the depressions (Sd units) or recurring as shallow local depressions within the cover floodplain.
Extent of Occurrence:	Widespread, throughout survey area (3188 ha).
Elevation:	17.75-12.75 m.a.d.
Slopes (est.):	Average 0.01 per cent. Rarely $>$ 0.5 per cent.
Microrelief:	Slight - moderate gilgai present (M1-M2). Less recognisable in cultivated areas.
Surface:	Dominantly greyish brown with common cracks and 'sink holes' due to soil collapse. Common shell fragments (snails).
Soils:	A silty clay - clay blocky surface horizon overlying greyish brown (10YR 4/2) clays of very coarse prismatic structure and subangular - angular blocky substructure to approximately 1m depth; over subsoil clays of weak angular blocky-wedge structure with common slickensides Calcium carbonate is present as powdery-crystalline pockets, and usually increases with depth.
Distinguishing Features:	Soil colour (10YR 4/2 dominant). Soil texture (heavier than Sb_1). Topographic position (lower than Sb_1, higher than Sd).
Profile Drainage:	Poor.
Natural Vegetation:	Similar to Sb_1, but with a greater percentage of thicket. *Acacia nilotica* common.
Land Use:	Commonly cultivated. Maize, some sesame (Gu season), sorghum (Der season). Generally better growth than on Sl and Sb_1 units (moister soils).
Development Limitations:	Drainability. Poor physical properties of rooting zone
Irrigation Land Class:	II sw (Class I for rice)
Representative Pits:	A058, C179, A337, A379.
Total No. of Observations:	121

Coarse Subsoil Phase (Sb_{2s}) has a lighter textured (light silty clay, silty clay loam, silt loam or more rarely sandy loam) subsoil layer, more than 10cm thick and occurring between 1m and 2m depth in the profile. Subsoil drainability is considered less limiting in this phase. Sb_{2s} is only mapped as a complex with the typical Sb_2 soil unit. A300 and A416 are representative soil profile pits. (Total number of observations: 24).

UNIT:	Sd_1 *Shabeelle depressions (shallow).*
FAO/UNESCO Classification:	Chromic Vertisols.
Physiography:	Broad shallow depressions and transitional areas surrounding deeper depressions (Sd_2, Sd_3). Normally flooded during rainy seasons.
Extent of Occurrence:	Concentrated along eastern and western edges of floodplain. Also local areas within cover floodplain (2774 ha).
Elevation:	16.0 - 12.75 m.a.d
Slope (est.):	Average 0-0.1 per cent. Rarely > 5 per cent.
Microrelief:	Slight - moderate gilgai (M1-2).
Surface:	Brownish grey. Cracks 'sink hole' common. Common shell fragments. Slightly self mulching surface breaking into subangular blocky or granular aggregates on drying.
Soils:	Dominantly greyish brown (10YR 4/2) clays, with angular - subangular blocky topsoils and coarse prismatic subsurface horizons giving way to more massive/wedge structured clay below 1m. Slickensides common in subsurface and subsoil horizons. Calcium carbonate generally increases with depth.
Distinguishing Features:	Texture (usually clay throughout). Colour (10YR 4/2 dominant). Topographic position.
Profile Drainage:	Poor.
Natural Vegetation:	Dominantly low thicket (c2.5m) of *Acacia nilotica.*
Land Use:	Sometimes cultivated (maize, sorghum, sesame).
Limitations:	Drainability, physical properties of root zone, minor flood hazard.
Irrigation Land Class:	III Wsf (Class I for rice)
Representative Pits:	A377, C009, C288.
Total No. of Observations:	82

UNIT:	Sd_2 Shabeelle depressions (moderately deep).
FAO/UNESCO Classification:	Pellic Vertisols.
Physiography:	Linear backswamp and depressional areas within shallow depressions (Sd_1). Usually flooded several months per year.
Extent:	Occur in lower parts of depressions along eastern and western perimeters of the floodplain (824 ha).
Elevation:	15.25-11.25 m.a.d.
Slope (est.):	Usually 0-0.1 per cent, except adjacent to channels.
Microrelief:	Usually marked gilgai (M2).
Surface:	Grey - brownish grey. Common cracks and sink holes, many shell fragments. 'Self mulching' character.
Soils:	Dark grey (typically 2.5Y 4/1) clays extending from the surface to more than 2m depth. Subangular blocky surface structure, giving way to very coarse prismatic sub-surface horizon and massive/wedge structured clay below about 180 cm. Slickensides common in subsurface and subsoil. Common shell fragments and calcium carbonate (the latter increases with depth).
Distinguishing Features:	Soil colour (Chromas of 1 dominant). Soil texture (clay throughout). Topographic position.
Profile Drainage:	Very poor.
Natural Vegetation:	Dominantly dense *A nilotica* thicket.
Land Use:	Occasionally cultivated.
Development Limitations:	Drainability. Physical properties of root zone. Flood hazard.
Irrigation Land Class:	VI SWF (Class II - VI for rice).
Representative Pits:	A299, A302, A378.
Total No. of Observations:	39

Extreme Gilgai Phase, Sd_{2g} occurs in a limited area in the extreme south west of the survey area, which is subject to flooding from the Jubba river as well as the lower Shabeelle catchment. Soil profiles are disturbed and gilgai of amplitude around 1m is present. (Total number of observations: 7).

UNIT:	Sd_3 Shabeelle depressions - deep.
FAO/UNESCO Classification:	Pellic Vertisols.
Physiography:	Broad concave - flat depressions. Normally flooded for several months per year.
Extent:	Local well defined areas, usually on eastern perimeter of flood-plain (340 ha).
Elevation:	15.5 - 11.25 m.a.d.
Slope:	Usually < 0.1 per cent.
Microrelief:	Usually slight - moderate gilgai (M1-2)
Surface:	Grey. Common wide cracks and 'sink holes'. 'Self mulching character'. Common shell fragments.
Soils:	Similar to Sd_2. Fairly uniform grey (2.5Y 4/1 - 5Y 4/1) clay with very coarse prismatic subsurface horizon and massive/ weak angular - subangular blocky subsoil. Slickensides very well developed in subsurface horizon, common shell fragments. Clay usually extends to > 5m. Pellic vertisols.
Distinguishing Features:	Topographic situation. Soil texture (clay throughout). Soil colour (chromas of 1 dominant). Vegetation.
Profile Drainage:	Very poor.
Natural Vegetation:	Usually characterised by absence of trees and dominance of hydrophilic grasses and broad leafed species.
Land Use:	Often extensively cultivated on receding flood waters. Sesame, maize, sorghum, cotton observed.
Development Limitations:	Drainability. Flood hazard. Poor physical properties of root zone.
Irrigation Land Class:	VI SWF (Class II - VI for rice)
Representative Pits:	A178.
Total No. of Observations:	17

UNIT:	Sdw - Depressional Lakes.
FAO/UNESCO Classification:	Pellic Vertisols.
Physiography:	Broad, flat floored depressions, inundated in all but the driest months of the year.
Extent of Occurrence:	Two well defined locations in extreme south of survey area (388 ha).
Elevation:	12.0 - 10.5 m.a.d.
Slope:	Generally flat.
Microrelief:	Gilgai not usually well developed (c.f. Sd_2, Sd_3 units), presumably because soil is not dry for long enough periods for severe cracking to occur (M1-M0).
Surface:	Grey self mulching surface with subangular blocky aggregates, common cracks.
Soil:	Grey subangular blocky/prismatic clay becoming massive from about 1 metre depth. Common soft calcium carbonate concretion throughout profile. Soil relatively moist but permanent water table not encountered within 5 metre depth.
Distinguishing Features:	Topographic position. Lack of well developed gilgai microrelief. Texture (clay throughout). Colour (chromas < 1).
Profile Drainage:	Very poor.
Natural Vegetation:	Dominantly swamp grasses, sedges.
Land Use:	Extensively cultivated as water recedes during dry seasons. Sesame, maize, cotton, sorghum observed. Also fishing.
Development Limitations:	Flood protection. Drainability. Poor physical properties of root zone.
Irrigation Suitability Class:	VI SWF
Representative Soil Pits:	C263.
Total No. of Observations:	8

UNIT:	Sf - Shabeelle Fartas.
FAO/UNESCO Classification:	Calcaric Fluvisols.
Physiography:	Old and existing flood channels (fartas).
Extent:	'Farta Tukuule' through centre of survey area and discontinuous fartas western and eastern perimeters. Total area occupied by channels is very small (259 ha).
Slope:	Side slopes may be > 10 per cent.
Microrelief:	Usually moderate-slight gilgai (M2-M1).
Surface:	Commonly grey with common cracks. Surface wash common on bordering slopes.
Soils:	Variable. Commonly clay throughout or clay over lighter textured subsoil.
Distinguishing Features:	Topographic situation.
Profile Drainage:	Imperfect - very poor.
Natural Vegetation:	Dense growth of either *A. nilotica* or non thorny thicket.
Land Use:	Commonly planted with sesame (effective flood irrigation).
Development Limitations:	Topography, Soil physical properties, drainage, flood hazard.
Irrigation Land Class:	IV T swf
Total No. of Observations:	9

UNIT:	Sot_2 - Shabeelle Terrace (lower).
FAO/UNESCO Classification:	Calcaric Regosols
Physiography:	Slightly raised areas on periphery of present flood plain.
Extent of Occurrence:	Local, uncommon. (Total 514 ha)
Elevation:	17.25 - 13.0
Slope:	Normally 0.5 - 0.1 per cent
Microrelief:	Usually slight gilgai microrelief (M1).
Surface:	Pale greyish brown - brownish grey. Sometimes slightly crusted. Common termite mounds.
Soil:	Brown-greyish brown clays, often with lighter (clay loam - silty clay) surface layers. Calcium carbonate (soft and hard concretions) generally increases with depth. Soil fairly compact.
Diagnostic Features:	Topographic positions. Termite mounds.
Profile Drainage:	Poor - imperfect.
Natural Vegetation:	Mixed Acacia/non thorny shrubland.
Land Use:	Not cultivated at observed sites.
Development Limitations:	Drainability Poor physical properties of root zone, salinity
Irrigation Suitability Class:	III Wsx (Class II for rice).
Total No. of Observations:	14

UNIT:	Som - Shabeelle Meander Complex.
FAO/UNESCO Classification:	Calcaric Regosols.
Physiography:	Raised, very slightly undulating plain dissected by shallow channels $<$ 1m deep. A fossil rather than an active feature.
Extent of Occurrence:	Well defined area in extreme south of survey area (417 ha).
Elevation:	14.25-12.25 m.a.d.
Slope:	Normally c. 0.5 per cent
Microrelief:	Slightly uneven mainly due to erosion and surface wash.
Surface:	Pale greyish brown crusted surface with common sandy wash.
Soil:	Greyish brown to olive brown fine sandy clays and sandy clay loams passing into clay at about 1m depth. Compact and poorly structured. Hard calcium carbonate nodules usually present throughout profile.
Diagnostic Features:	Air photo pattern. Texture (sandy, rather than silty clays). Colour (2.5Y hues dominant).
Profile Drainage:	Poor - imperfect.
Natural Vegetation:	Dense shrubland and thicket with both Acacia and non thorny species. *Acacia zanzibarica* common. Few *Hyphaenae* palms.
Land Use:	Uncultivated.
Development Limitations:	Poor physical properties of root zone, permeability, topography, erosion risk.
Irrigation Suitability Class:	IV Swte
Representative Profile Pits:	C286
Total No. of Observations:	15

UNIT:	Sox - Shabeelle Old Oxbow Lakes.
FAO/UNESCO Classification:	Pellic vertisols.
Physiography:	'Oxbow' shaped depression associated with old meander complex. Flooded several months per year.
Extent of Occurrence:	Single unit associated with Som unit in extreme south of survey area (232 ha).
Elevation:	11.75 - 10.75 m.a.d.
Slope:	Less than 0.5 per cent
Microrelief:	Slight gilgai (M1).
Surface:	Greyish brown-grey self mulching with subangular blocky aggregates.
Soil:	Dominantly grey clay, sandy layers at depth.
Diagnostic Features:	Air photo pattern. Physiographic position.
Profile Drainage:	Very poor.
Natural Vegetation:	Swamp grass/sedge dominant.
Land Use:	Cultivated on receding flood water. Sesame noted.
Development Limitations:	Flood hazard. Drainability. Physical properties of rooting zone.
Irrigation Suitability Class:	VI SWF
Total No. of Observations:	3

UNIT:	JSfx - Jubba Shabeelle Floodplain Complex.
FAO/UNESCO Classification:	Calcaric Fluvisols and Chromic Vertisols.
Physiography:	Gently undulating plain dissected by small channels and associated levees to give complex topography.
Extent of Occurrence:	Limited area in extreme south west of survey area (641 ha).
Elevation:	13.75 - 12.0 m.a.d.
Slope:	Less than 0.5 per cent, except adjacent to flood channels.
Microrelief:	Usually well developed gilgai (M2) except in levee areas.
Surface:	Brown-brownish grey self mulching with subangular blocky aggregate Common active termite mounds.
Soils:	Variable, with greyish brown clays dominant in 'cover floodplain' and depression areas and brown silty clay loams and silty clays on levees.
Diagnostic Features:	Topography
Profile Drainage:	Imperfect - poor.
Natural Vegetation:	Shrubland with relatively good grass growth and *Thespesia darlis* emergents.
Land Use:	Commonly cultivated (maize, sesame). Irrigated banana plantations on this unit outside survey area.
Development Limitations:	Topography. Flood hazard. Drainability, Soil Physical Properties.
Irrigation Land Class:	IV wsft
Total No. of Observations:	12

UNIT:	SMP - Shabeelle Alluvium over Marine Plain Clays.
FAO/UNESCO Classification:	Chromic Vertisols.
Physiography:	Sloping areas at Marine Plain/Shabeelle floodplain interface.
Extent of Occurrence:	Local discontinuous thin strips along edge of survey area (100 ha).
Elevation:	19.0 - 16.0 m.a.d.
Slope:	Generally about 1 per cent
Microrelief:	Usually slight gilgai (M1).
Surface:	Dominantly brownish grey self mulching with common cracks and 'sink holes'.
Soil:	Brownish grey clay, passing into brownish grey marine clay with many crystalline calcium carbonates within 150cm depth.
Diagnostic Features:	Marine clay subsoil (with 2.5Y hue and many crystalline calcium carbonates).
Profile Drainage:	Poor.
Natural Vegetation:	*Acacia nilotica* thicket usually dominant.
Land Use:	Normally uncultivated.
Development Limitations:	Topography (slope). Drainability. Poor physical properties of root zone. Salinity and sodicity of subsoil.
Irrigation Land Class:	IV Wstx
Total No. of Observations:	5

Peripheral Mapping Units

The Marine Plain and Beach Remnant soils (units MP, Mpd, BR, BM) which occur adjacent to the Shabeelle floodplain and form the boundary of the present survey area are described in some detail in the Reconnaissance Report (HTS, 1978). For completeness, the dominant soil features of all the soil units fringing the present survey area are summarised below:

Marine Plain (MP) soils consist of a thin clay loam - clay surface overlying a very coarse prismatic subsurface horizon and passing into massive/wedge structured grey brown - olive subsoil at about 120cm. Cracks commonly extend to more than 1m depth. Calcium carbonate and gypsum are usually present below 30cm. Subsoil is saline and sodic, permeability is extremely low and drainage is poor.

Marine Plain depression (MPd) soils are similar to MP soils but are generally greyer and sometimes heavier textured. Gilgai microrelief is prominant at surface.

Beach Remnant (BR) soils consist of reddish brown sandy loams and sandy clay loams overlying highly calcareious (nodular) sandy clay at c. 175cm depth.

Beach Remnant/Marine Plain transitional (BM) soils are dominantly brown sandy clay loams or heavy sandy loams overlying compact sandy clay at 30-50cm depth.

Coastal Ridge (CR) soils consist dominantly of reddish brown loamy fine sands and light sandy loams extending to at least 2m depth. In addition to coarse textures and resulting poor available water capacity, steep slopes and irregular topography make the Coastal Ridge area totally unsuitable for development of irrigated cropping.

UNIT:	Sot_1 Shabeelle Terrace (Higher)
FAO/UNESCO Classification:	Calcaric Regosols.
Physiography:	Raised area in Shabeelle Floodplain.
Extent:	Very limited - in SW of survey area (139 ha).
Elevation:	16.5 - 14.25 m.a.d.
Slope:	Average 2 - 3 per cent Maximum 5 per cent.
Microrelief:	Slightly uneven due to erosion.
Surface:	Pale brown - greyish brown. Some crusting. Common surface wash.
Soils:	Silt loams - clays overlying layers of calcareous nodules at c100 cm depth.
Distinguishing:	Topographic Situation.
Features:	Calcareous nodules dominant in subsoil.
Profile Drainage:	Imperfect.
Natural Vegetation:	Dominantly non thorny shrubland/thicket.
Land Use:	None
Development:	Topography, effective soil volume
Limitations:	Erosion Risk, Salinity.
Irrigation Land Class:	VI STex.
Pits:	C237

Total Number of Observations: 5

C

Soil Profile Pit Descriptions and Laboratory Analysis

Soil Profile Pits

Soil Mapping Unit	Described, Sampled and Analysed	Described Only
Sl_1	A301	C287
Sl_2	C239	A302
Sb_1	A364 C038	C035
Sb_2	A379	A337
Sb_{2s}	A300	A416 C179
Sd_1	A377 C009	C288
Sd_2	C238	A299 A378
Sd_3	C178	-
Sdw	C263	-
Sot_1	-	C237
Som	-	C286
Complex Sl/Sd1	-	C240

Descriptions and Analytical Data for Soil Profile Pits A058 (Sb2) and B035 (Sl2) are given in the Reconnaissance Report.

Gilgai Microrelief Classes

Mo	No perceptable	Gilgai
M1	Gilgai present	Amplitude 10-25 cm
M2	Gilgai present	Amplitude 25-50 cm
M3	Gilgai present	Amplitude more than 50 cm

Profile No:	A301	Date: 10.2.1979
Soil Unit:	Sl_1	FAO/UNESCO Classification: Calcaric Fluvisol Irrigated Land Class: III tex
Location:	On Trace Line 9, 1.5 km from western end.	
Topography:	Crest of levee alongside Farta Tukuule. Slope 1%.	
Microrelief:	Even (MO)	
Surface Features:	Grey brown, dry and hard with slight crusting and surface wash; scatter shell fragments.	
Profile Drainage:	Imperfect.	
Vegetation and Land Use:	Dense shrubland dominated by non thorny species, including *Balanites* Land Use Class: U	

Depth (cm)	Horizon Description
0-10	Dark brown (10YR3/3) silty clay loam with moderate medium subangular blocky structure; slightly moist, firm; low organic matter; common fine vertical and horizontal cracks; common fine-coarse pores; common fine-medium roots; common fine shell fragments. Clear smooth boundary to:
10-25	Dark yellowish brown (10YR4/4) heavy silty clay loam with few medium faint yellowish brown mottles and moderate medium subangular blocky structure; slightly moist, firm; common fine vertical cracks; common fine-medium pores; common fine-medium roots; few small calcium carbonate concretions; strong reaction to HCl. Gradual smooth boundary to:
75 - 160	Dark yellowish brown (10YR4/4) light silty clay with a compound structure of moderate medium-coarse prismatic breaking into weak-moderate medium angular blocky; slightly moist, firm; many fine vertical cracks; common fine-medium tubular pores; common very fine cutans common fine-coarse roots; few ant chambers (5 cm diameter); many soft amorphorus calcium carbonate concretions; few shell fragments, strong reaction to HCl. Gradual smooth boundary to:
75 - 160	Dark yellowish brown (10YR4/4) light silty clay with common fine faint pale grey and few medium distinct strong brown mottles; weak medium subangular blocky structure; slightly moist, firm; few fine vertical cracks; common fine-medium tubular pores; few fine roots; common small cutans; common powdery calcium carbonate concretions; strong reaction to HCl. Clear wavy boundary to:
160 - 200	Brown (10YR5/3) gravelly silty clay with common medium distinct strong brown and common fine faint pale grey mottles; weak medium angular blocky structure; slightly moist, firm; few fine pores; few fine roots; common (c30%) semi hard ferromanganese coated calcium carbonate concretions; strong reaction to HCl.

Profile Pit No. A301

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-10	1	40	39	20	L
P2	10-25	3	54	21	22	FSCL
P3	25-75	2	25	46	27	L
P4	75-160	3	26	53	18	SiL
P5	160-200	1	23	43	33	CL

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	15	0.04	7.8	1.6	17.9	3.9	0.4	2.2	24.4*	23.1
P2	18	0.04	7.9	1.5	10.3	2.6	0.7	1.2	14.8	20.4
P3	25	0.17	7.6	3.6	17.8	4.8	0.6	1.0	24.2	24.1
P4	36	1.31	7.9	4.2	33.8*	1.3	0.0	0.9	36.0*	16.5
P5	27	1.36	7.9	5.2	16.6	5.1	0.5	1.4	23.6	23.8

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	2	7.9	2.2	3.8	1.2	2.6	13.3	4.0	1.4	1.7	-
P2	3	10.4	2.6	3.5	0.9	3.8	11.5	3.0	1.1	1.4	73
P3	2	35.0	11.4	9.1	1.0	9.6	33.3	2.5	1.8	1.9	100
P4	0	18.8	10.8	10.0	0.9	6.4	45.8	2.5	2.0	2.6	-
P5	2	20.0	16.5	19.8	2.0	7.0	64.2	3.5	4.3	4.6	99

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-10	95.0	0.12	1.4	12	2.8
P2	10-25	79.8	0.07	0.8	11	2.5

* Disregard due to breakdown of Calcium Carbonate.

Profile No:	C239	Date: 16.2.1979
Soil Unit:	Sl_2	FAO/UNESCO Classification: Calcaric Fluvisol Irrigated Land Class: III wtx

Location: On Trace line 15

Topography: Low levee of Farta Tukuule Channel. Slope c1% towards channel.

Microrelief: Even, MO.

Surface Features: Dry and fairly hard, yellowish brown with common irregular cracks.

Profile Drainage: Imperfect

Vegetation and Land Use: Bare ground, adjacent to sorghum plot. Land Use Class: F1.

Depth (cm)	Horizon Description
0 - 20	Dark brown (10YR3/3) heavy silty clay loam with moderate medium subangular blocky structure, dry, slightly hard; low organic matter; common fine vertical and few fine horizontal cracks; common fine inped and interstitial pores; common fine roots; common very fine calcium carbonate concretions; strong reaction to hydrochloric acid. Clear wavy boundary to:
20 - 50	Brown (10YR4/3) silty clay with moderate medium subangular blocky structure with some weak coarse prismatic aggregates; slightly moist, firm; common fine vertical and few fine horizontal cracks; few fine inped and interstitial pores; common fine roots; common very fine calcium carbonate concretions; strong reaction to hydrochloric acid. Gradual smooth boundary to:
50 - 85	Brown (10YR4/3) clay with moderate medium platy structure; slightly moist, very firm; common fine vertical and horizontal cracks; rare very fine pores; few fine roots; few weak slickensides, patchy cutans; common very fine calcium carbonate concretions. Strong reaction to hydrochloric acid. Gradual smooth boundary to:
85 - 110	Brown (10YR4/3) light clay with moderate medium subangular blocky structure; moist, very firm; few fine vertical cracks; few fine pores; few fine roots; few weak slickensides, patchy cutans; common very fine calcium carbonate concretions; strong reaction to hydrochloric acid. Gradual smooth boundary to:
110 - 200	Brown (10YR4/3) light clay with few fine faint grey mottles and weak medium subangular blocky structure; moist, extremely firm; few fine vertical cracks; few fine pores; few fine roots; many hard calcium carbonate nodules; few shell fragments. Strong reaction to hydrochloric acid.

Profile Pit No. C239

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-20	3	16	48	33	SiCL
P2	20-50	2	15	43	40	SiC(I)
P3	50-85	2	12	41	45	SiC
P4	85-110	2	15	48	35	SiCL
P5	110-200	3	14	45	38	SiCL

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	20	0.17	7.8	4.2	107.6*	2.3	1.0	2.0	112.9*	27.3
P2	22	0.11	7.7	2.8	116.2*	5.6	0.5	1.9	124.2*	28.0
P3	21	0.09	7.8	3.9	75.5*	5.7	0.1	1.2	82.5*	27.9
P4	20	0.96	7.8	0.7	39.4*	5.2	0.4	1.3	46.3*	30.4
P5	19	1.12	7.7	5.7	27.5*	7.1	0.0	1.2	35.8*	27.9

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	4	31.2	9.9	5.8	2.2	13.4	32.1	3.5	3.9	0.8	-
P2	2	22.5	5.0	3.2	1.3	7.7	19.5	2.5	3.9	0.9	-
P3	0	27.5	13.0	7.2	0.9	17.9	27.5	2.5	2.5	1.6	-
P4	1	44.4	33.8	23.8	1.2	41.4	40.8	3.0	4.6	3.8	-
P5	0	37.5	32.0	21.2	1.0	40.8	25.0	2.0	5.0	3.6	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-20	90.4	0.11	1.0	9	1.8
P2	20-50	86.4	0.09	0.9	10	1.4

* Disregard - Due to breakdown of Calcium Carbonate.

Profile No:	A364	Date: 21.2.1979
Soil Unit:	Sb_1	FAO/UNESCO Classification: Calcaric Fluvisol Irrigated Land Class: II w
Location:	Line 17Y, 1.6 km east of trace line.	
Topography:	Flat cover floodplain	
Microrelief:	Slight gilgai (M1)	
Surface Features:	Brown, slight crusting. Common discontinuous cracks.	
Profile Drainage:	Imperfect - Poor	
Vegetation and Land Use:	Cropped with sorghum. Poor and patchy crop. Land Use Class: C	

Depth (cm)	Horizon Description
0 - 10	Brown (10YR4/3) silty clay with moderate medium-coarse subangular blocky structure; slightly moist, firm; low organic matter; common fine vertical cracks; common fine tubular pores; common fine roots; common shell fragments; clear smooth boundary to:
10 - 45	Brown (10YR4/3) clay with moderate coarse angular blocky structure tending to moderate medium platy; slightly moist, very firm; common fine vertical and horizontal cracks; common fine pores; common small slickensides; common shell fragments. Clear smooth boundary to:
45 - 90	Brown (10YR4/3) clay with common medium faint brownish grey mottles and a compound structure of strong coarse angular blocky breaking into moderate medium angular blocky; slightly moist, extremely firm, common fine-medium vertical and horizontal cracks; few fine pores; few fine roots; common small slickensides; few soft calcium carbonate concretions; few shell fragments. Diffuse boundary to:
90 - 145	Brown (10YR4/3) clay with many medium distinct grey and few medium distinct strong brown mottles; moderate coarse angular blocky structure with some wedge shaped aggregates; moist, very firm; common fine vertical and horizontal cracks; few fine pores; many well developed slickensides; few soft calcium carbonate concretions; few ferromanganese coated calcium carbonate nodules; few shell fragments. Gradual smooth boundary to:
145 - 190	Dark greenish grey (5BG4/1) clay with many medium distinct brown mottles and very weak coarse subangular blocky structure; moist, very firm; few fine vertical cracks; rare fine pores; common pockets crystalline calcium carbonate; common shell fragments.

Profile Pit No. A364

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-10	1	18	39	42	C(I)
P2	10-45	1	18	32	49	C
P3	45-90	1	18	19	62	C
P4	90-145	1	15	22	62	C
P5	145-190	2	24	17	57	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	23	0	8.1	1.1	24.8	8.5	0.5	1.5	35.3*	31.5
P2	18	0	8.2	0.8	7.2	4.1	0.4	0.8	12.5	30.7
P3	23	0.01	8.2	0.8	12.4	6.5	1.9	1.0	21.8	30.6
P4	21	0	8.0	1.8	17.4	10.2	1.4	1.0	30.0	33.0
P5	21	1.05	7.8	5.5	10.6	5.4	0.9	1.3	18.2	32.3

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	2	6.5	2.2	3.2	0.2	6.4	3.7	3.5	1.1	1.5	-
P2	1	3.0	1.0	4.3	0.1	5.1	2.4	3.5	1.1	3.0	41
P3	6	0.8	0.4	3.0	0.1	3.8	1.4	3.1	1.6	3.9	71
P4	4	5.0	2.6	15.4	0.1	5.8	11.7	4.0	1.8	7.9	91
P5	3	26.2	19.0	34.6	0.3	11.5	62.9	2.5	2.3	7.2	56

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-10	73.6	0.07	0.8	11	1.6
P2	10-45	72.6	0.06	0.7	12	1.4

* Disregard, due to breakdown of Calcium or Magnesium Carbonate.

Profile No:	C038	Date: 24.1.1979
Soil Unit:	Sb_1	FAO/UNESCO Classification: Calcaric Fluvisol Irrigated Land Class: II w

Location: *On Trace line 22, 2.05 km from western end.*

Topography: Almost flat site on cover floodplain near levee boundary.

Microrelief: Even, MO.

Surface Features: Grey brown, dry and hard with slight crusting, breaking into subangular blocky/granular aggregates. Few irregular cracks.

Profile Drainage: Imperfect.

Vegetation and Land Use: Cropped with Sorghum. Rather patchy growth. Land Use Class: C.

Depth (cm)	Horizon Description
0 - 25	Brown (10YR4/3) silty clay loam with strong fine subangular blocky structure, tending to platy, dry, slightly hard; common medium vertical and many fine horizontal cracks; few fine inped pores; common fine roots; common very fine soft calcium carbonate concretions. Gradual smooth boundary to:
25 - 50	Dark greyish brown (10YR4/2) clay with moderate medium subangular blocky structure, breaking into slightly platy aggregates; dry slightly hard; common medium vertical and few fine horizontal cracks; few fine inped pores; few fine roots; few patches soft calcium carbonate; few fine shell fragments. Gradual smooth boundary to:
50 - 110	Brown (10YR4/3) clay with strong coarse prismatic structure breaking into moderate medium subangular blocky aggregates; moist, extremely firm; common medium vertical and few fine horizontal cracks; few fine inped pores; few fine roots; common weak slickensides; many very fine soft calcium carbonate; few medium calcium carbonate concretions; strong reaction with HCl. Gradual smooth boundary to:
110 - 180	Brown (10YR4/3) clay with weak medium subangular blocky structure; moist, extremely firm; few medium vertical cracks; few fine pores; few fine roots; evidence of termite activity at base of horizon; few large and many very fine calcium carbonate concretions; strong reaction with HCl. Gradual smooth boundary to:
180 - 200	Brown (10YR4/3) silty clay with few fine faint dark brown mottles and moderate medium-fine subangular blocky structure; moist; extremely firm; few fine pores; many very fine ferromanganese coated calcium carbonate concretions; strong reaction with hydrochloric acid.

Profile Pit No. C038

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-25	3	13	42	42	SiC
P2	25-50	3	18	27	52	C
P3	50-110	2	14	42	42	SiC
P4	110-180	3	23	43	31	CL
P5	180-200	2	17	41	40	SiC

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	24	0.04	7.8	2.2	20.8	9.0	0.5	1.6	31.9*	29.8
P2	22	0.17	7.7	4.7	10.6	5.4	0.0	0.8	16.8	29.8
P3	22	1.09	7.9	8.3	33.1*	7.2	0.0	0.8	41.1*	31.0
P4	24	0.88	8.0	10.2	50.7*	13.2	4.0	1.1	69.0*	27.8
P5	23	1.05	7.8	5.1	28.7*	7.8	1.2	1.7	39.4*	13.3

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	2	12.8	6.0	5.8	0.4	7.7	15.3	2.5	1.5	1.9	-
P2	0	17.5	10.9	11.8	0.4	16.6	40.8	2.5	2.4	3.1	56
P3	0	31.2	36.5	48.5	0.4	39.2	83.3	2.0	3.1	8.3	-
P4	13	18.9	21.5	30.5	0.5	62.0	76.7	3.0	7.2	6.8	-
P5	9	20.0	14.9	18.5	0.8	16.6	62.9	3.0	7.4	4.4	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-25	77.8	0.07	0.7	10	1.3
P2	25-50	69.6	0.07	0.6	9	0.8

* Due to breakdown Calcium Carbonate - Disregard.

Profile No:	A379	Date: 27.2.1979
Soil Unit:	Sb′ 2	FAO/UNESCO Classification: Chromic Vertisol Irrigated Land Class: II sw
Location:	Intersection of trace line No. 26 and the western base line.	
Topography:	Flat cover floodplain	
Microrelief:	Slight gilgai M1	
Surface Features:	Grey brown, dry and hard, slightly self mulching.	
Profile Drainage:	Poor	
Vegetation and Land Use:	Mixed shrubland, including *Acacia nilotica*, *Thespesia* spp. Land Use Class: U	

Depth (cm)	**Horizon Description**
0 - 6	Dark brown (10YR3/3) silty clay with moderate medium prismatic tending to subangular blocky structure; dry, slightly hard, low organic matter; common fine vertical cracks; common fine-medium pores; common fine and medium roots; few fine amorphous calcium carbonate; common shell fragments; clear smooth boundary to:
6 - 20	Dark greyish brown (10YR4/2.5) clay with moderate medium-coarse prismatic structure breaking into moderate coarse subangular blocky aggregates; slightly moist; very firm; common fine-medium vertical and few fine horizontal cracks; common fine-medium pores; common fine and medium roots; common very fine calcium carbonate nodules; common shell fragments. Clear smooth boundary to:
20 - 80	Dark greyish brown (10YR4/2) clay with strong coarse prismatic structure, breaking to moderate medium-coarse wedge aggregates; slightly moist, very firm; common fine-medium vertical and common fine horizontal cracks; few fine pores; common fine-medium roots; many well developed slickensides; common fine calcium carbonate nodules; few fine amorphous calcium carbonate; common shell fragments. Gradual smooth boundary to:
80 - 115	Brown (10YR4/3) clay with weak coarse subangular blocky structure; moist, very firm; few fine vertical cracks; few fine pores; few fine roots; common small slickensides; common fine medium carbonate nodules (some ferromanganese coated); common shell fragments; some termite activity. Clear wavy boundary to:
115 - 170	Brown (10YR4/3) clay with weak-moderate fine angular blocky structure; moist, very firm; few very fine vertical cracks; common fine pores; few fine roots; common ferromanganese coated calcium carbonate nodules, few amorphous calcium carbonate; few gypsum crystals; few shell fragments; Gradual smooth boundary to:

170 - 200	Brown (10YR4/3) clay with few medium distinct strong brown and black manganiferrous mottles and weak-moderate fine angular blocky structure; moist, very firm; few fine pores; few fine roots.

Profile Pit No. A379

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-20	3	17	36	42	C
P2	20-80	2	23	21	53	C
P3	80-170	2	21	25	52	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	23	0.03	7.9	1.6	24.4*	12.2	0.7	1.2	38.5*	29.5
P2	19	0.02	8.0	1.7	15.2	8.1	1.3	0.6	25.2	29.9
P3	22	0.55	7.6	6.0	17.5	6.0	0.0	0.8	24.3	30.6

Chemical Analysis (contd).

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	2	6.8	3.4	4.5	0.2	9.6	5.2	2.0	0.7	2.0	-
P2	4	3.0	2.4	5.6	0.2	9.6	5.5	3.0	0.7	3.4	84
P3	0	17.5	13.2	17.5	0.3	24.3	35.0	2.5	3.0	4.5	79

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-20	71.0	0.07	0.8	11	1.3
P2	20-80	69.6	0.05	0.7	14	0.9

* Disregard due to breakdown of Calcium Carbonate.

Profile No:	A300	Date: 6.2.1979
Soil Unit:	Sb	FAO/UNESCO Classification: Chromic Vertisols Irrigated Land Class: IIsw

Location: On line 23, 1.05 km from western end.

Topography: Cover floodplain, very gentle slope (< 0.5%) to western depression.

Microrelief: Slight gilgai (M1)

Surface Features: Greyish brown self mulching breaking into granular aggregates. Common Shell fragments.

Profile Drainage: Poor

Vegetation and Land Use: Mixed shrubland edge of *A. nilotica* thicket. Uncultivated. Land Use Class U.

Depth (cm)	Horizon Description
0 - 15	Dark greyish brown (10YR4/2) silty clay with moderate medium subangular blocky structure, slightly moist, firm; low organic matter; common fine vertical cracks; common fine tubular pores; common fine-medium roots; common shell fragments; strong reaction to HCl. Gradual smooth boundary to:
15 - 90	Dark greyish brown (10YR4/2) clay with a compound structure of strong very coarse prismatic breaking into moderate medium subangular blocky; slightly moist, very firm; common fine-coarse (to 2 cm wide) vertical cracks, few fine horizontal cracks; few fine tubular pores; common fine-medium roots; few slickensides; common shell fragments; strong reaction to HCl. Diffuse boundary to:
90 - 120	Brown (10YR4/3) clay with common medium distinct dark grey mottles and a structure of strong very coarse prismatic breaking into very weak medium subangular blocky; slightly moist, extremely firm; common fine vertical cracks; few fine tubular pores; few fine-medium roots; few slickensides, common shell fragments; few soft calcium carbonate concretions; strong reaction to HCl: Gradual smooth boundary to:
120 - 153	Brown (10YR5/3) clay loam with few medium distinct dark grey mottles and very weak medium subangular blocky structure; slightly moist, very firm, no cracks; common fine tubular pores; rare fine roots; common soft calcium carbonate concretions; strong reaction to HCl. Clear wavy boundary to:
153 - 200	Light yellowish brown (10YR6/4) loamy fine sand with few clay lenses; structureless; dry, soft; porous; few soft calcium carbonate concretions; moderate reaction to HCl.

Profile Pit No. A300

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-15	4	25	28	43	C
P2	15-90	3	34	20	43	C
P3	90-120	2	30	38	30	CL
P4	120-153	1	48	31	20	FSCL
P5	153-200	1	60	21	18	FSL

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	19	0.00	7.7	1.2	20.9	4.9	0.6	1.0	27.4	30.0
P2	22	0.01	7.9	0.9	19.8	8.4	0.7	0.8	29.7*	28.4
P3	24	0.01	7.9	1.2	15.2	6.4	0.8	0.4	22.8*	22.1
P4	20	0.00	8.0	1.1	13.5	6.5	0.4	0.4	20.8*	17.9
P5	18	0.01	7.9	0.8	15.4*	5.5	0.3	0.4	21.6*	13.8

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	2	11.2	2.8	2.5	0.4	5.8	4.2	3.5	0.6	0.9	91
P2	2	5.2	2.2	2.1	0.2	6.4	1.8	3.0	0.4	0.5	-
P3	4	4.8	1.7	3.7	0.2	6.4	5.8	3.0	0.5	2.1	-
P4	2	4.0	1.9	3.6	0.2	4.1	4.5	3.5	0.6	0.9	-
P5	2	4.0	1.7	2.3	0.2	3.2	2.7	3.0	0.5	1.5	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-15	77.0	0.08	0.8	10	2.0
P2	15-90	72.6	0.05	0.6	12	0.8

* Disregard, due to breakdown of Calcium or Magnesium Carbonate.

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Bore Analysis Results

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A125/1	0-25	Sd_1	8.6	0.9	0.4	31.7	1
A125/2	25-50		8.5	1.7	0.5	32.3	2
A125/3	50-100		8.2	3.8	0.8	33.7	2
A125/4	100-150		8.1	6.5	3.0	33.2	9
A125/5	150-200		8.3	9.5	2.0	25.1	8
A126/1	0-25	Sb_1	8.4	1.3	0.3	32.5	1
A126/2	25-50		8.3	1.5	1.1	31.9	3
A126/3	50-100		8.3	2.4	0.5	30.5	2
A127/1	0-25	Sl_2	8.5	0.7	0.5	31.2	2
A127/2	25-50		8.5	0.9	0.7	29.7	2
A127/3	50-100		8.1	2.4	2.9	29.4	10
A128/1	0-25	Sl_2	8.0	3.0	0.1	30.8	0
A128/2	25-50		8.0	2.5	0.2	29.9	1
A128/3	50-100		8.1	3.4	0	29.9	0
A130/1	0-25	Sl_2	8.1	2.2	0.2	29.9	1
A130/2	25-50		8.2	1.6	0.3	28.6	1
A130/3	50-100		8.0	4.4	0.1	27.7	1
A130/5	150-200		8.5	3.5	3.1	23.9	13
A132/1	0-25	Sb_1	8.0	2.0	0.3	29.8	1
A132/3	50-100		8.0	3.4	0.8	31.8	2
A134/1	0-25	Sd_1	8.7	0.5	0.3	30.5	1
A134/2	25-50		8.7	0.9	1.0	29.5	3
A134/3	50-100		8.7	2.0	1.6	29.5	5
A136/1	0-25	Sd_1	8.6	0.5	0.4	31.9	1
A136/2	25-50		8.7	0.7	0.7	31.5	2
A136/3	50-100		8.8	1.2	0.8	30.4	3
A138/1	0-25	Sb_2	8.4	1.2	0.6	34.3	2
A138/2	25-50		8.7	1.2	0.8	33.1	3
A138/3	50-100		8.1	4.0	1.8	34.5	5
A140/1	0-25	Sb_1	8.6	1.0	0.9	32.8	3
A140/2	25-50		8.8	0.8	1.1	31.8	3
A140/3	50-100		8.7	2.5	3.4	33.3	10
A140/4	100-150		8.2	6.3	1.0	29.1	3
A140/5	150-200		8.4	7.0	3.7	30.7	12
A142/1	0-25	Sb_1	8.5	0.6	0.4	29.2	1
A142/2	25-50		8.5	1.5	1.5	27.3	5
A142/3	50-100		8.6	2.7	4.8	28.5	17
A143/1	0-25	Sb_2	8.2	3.5	0.1	27.6	1
A143/2	25-50		8.1	2.7	0.6	27.5	2
A143/3	50-100		8.8	1.8	1.3	27.2	5
A145/1	0-25	MP	8.4	4.0	4.4	33.5	13
A145/2	25-50		8.1	7.5	3.9	33.1	12
A145/3	50-100		8.5	7.5	5.8	34.4	17
A147/1	0-25	Sot_2	8.5	0.9	1.2	29.7	4
A147/2	25-50		8.5	2.4	9.9	28.3	35
A147/3	50-100		8.5	8.0	6.1	26.7	22
A149/1	0-25	Sd_3	8.5	0.8	0.4	27.1	1
A149/2	25-50		8.6	0.7	0.4	31.2	1
A149/3	50-100		8.9	0.7	0.9	23.8	4

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A150/1	0-25	MP	8.7	1.2	1.3	32.5	4
A150/2	25-50		9.1	3.0	6.4	28.8	22
A150/3	50-100		9.1	11.1	0	28.8	0
A152/1	0-25	Sf	8.3	0.9	0.2	30.8	1
A152/2	25-50		8.2	2.6	0.4	29.6	1
A152/3	50-100		8.0	3.4	0.5	29.9	2
A154/1	0-25	$Sl_{1,2}$	8.3	1.9	0.2	29.8	1
A154/2	25-50		8.2	3.3	0.5	28.0	2
A154/3	50-100		8.2	7.0	1.7	26.1	6
A154/4	100-150		8.2	10.0	1.9	16.1	12
A154/5	150-200		8.3	12.5	4.9	24.9	19
A156/1	0-25	Sb_{1s}	8.6	1.0	0.3	27.3	1
A156/2	25-50		8.4	1.4	0.4	24.0	2
A156/3	50-100		8.3	3.4	0.9	26.7	3
A158/1	0-25	Sl_2	8.4	1.0	0.4	32.9	1
A158/2	25-50		8.5	1.1	0.7	31.2	2
A158/3	50-100		8.4	4.0	0.8	30.3	3
A160/1	0-25	Sb_2	8.5	1.6	0.8	28.9	3
A160/2	25-50		8.6	0.6	1.0	30.0	3
A160/3	50-100		8.6	1.3	1.6	30.7	5
A162/1	0-25	Sd_3	8.3	0.7	0.2	36.4	1
A162/2	25-50		8.3	0.6	0.5	34.3	1
A162/3	50-100		8.2	3.2	0.8	34.7	2
A162/4	100-150		8.0	4.5	1.3	30.9	4
A162/5	150-200		8.1	6.9	0.7	29.4	2
A164/1	0-25	Sd_3	8.2	0.5	0.3	33.9	1
A164/2	25-50		8.5	0.8	0.6	33.7	2
A164/3	50-100		8.6	1.5	1.3	33.8	4
A166/1	0-25	Sb_2	8.5	1.4	0.3	36.8	1
A166/2	25-50		8.6	1.2	0.9	34.0	3
A166/3	50-100		8.1	3.6	0.4	36.5	1
A168/1	0-25	Sb_1	8.1	2.0	0.7	31.8	2
A168/2	25-50		8.1	4.2	1.2	29.2	4
A168/3	50-100		8.2	6.1	2.3	29.4	8
A170/1	0-25	Sb_1	7.8	2.7	0.2	31.3	1
A170/2	25-50		7.8	3.0	0.3	33.8	1
A170/3	50-100		8.0	3.0	0.7	30.9	2
A170/4	100-150		8.1	5.0	4.5	30.3	15
A170/5	150-200		8.0	8.0	4.1	32.5	13
A172/1	0-25	Sb_1	7.9	3.2	0.3	29.5	1
A172/2	25-50		7.9	3.4	0.6	28.0	2
A172/3	50-100		8.1	4.9	1.5	29.1	5
A174/1	0-25	Sb_{1s}	8.8	0.8	0.9	27.4	3
A174/2	25-50		8.9	0.7	1.5	31.2	5
A174/3	50-100		8.7	1.5	2.7	28.7	10
A176/1	0-25	Sb_{1s}	8.2	2.2	0.8	35.2	2
A176/2	25-50		8.3	1.6	0	34.8	0
A176/3	50-100		8.5	3.2	0.6	37.1	2
A178/1	0-25	Sb_1	8.1	1.0	0.7	28.3	3

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A178/2	25-50		8.4	1.5	0.9	28.6	3
A178/3	50-100		8.4	2.4	1.1	27.2	4
A180/1	0-25	Sl_{2s}	8.6	2.6	0.6	27.8	2
A180/2	25-50		8.5	1.5	1.1	27.1	4
A180/3	50-100		8.4	3.8	2.8	26.7	11
A180/4	100-150		8.2	6.9	4.0	28.4	14
A180/5	150-200		8.3	9.1	2.6	29.8	9
A182/1	0-25	Sb_{1s}	8.4	1.4	0.6	27.5	2
A182/2	25-50		8.7	1.0	1.1	27.1	4
A182/3	50-100		9.1	1.7	0	26.0	0
A184/1	0-25	Sl_{2s}	7.9	1.6	2.5	30.7	8
A184/2	25-50		8.3	1.0	0.5	28.5	2
A184/3	50-100		8.3	1.1	0.5	28.7	2
A186/1	0-25	Sf	8.2	1.3	0.1	26.1	0
A186/2	25-50		8.2	1.2	0.2	24.8	1
A186/3	50-100		8.4	0.7	0.1	18.2	1
A188/1	0-25	BM	8.5	0.6	0.1	21.8	1
A188/2	25-50		8.5	0.6	0.3	24.4	1
A188/3	50-100		8.5	1.5	1.0	25.9	4
A190/1	0-25	Sd_1	8.4	0.6	0.2	21.7	1
A190/2	25-50		8.5	0.6	0.4	21.5	2
A190/3	50-100		8.6	0.7	0.7	24.1	3
A190/4	100-150		8.7	1.0	1.8	26.1	7
A190/5	150-200		8.4	1.5	2.5	26.0	10
A192/1	0-25	MP	8.6	0.4	0.5	32.3	2
A192/2	25-50		8.8	0.5	1.7	33.0	5
A192/3	50-100		8.2	1.7	2.9	33.6	9
A194/1	0-25	BM	8.5	1.3	0.1	18.8	1
A194/2	25-50		8.3	0.9	0.2	21.7	1
A194/3	50-100		8.6	0.5	0.3	20.4	2
A198/1	0-25	Sd_2	8.3	0.6	0.5	34.1	2
A198/2	25-50		8.6	2.8	0.8	32.7	3
A198/3	50-100		8.6	0.8	1.7	30.3	6
A200/1	0-25	Sb_1	8.2	0.7	0.2	32.7	1
A200/2	25-50		8.3	0.8	0.4	30.0	2
A200/3	50-100		8.5	0.6	0.5	29.4	2
A200/4	100-150		8.3	4.3	2.5	32.5	8
A200/5	150-200		8.1	3.0	1.5	31.5	5
A202/1	0-25	Sb_1	8.0	1.5	0.2	31.5	1
A202/2	25-50		7.9	2.4	0.2	30.4	1
A202/3	50-100		8.0	2.1	0.3	28.6	1
A204/1	0-25	Sd_1	8.4	0.8	0.3	31.4	1
A204/2	25-50		8.1	0.5	0.5	27.2	2
A204/3	50-100		8.5	0.5	0.9	31.3	3
A206/1	0-25	Sb_2	8.4	0.5	0.3	28.4	1
A206/2	25-50		8.4	0.5	0.5	29.7	2
A206/3	50-100		8.5	0.8	0.6	33.4	2
A208/1	0-25	Sb_1	8.5	0.5	0.3	28.2	1
A208/2	25-50		8.5	0.4	0.5	32.1	2
A208/3	50-100		8.5	0.9	1.1	31.5	3

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A210/1	0-25	Sb_{1s}	8.6	0.9	0.2	29.2	1
A210/2	25-50		8.6	0.6	0.3	30.6	1
A210/3	50-100		8.5	0.9	0.7	30.6	2
A210/4	100-150		8.9	0.6	1.3	29.9	4
A210/5	150-200		8.9	1.8	0.7	20.0	4
A212/1	0-25	Sb_1	8.6	0.9	0.4	32.0	1
A212/2	25-50		8.7	0.9	0.8	32.9	2
A212/3	50-100		8.2	3.4	0.5	34.4	2
A214/1	0-25	Sb_1	8.0	5.3	0.2	30.6	1
A214/2	25-50		7.9	5.8	0.3	30.4	1
A214/3	50-100		8.0	6.4	0.1	32.6	0
A216/1	0-25	Sl_2	8.3	1.4	0.2	29.6	1
A216/2	25-50		8.2	1.7	0.3	27.9	1
A216/3	50-100		8.3	2.7	1.5	27.2	6
A218/1	0-25	Sd_1	8.6	0.7	0.3	31.0	1
A218/2	25-50		8.7	0.6	0.6	31.6	2
A218/3	50-100		8.9	0.6	1.1	31.2	4
A220/1	0-25	Sb_1	8.2	2.4	0.1	28.9	0
A220/2	25-50		8.0	2.6	0.1	32.5	0
A220/3	50-100		8.1	2.9	0.2	30.9	1
A220/4	100-150		8.1	3.4	0.1	27.8	0
A220/5	150-200		8.1	3.8	0.2	29.3	1
A222/1	0-25	Sb_1	8.7	0.6	0.3	29.8	1
A222/2	25-50		8.9	0.7	0.7	30.2	2
A222/3	50-100		8.6	1.3	1.3	32.1	4
A224/1	0-25	Sl_1	8.7	0.7	0.2	24.2	1
A224/2	25-50		8.6	0.8	0.2	23.2	1
A224/3	50-100		8.9	1.0	0.9	24.6	4
A226/1	0-25	Sd_1	8.5	0.7	0.3	31.6	1
A226/2	25-50		8.7	0.7	0.5	31.2	2
A226/3	50-100		8.8	0.8	1.2	29.9	4
A228/1	0-25	MP	8.7	1.3	1.2	28.6	4
A228/2	25-50		8.7	2.5	4.6	31.6	15
A228/3	50-100		8.6	7.9	4.3	31.5	14
A229/2	25-50	Sd_1	8.5	1.4	4.0	33.5	12
A229/3	50-100		8.5	5.6	7.2	32.0	23
A232/1	0-25	MP	8.5	3.3	3.7	30.8	12
A232/2	25-50		8.8	8.8	12.1	33.2	36
A232/3	50-100		8.7	11.0	4.8	31.8	15
A234/1	0-25	Sb_1	8.7	0.7	0.4	31.0	2
A234/2	25-50		8.3	0.8	1.2	30.8	4
A234/3	50-100		8.3	4.7	0.2	32.6	0
A234/4	100-150		8.3	7.2	2.0	32.9	6
A234/5	150-200		8.1	7.9	0.8	28.5	3
A236/1	0-25	Sb_1	8.2	1.6	0.3	32.5	1
A236/2	25-50		8.0	2.8	0.6	33.3	2
A236/3	50-100		8.4	5.4	0.7	34.8	2
A238/1	0-25	Sl_1	8.6	1.1	0.1	29.2	0
A238/2	25-50		8.8	1.0	0.2	26.5	1
A238/3	50-100		8.5	1.2	0.6	23.8	3

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A240/1	0-25	Sb_2	8.7	1.5	0.5	36.7	2
A240/2	25-50		8.6	1.3	0	35.2	0
A240/3	50-100		8.6	2.8	2.0	35.0	6
A240/4	100-150		8.3	5.8	1.6	28.9	6
A240/5	150-200		8.3	6.3	1.7	24.2	7
A242/1	0-25	Sd_1	8.4	1.8	0.5	36.9	2
A242/2	25-50		8.7	0.8	0	37.1	4
A242/3	50-100		8.6	3.4	1.7	38.1	4
A244/1	0-25	Sd_1	8.6	1.4	0.3	34.7	1
A244/2	25-50		8.9	1.4	1.0	34.1	3
A244/3	50-100		8.5	3.4	1.2	36.5	3
A246/1	0-25	Sl_1	8.7	0.5	0.1	22.6	0
A246/2	25-50		8.6	0.8	0.1	21.8	0
A246/3	50-100		8.7	1.3	0.1	29.8	0
A248/1	0-25	Sd_1	8.3	1.2	0.3	35.4	1
A248/2	25-50		8.3	1.2	0.6	37.2	2
A248/3	50-100		8.2	1.9	0	36.5	0
A250/1	0-25	Sd_1	8.8	0.4	0.5	37.4	1
A250/2	25-50		8.6	0.5	1.0	37.6	3
A250/3	50-100		8.7	1.4	1.1	39.4	3
A250/4	100-150	Sd_1	8.3	3.2	0.9	38.6	2
A250/5	150-200		8.2	3.5	1.3	34.3	4
A252/1	0-25	Sb_1	8.8	1.0	0.3	31.3	1
A252/2	25-50		8.9	1.3	0.1	32.1	0
A252/3	50-100		8.5	3.3	1.8	34.9	5
A254/1	0-25	Sb_1	8.3	2.1	0.2	35.5	1
A254/2	25-50		8.2	3.6	0.9	34.2	3
A254/3	50-100		8.3	5.0	1.4	33.8	4
A256/1	0-25	Sl_2	8.3	1.7	3.3	31.9	11
A256/2	25-50		8.7	1.0	0.6	29.9	2
A256/3	50-100		8.9	1.4	0.5	28.6	2
A258/1	0-25	Sd_{1-2}	8.4	1.6	0.5	35.2	1
A258/2	25-50		8.6	1.1	0.6	33.6	2
A258/3	50-100		8.8	1.0	0.8	35.0	2
A260/1	0-25	Sb_1	8.6	0.9	0.3	37.6	1
A260/2	25-50		8.7	0.7	0.8	34.6	2
A260/3	50-100		8.8	0.8	0.6	33.7	2
A260/4	100-150		8.5	3.6	1.5	37.1	4
A260/5	150-200		8.2	5.4	0.4	37.0	1
A262/1	0-25	Sb_1	8.9	0.8	1.2	36.0	3
A262/2	25-50		8.8	2.6	3.3	36.5	9
A262/3	50-100		8.5	5.7	2.2	39.2	6
A264/1	0-25	Sl_{2s}	8.8	1.1	0.5	27.6	2
A264/2	25-50		9.1	0.8	0.2	29.5	1
A264/3	50-100		8.9	1.3	1.5	29.7	5
A266/1	0-25	Sb_1	8.7	0.7	0.5	32.3	2
A266/2	25-50		9.2	0.8	1.4	33.9	4
A266/3	50-100		8.7	2.6	3.3	32.3	10

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A268/1	0-25	Sb_1	8.5	1.0	0.4	35.4	1
A268/2	25-50		8.3	2.5	0.2	33.2	1
A268/3	50-100		8.8	1.0	1.5	33.4	4
A270/1	0-25	Sl_1	8.5	0.6	0.1	22.7	0
A270/2	25-50		8.7	0.5	0.1	22.9	1
A270/3	50-100		8.7	0.6	0.2	27.8	1
A270/4	100-150		8.8	0.5	0.2	25.7	1
A270/5	150-200		8.6	0.6	0.3	24.9	1
A272/1	0-25	Sl_1	8.6	0.8	0.3	29.6	1
A272/2	25-50		8.0	2.2	0.1	30.4	0
A272/3	50-100		8.0	2.7	0.1	28.5	0
A274/1	0-25	Sl_1	8.0	2.4	0.1	25.3	0
A274/2	25-50		8.0	2.6	0.1	24.7	0
A274/3	50-100		8.0	3.2	0.2	24.8	1
A276/1	0-25	Sb_2	8.0	2.5	0.1	27.5	0
A276/2	25-50		8.1	2.7	0	30.1	0
A276/3	50-100		8.3	4.2	1.0	30.7	3
A278/1	0-25	Sb_1	8.5	0.7	0.2	24.0	1
A278/2	25-50		8.3	1.7	0.3	25.6	1
A278/3	50-100		8.7	0.9	0.6	26.9	2
A280/1	0-25	Sd_1	8.6	0.5	0.6	19.8	3
A280/2	25-50		8.4	1.3	0.1	19.3	0
A280/3	50-100		8.7	0.6	0.1	22.8	0
A282/1	0-25	MP	8.6	0.7	0.1	19.3	0
A282/2	25-50		8.5	0.9	0.1	23.7	0
A282/3	50-100		8.3	2.5	0.1	25.5	0
A284/1	0-25	Sd_1	8.2	2.2	0.4	32.3	1
A284/2	25-50		8.3	1.8	0.5	32.5	2
A284/3	50-100		8.3	4.1	1.5	30.6	5
A284/4	100-150		8.3	4.3	1.4	31.8	5
A284/5	150-200		8.2	4.7	0.7	31.6	2
A286/1	0-25	Sd_1	8.6	0.8	0.5	34.5	1
A286/2	25-50		8.8	0.8	0.9	32.6	3
A286/3	50-100		8.3	3.8	0.4	34.9	1
A288/1	0-25	Sd_1	8.6	0.8	0.4	30.3	1
A288/2	25-50		8.7	1.3	1.1	32.8	3
A288/3	50-100		8.9	1.9	0.2	32.9	1
A290/1	0-25	Sl_{2s}	8.6	0.8	0	22.9	0
A290/2	25-50		8.6	0.8	0.3	26.2	1
A290/3	50-100		8.0	2.7	0.2	25.7	1
A290/4	100-150		8.1	2.8	0	17.5	0
A290/5	150-200		8.1	3.5	0.1	18.6	1
A292/1	0-25	Sb_1	8.7	0.6	0.3	32.1	1
A292/2	25-50		8.7	0.7	0.5	31.7	2
A292/3	50-100		8.7	1.4	0.8	32.2	2
A294/1	0-25	Sl_2	8.5	0.9	0.3	29.5	1
A294/2	25-50		8.4	1.0	0.5	30.5	2
A294/3	50-100		8.2	3.3	0.7	32.1	2
A296/1	0-25	Sb_1	8.5	0.9	0.4	31.3	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A296/2	25-50		8.7	0.9	0.7	30.2	2
A296/3	50-100		8.5	1.6	0.2	33.2	1
A298/1	0-25	Sb_1	8.5	0.8	0.3	22.2	1
A298/2	25-50		8.7	1.6	0.6	32.4	2
A298/3	50-100		8.4	1.9	1.4	33.8	4
A304/1	0-25	Sb_1	8.6	1.2	0.5	29.0	2
A304/2	25-50		8.7	1.8	0.9	28.5	3
A304/3	50-100.		8.3	6.0	1.2	31.8	4
A306/1	0-25	Sb_2	8.5	1.3	0.3	32.5	1
A306/2	25-50		8.6	1.4	0.6	31.1	2
A306/3	50-100		8.5	4.7	2.1	32.5	7
A308/1	0-25	Sb_2	8.5	1.5	0.4	38.8	1
A308/2	25-50		8.6	1.3	0.7	39.0	2
A308/3	50-100		8.8	2.4	4.1	35.1	12
A310/1	0-25	Sd_2	8.6	1.2	0.4	31.5	1
A310/2	25-50		8.2	6.0	1.7	29.5	6
A310/3	50-100		8.8	1.5	1.1	30.0	4
A310/4	100-150		8.6	3.7	2.3	31.9	7
A312/1	0-25	Sb_{2s}	8.9	8.1	0.9	34.6	2
A312/2	25-50		9.2	1.8	2.9	33.6	9
A312/3	50-100		8.9	3.5	4.4	34.3	13
A314/1	0-25	Sb_{2s}	8.8	0.8	0.3	30.6	1
A314/2	25-50		8.8	1.2	0.7	29.0	3
A314/3	50-100		8.5	4.2	0.3	29.9	1
A316/1	0-25	Sl_{2s}	8.5	0.7	0.2	28.2	1
A316/2	25-50		8.6	1.6	0.4	30.0	2
A316/3	50-100		8.9	0.8	0.7	29.7	2
A318/1	0-25	Sd_3	8.5	1.1	0.3	28.3	1
A318/2	25-50		8.6	0.9	0.3	32.2	1
A318/3	50-100		8.6	0.9	0.4	27.7	1
A318/4	100-150		8.1	2.6	0.2	29.8	1
A318/5	150-200		9.1	3.0	0.3	25.3	1
A320/1	0-25	Sd_3	8.3	0.9	0.2	33.9	1
A320/2	25-50		8.7	0.6	0.4	33.0	1
A320/3	50-100		8.6	0.9	0.6	33.1	2
A322/1	0-25	Sd_3	8.1	1.3	0.2	35.6	1
A322/2	25-50		8.6	1.0	0.6	32.8	2
A322/3	50-100		8.4	0.9	0.3	33.1	1
A324/1	0-25	CR	8.3	1.8	0.1	8.1	1
A324/2	25-50		8.2	3.7	0.1	7.7	1
A324/3	50-100		8.1	4.6	0.1	6.7	1
A326/1	0-25	Sl_{1-2}	8.5	0.9	0.1	24.8	0
A326/2	25-50		8.4	1.8	0.1	23.8	1
A326/3	50-100		8.5	2.2	0.4	25.8	2
A328/1	0-25	Sl_2	8.4	1.2	0.1	30.5	0
A328/2	25-50		8.6	0.9	0.1	29.2	0
A328/3	50-100		8.2	1.9	0.2	30.2	1
A330/1	0-25	Sd_{1s}	8.3	1.3	0.2	31.1	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A330/2	25-50		8.5	0.8	0.2	29.6	1
A330/3	50-100		8.6	0.4	0.4	30.0	1
A330/4	100-150		8.6	1.6	0.6	30.8	2
A330/5	150-200		8.8	1.3	0.7	24.3	3
A332/1	0-25	Sd2	8.2	1.1	0.3	39.2	1
A332/2	25-50		8.8	1.5	1.8	35.8	5
A332/3	50-100		8.7	1.4	2.9	36.2	8
A334/1	0-25	Sd_{2g}	7.8	2.7	0.2	40.2	1
A334/2	25-50		8.3	1.1	0.3	35.0	1
A334/3	50-100		8.3	1.1	0.4	35.2	1
A336/1	0-25	Sd_{2-3}	8.3	0.5	0.5	37.7	1
A336/2	25-50		8.3	0.9	0.4	37.3	1
A336/3	50-100		8.6	1.2	1.2	36. 2	3
A338/1	0-25	Sd_1	8.6	0.6	0.4	29.2	1
A338/2	25-50		8.7	0.9	0.6	31.0	2
A338/3	50-100		8.6	0.9	0.7	31.4	2
A340/1	0-25	Sd_{2g}	8.5	0.9	0.7	31.3	2
A340/2	25-50		8.7	1.1	0.9	31.9	3
A340/3	50-100		8.8	1.0	1.2	30.2	4
A340/4	100-150		8.8	1.4	2.2	32.6	7
A340/5	150-200		8.4	5.2	1.3	31.4	4
A342/1	0-25	Sb_2	8.8	0.7	0.7	33.8	2
A342/2	25-50		8.9	0.7	1.0	33.6	3
A344/1	0-25	Sb_2	8.7	0.5	0.4	30.5	1
A344/2	25-50		8.8	0.7	0.8	29.9	3
A344/3	50-100		8.9	0.8	1.7	32.9	5
A346/1	0-25	Sb_{2s}	8.4	1.0	0.2	32.9	1
A346/2	25-50		8.6	1.7	0.5	29.4	2
A346/3	50-100		-	3.1	2.1	31.3	7
A352/1	0-25	Sd_1	8.4	0.8	1.2	34.9	3
A352/2	25-50		8.3	0.9	0.5	36.1	1
A352/3	50-100		8.5	2.4	1.5	37.7	4
A354/1	0-25	Sm	8.4	0.8	0.1	17.0	1
A354/2	25-50		8.4	0.6	0.1	22.7	0
A354/3	50-100		8.6	0.5	0.4	23.6	2
A356/1	0-25	St_2	8.4	1.1	0.2	22.9	1
A356/2	25-50		8.7	1.5	0.6	23.3	3
A356/3	50-100		8.6	5.8	1.7	27.4	6
A358/1	0-25	Sm	8.4	1.6	0.3	17.5	2
A358/2	25-50		8.6	1.3	0.6	17.4	3
A358/3	50-100		8.6	3.0	1.0	18.4	5
A360/1	0-25	Sm	8.6	1.4	0.2	17.3	1
A360/2	25-50		8.5	1.7	0.5	15.8	3
A360/3	50-100		9.2	0.9	1.1	16.9	7
A360/4	100-150		9.0	1.8	1.5	18.1	8
A360/5	150-200		8.8	4.0	3.4	21.8	16

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A362/1	0-25	Sm	8.3	0.7	0	12.3	0
A362/2	25-50		8.5	0.7	0.1	10.7	0
A362/3	50-100		8.6	1.1	0.1	10.8	0
A366/1	0-25	Sb_{1-2}	8.4	1.0	0.7	34.3	2
A366/2	25-50		8.7	1.2	1.2	33.7	4
A366/3	50-100		8.5	2.6	1.6	35.3	4
A368/1	0-25	Sb_{2s}	8.5	1.0	0.4	32.8	1
A368/2	25-50		8.5	0.9	0.7	30.4	2
A368/3	50-100		8.5	7.7	0.7	29.9	2
A370/1	0-25	Sb_2/Sd_1	8.3	1.3	0.5	38.3	1
A370/2	25-50		8.5	0.9	0.7	33.8	2
A370/3	50-100		8.5	1.3	1.2	33.6	3
A370/4	100-150		8.3	4.2	0.6	31.9	2
A370/5	150-200		8.3	5.2	1.9	29.5	6
A372/1	0-25	Sb_2/Sd_1	8.1	1.8	0.4	39.9	1
A372/2	25-50		8.2	1.9	0.4	36.9	1
A372/3	50-100		8.3	3.6	1.1	31.2	3
A374/1	0-25	Sd_1	8.1	4.0	0.5	33.4	2
A374/2	25-50		8.1	4.1	0.6	31.5	2
A374/3	50-100		8.2	4.8	1.2	32.7	4
A376/1	0-25	Sd_1	8.3	1.1	0.2	34.7	0
A376/2	25-50		8.6	0.6	0.5	32.0	2
A376/3	50-100		8.6	0.5	0.4	31.8	1
A380/1	0-25	Jsfx	8.4	0.7	0.2	37.5	1
A380/2	25-50		8.4	0.6	0.4	36.6	1
A383/1	0-25	Jsfx	8.3	0.7	0.2	35.1	1
A383/2	25-50		8.4	0.9	0.3	31.6	1
A383/3	50-100		8.4	0.8	0.5	29.4	2
A383/4	100-150		8.2	2.7	0.6	32.5	2
A383/5	150-200		8.0	4.1	0.8	32.3	2
A385/1	0-25	Sd_1	8.2	1.9	0.2	35.0	1
A385/2	25-50		8.7	0.6	0.9	32.8	2
A385/3	50-100		8.9	0.8	2.1	34.2	6
A387/1	0-25	Sd_1	8.5	0.6	0.3	34.9	1
A387/2	25-50		8.6	0.4	0.7	34.8	2
A387/3	50-100		8.7	0.8	1.5	36.3	4
A388/1	0-25	Sb_2/Sd_{1s}	8.7	0.3	0.2	31.3	1
A388/2	25-50		8.6	0.9	0.5	29.3	2
A388/3	50-100		8.7	0.9	0.9	31.3	3
A390/1	0-25	Sd_{1s}	8.4	0.7	0.2	29.3	1
A390/2	25-50		8.6	0.8	0.4	28.1	1
A390/3	50-100		8.7	1.0	0.7	20.9	3
A390/4	100-150		8.7	3.8	0.5	23.7	2
A390/5	150-200		8.7	3.3	0.9	16.9	5
A391/1	0-25	Sb_{2s}	8.6	1.4	0.3	26.9	1
A391/2	25-50		8.9	0.5	0.5	26.6	2
A391/3	50-100		8.5	2.5	1.1	29.1	4
A394/1	0-25	Sb_2	8.5	0.9	0.3	30.1	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
A394/2	25-50		8.7	0.5	0.4	30.3	2
A394/3	50-100		8.9	0.8	1.7	31.8	5
A396/1	0-25	Sb_2	8.5	0.8	0.3	32.2	1
A396/2	25-50		8.6	1.1	0.6	32.5	2
A396/3	50-100		8.8	2.1	0.8	32.1	3
A398/1	0-25	Sb_2	8.6	1.1	0.8	31.1	3
A398/2	25-50		8.4	1.3	1.7	32.9	5
A400/1	0-25	Sb_{2s}	8.4	0.9	0.5	32.9	1
A400/2	25-50		8.7	0.8	1.2	35.1	3
A400/3	50-100		8.4	2.3	3.0	34.7	9
A400/4	100-150	Sb_{2s}	8.3	6.0	1.1	33.1	3
A400/5	150-200		8.7	7.2	0.6	25.4	2
A402/1	0-25	Sb_{1s}	8.9	0.9	0.4	23.8	2
A402/2	25-50		8.1	2.1	0.4	27.4	1
A402/3	50-100		8.2	4.1	1.2	27.1	5
A404/1	0-25	Sd_1	8.3	1.3	0.4	34.1	1
A404/2	25-50		8.6	1.1	0.8	32.5	3
A404/3	50-100		8.5	1.1	1.4	32.7	4
A406/1	0-25	Sd_1	8.2	1.1	0.4	33.0	1
A406/2	25-50		8.5	0.7	0.9	32.7	3
A406/3	50-100		8.5	0.9	1.2	35.5	3
A408/1	0-25	Sb_2	8.2	1.0	0.2	27.4	1
A408/2	25-50		8.7	0.8	0.4	26.2	2
A408/3	50-100		8.7	0.9	0.8	30.1	3
A411/1	0-25	Sd_1	8.2	0.8	0.2	35.8	1
A411/2	25-50		8.2	0.7	0.9	35.2	2
A411/3	50-100		8.5	1.2	2.0	36.4	5
A411/4	150-200		8.5	5.8	0.6	33.3	2
A413/1	0-25	St_2	8.2	1.1	0.1	23.1	0
A413/2	25-50		8.3	0.9	0.1	20.1	0
A413/3	50-100		8.4	0.7	0.1	19.4	1
A415/1	0-25	Sl_2	8.3	1.3	0.1	25.0	1
A415/2	25-50		8.5	0.8	0.2	23.3	1
A415/3	50-100		8.5	1.8	0.6	26.5	2
C004/1	0-25	Sb_1	8.5	0.7	0.3	30.3	1
C004/2	25-50		8.5	0.7	0.5	30.7	2
C004/3	50-100		8.1	2.9	0.7	30.6	2
C005/1	0-25	Sb_2	8.4	0.9	0.4	26.7	1
C005/2	25-50		8.5	0.8	0.7	28.2	2
C005/3	50-100		8.8	1.1	1.5	18.8	8
C006/1	0-25	Sb_2	8.7	0.7	0.7	30.7	2
C006/2	25-50		8.6	0.6	1.0	31.1	3
C006/3	50-100		8.9	0.8	2.5	29.8	8
C007/1	0-25	Sb_2	8.5	0.9	0.8	32.0	3
C007/2	25-50		8.7	0.5	0.9	30.2	3
C007/3	50-100		8.7	0.8	1.0	30.4	3
C010/1	0-25	Sd_1	8.4	0.8	0.6	33.4	2

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C010/2	25-50		8.5	0.8	1.0	32.5	3
C010/3	50-100		8.6	0.9	0.5	31.9	1
C012/1	0-25	Sd_1	8.5	0.7	0.5	31.7	2
C012/2	25-50		8.4	0.8	0.6	32.5	2
C012/3	50-100		8.4	0.8	0.9	35.6	2
C014/1	0-25	BM	8.2	3.2	0.4	15.6	2
C014/2	25-50		8.4	1.8	0.2	17.8	1
C014/3	50-100		8.5	0.6	0.2	23.2	1
C016/1	0-25	Sd_2	8.3	1.7	1.1	37.8	3
C016/2	25-50		8.1	1.3	1.5	39.0	4
C016/3	50-100		8.4	0.9	1.2	37.8	3
C018/1	0-25	Sd_1	8.5	0.8	0.7	40.8	2
C018/2	25-50		8.8	0.8	0.5	25.5	2
C018/3	50-100		8.8	1.3	2.5	34.5	7
C019/1	0-25	MP	8.4	1.6	0.5	30.1	2
C019/2	25-50		8.3	4.8	3.4	31.7	11
C019/3	50-100		8.5	7.0	4.5	31.0	14
C019/4	100-150		8.3	19.0	11.9	34.3	35
C019/5	150-200		8.4	13.0	15.3	35.6	43
C021/1	0-25	MP	8.4	1.7	0.9	31.5	3
C021/2	25-50		8.4	2.8	2.1	31.3	7
C021/3	50-100		8.5	6.0	3.2	31.2	10
C023/1	0-25	Sd_1	8.5	0.7	0.5	32.6	2
C023/2	25-50		8.8	0.8	0.8	32.4	2
C023/3	50-100		9.0	0.9	1.8	33.1	6
C025/1	0-25	Sb_2	8.5	0.7	0.8	33.1	3
C025/2	25-50		8.3	7.4	2.9	34.3	9
C025/3	50-100		8.3	3.6	2.8	33.1	8
C027/1	0-25	Sb_{1s}	8.3	2.1	0.7	29.8	2
C027/2	25-50		8.3	5.1	1.1	29.1	4
C027/3	50-100		8.3	10.0	1.4	31.1	4
C029/1	0-25	Sb_2	8.6	0.7	0.5	29.6	2
C029/2	25-50		8.8	0.9	1.0	29.7	3
C029/3	50-100		8.5	4.4	3.6	30.1	12
C029/4	100-150		8.2	11.5	1.2	31.8	4
C029/5	150-200		8.2	9.4	2.6	29.8	9
C031/1	0-25	Sb_{1s}	8.5	1.1	0.3	31.0	1
C031/2	25-50		8.5	0.9	0.6	29.7	2
C031/3	50-100		8.0	3.5	0.3	30.0	1
C033/1	0-25	Sb_2	8.4	0.6	0.2	30.1	1
C033/2	25-50		8.1	1.7	0.7	29.1	2
C033/3	50-100		7.8	5.0	1.0	33.5	3
C037/1	0-25	Sb_1	8.2	1.1	0.3	32.8	1
C037/2	25-50		8.2	1.6	0.5	32.5	2
C037/3	50-100		8.0	*	0.5	35.0	2
C039/1	0-25	Sb_1	8.9	0.5	0.6	31.5	2

*Insufficient sample for S.E.

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C039/2	25-50	Sb_1	9.0	0.6	1.4	31.4	4
C039/3	50-100		8.4	2.0	4.8	30.4	14
C039/4	100-150		8.4	8.0	2.5	33.5	7
C039/5	150-200		8.5	7.0	2.0	28.4	7
C041/1	0-25	$Sb_{1\text{-}2s}$	8.3	0.6	0.1	21.6	1
C041/2	25-50		8.6	2.7	0.2	27.1	1
C041/3	50-100		8.5	0.6	0.3	22.9	1
C043/1	0-25	Sd_2	8.5	0.9	0.4	31.2	1
C043/2	25-50		8.7	0.8	0.6	30.8	2
C043/3	50-100		8.8	0.8	0.6	30.2	2
C045/1	0-25	MP	8.6	0.5	0.1	17.7	1
C045/2	25-50		8.7	0.9	0.1	17.8	1
Co45/3	50-100		8.5	0.9	0.5	18.5	3
C047/1	0-25	Sd_1	8.8	0.7	0.6	32.3	2
C047/2	25-50		8.8	0.6	0.8	31.9	2
C047/3	50-100		8.7	1.0	1.5	31.6	5
C049/1	0-25	Sb_{2s}	8.3	1.8	0.2	32.9	1
C049/2	25-50		8.1	2.9	0.4	33.2	1
C049/3	50-100		8.2	4.2	0.4	33.3	1
C049/4	100-150		8.3	5.7	2.0	33.7	6
C049/5	150-200		8.4	7.5	1.2	30.8	4
C051/1	0-25	Sb_{2s}	8.5	0.6	0.3	31.0	1
C051/2	25-50		8.5	0.5	0.3	31.2	1
C051/3	50-100		8.7	0.6	0.7	29.0	2
C053/1	0-25	Sb_2	8.6	0.8	0.6	32.9	2
C053/2	25-50		8.7	1.1	1.9	31.9	6
C053/3	50-100		8.7	1.9	3.3	31.1	11
C055/1	0-25	Sb_1	8.6	0.6	0.9	32.1	3
C055/2	25-50		8.7	1.6	2.8	31.0	9
C055/3	50-100		8.3	4.2	2.5	32.7	8
C057/1	0-25	MP	8.4	0.6	1.2	31.2	4
C057/2	25-50		8.7	1.5	3.9	34.2	12
C057/3	50-100		8.4	4.6	7.2	33.7	21
C059/1	0-25	MP	9.0	0.7	1.6	34.8	5
C059/2	25-50		8.6	1.8	5.7	34.0	17
C059/3	50-100		8.3	10.0	8.2	34.7	24
C059/4	100-150		8.2	10.0	7.5	36.2	21
C059/5	150-200		8.3	10.0	5.7	33.9	17
C061/1	0-25	MP	8.0	4.0	0.8	26.6	3
C061/2	25-50		8.5	5.8	3.6	27.8	13
C061/3	50-100		8.5	10.4	7.4	32.1	23
C063/1	0-25	Sb_2	8.3	1.4	0.6	33.6	2
C063/2	25-50		8.3	2.1	1.4	33.5	4
C063/3	50-100		8.6	1.7	2.9	35.0	8
C065/1	0-25	Sb_1	8.6	0.9	0.4	27.9	1
C065/2	25-50		8.5	1.1	0.7	27.1	3
C065/3	50-100		8.2	4.2	0.4	26.8	2
C067/1	0-25	Sb_1	8.0	4.8	0.5	32.4	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C067/2	25-50	Sb_1	7.9	3.4	0.4	30.7	1
C067/3	50-100		8.0	6.5	0.9	30.7	3
C069/1	0-25	Sl_1	8.2	2.1	0.5	32.9	2
C069/2	25-50		8.2	2.8	0.8	32.1	2
C069/3	50-100		8.2	3.7	3.7	32.1	12
C069/4	100-150		8.3	8.0	1.6	32.0	5
C069/5	150-200		8.2	9.5	1.2	30.7	4
C071/1	0-25	MP	8.9	2.4	1.2	29.2	4
C071/2	25-50		8.8	3.9	5.1	35.5	15
C071/3	50-100		8.5	10.7	10.5	32.0	33
C073/1	0-25	MP	8.6	2.8	2.4	31.1	8
C073/2	25-50		8.5	7.6	9.8	31.9	31
C073/3	50-100		8.3	11.2	10.5	32.9	32
C075/1	0-25	MP	8.5	5.1	3.1	30.1	10
C075/2	25-50		8.4	9.9	10.5	31.4	33
C075/3	50-100		8.3	10.8	7.1	29.6	24
C077/1	0-25	Sb_1	8.3	1.4	0.4	35.5	1
C077/2	25-50		8.4	1.8	0.6	28.5	2
C077/3	50-100		8.6	3.9	6.2	30.2	21
C079/1	0-25	Sb_2	8.3	2.1	0.5	32.2	2
C079/2	25-50		8.4	0.9	0.7	32.8	2
C079/3	50-100		8.3	3.3	0.6	33.2	2
C079/4	100-150		8.0	5.1	2.4	34.8	7
C079/5	150-200		8.3	3.9	1.5	34.7	4
C081/1	0-25	Sb_2	8.4	1.1	0.4	34.8	1
C081/2	25-50		8.3	3.2	0.7	34.9	2
C081/3	50-100		8.6	1.2	1.4	33.4	4
C083/1	0-25	Sd_1	8.5	1.0	0.3	32.7	1
C083/2	25-50		8.4	1.1	0.5	33.5	2
C083/3	50-100		8.5	1.0	1.2	33.5	4
C085/1	0-25	Sb_1	8.5	0.5	0.4	33.6	1
C085/2	25-50		8.5	1.3	0.4	33.5	1
C085/3	50-100		8.2	2.1	0.4	34.3	1
C087/1	0-25	Sb_1	8.0	4.0	0.8	31.4	3
C087/2	25-50		8.2	2.0	0.2	32.7	1
C087/3	50-100		8.0	5.7	0.8	33.3	3
C089/1	0-25	Sl_2	8.1	0.9	0.6	33.0	2
C089/2	25-50		8.4	2.1	0.9	33.1	3
C089/3	50-100		8.7	1.2	1.5	32.8	5
C089/4	100-150		8.1	4.1	0.5	33.8	2
C089/5	150-200		8.1	5.2	0.8	31.0	2
C091/1	0-25	Sb_2	8.5	0.6	0.4	33.9	1
C091/2	25-50		8.6	0.9	6.1	32.9	19
C091/3	50-100		8.2	2.6	0.9	32.6	3
C093/1	0-25	Sb_2	8.4	0.5	0.5	33.7	2
C093/2	25-50		8.2	0.9	1.1	33.5	3
C093/3	50-100		8.2	4.8	1.5	34.1	4
C095/1	0-25	Sb_2	8.5	0.5	0.2	35.8	1
C095/2	25-50		8.6	0.8	0.7	33.7	2
C095/3	50-100		8.7	1.1	1.9	33.0	6

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C097/1	0-25	Sb_1	8.3	0.7	0.3	37.1	1
C097/2	25-50		8.3	1.2	0.8	35.0	2
C097/3	50-100		8.4	1.7	1.9	33.9	6
C099/1	0-25	Sl_2	8.5	0.8	0.3	31.6	1
C099/2	25-50		8.5	1.3	0.8	31.6	2
C099/3	50-100		8.3	4.7	0.5	34.8	2
C099/4	100-150		8.3	8.3	0.8	31.8	2
C099/5	150-200		8.2	6.9	2.3	30.5	8
C101/1	0-25	Sl_2	8.6	1.2	0.3	29.5	1
C101/2	25-50		8.5	1.1	0.5	30.6	2
C101/3	50-100		8.8	1.2	0.9	27.2	3
C103/1	0-25	Sb_1	8.4	1.4	0.4	30.6	1
C103/2	25-50		8.4	1.3	0.8	30.1	3
C103/3	50-100		8.6	1.7	0.7	28.5	2
C105/1	0-25	Sd_1	8.4	0.7	0.3	35.2	1
C105/2	25-50		8.8	0.7	0.6	33.6	2
C105/3	50-100		9.0	1.1	1.2	32.3	4
C107/1	0-25	Sb_{1s}	8.7	0.7	0.3	31.3	1
C107/2	25-50		8.8	0.6	0.6	31.2	2
C107/3	50-100		8.7	0.9	1.1	28.1	4
C109/1	0-25	Sd_1	8.3	1.7	1.1	29.6	4
C109/2	25-50		8.8	1.3	1.3	30.2	4
C109/3	50-100		8.4	5.4	1.9	31.2	6
C109/4	100-150		8.3	7.9	1.4	25.8	5
C109/5	150-200		8.6	8.6	0.6	27.3	2
C111/1	0-25	MP	8.8	2.6	1.3	35.7	4
C111/2	25-50		8.6	6.0	9.2	37.5	25
C111/3	50-100		8.3	14.1	2.2	36.8	6
C113/1	0-25	Sd_2	8.5	0.8	0.4	35.1	1
C113/2	25-50		8.7	1.2	1.1	33.9	3
C113/3	50-100		8.2	1.6	2.3	32.7	7
C115/1	0-25	Sd_1	8.5	0.9	0.4	31.8	1
C115/2	25-50		8.6	0.8	0.5	29.8	2
C115/3	50-100		8.8	0.8	1.3	31.8	4
C117/1	0-25	Sb_2	8.6	0.7	0.2	21.3	1
C117/2	25-50		8.5	1.3	0.2	27.2	1
C117/3	50-100		8.5	1.1	0.4	24.4	2
C119/1	0-25	Sb_2	8.4	1.0	0.4	34.1	1
C119/2	25-50		8.7	0.9	0.9	32.0	3
C119/3	50-100		8.9	0.8	1.7	32.1	5
C119/4	100-150		8.4	4.3	0.6	34.6	2
C119/5	150-200		8.2	5.7	0.0	33.4	-
C121/1	0-25	Sb_2	8.5	0.9	0.4	28.9	1
C121/2	25-50		8.8	0.9	0.3	29.9	1
C121/3	50-100		8.5	2.4	0.9	28.5	3
C123/1	0-25	Sb_1	8.8	1.2	0.9	31.9	3
C123/2	25-50		8.5	5.2	6.7	31.4	21
C123/3	50-100		8.6	8.7	4.9	31.6	16
C125/1	0-25	Sf	8.7	0.6	0.1	29.0	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C125/2	25-50	Sf	8.5	1.2	0.2	28.8	1
C126/3	50-100		8.7	0.6	0.2	28.6	1
C127/1	0-25	Sd_1	8.3	0.9	0.5	32.8	1
C127/2	25-50		8.5	0.9	0.5	33.9	1
C126/3	50-100		8.7	0.8	0.9	31.7	3
C129/1	0-25	Sb_2	7.9	2.2	0.3	35.0	1
C129/2	25-50		8.0	2.7	0.4	32.6	1
C129/3	50-100		8.1	3.9	1.7	34.1	5
C129/4	100-150		8.2	5.9	1.6	30.3	5
C129/5	150-200		8.3	6.5	0.4	33.2	1
C131/1	0-25	Sl_1	8.6	0.8	0.1	26.1	0
C131/2	25-50		8.3	0.7	0.3	24.2	1
C131/3	50-100		8.5	3.3	0.1	25.3	0
C133/1	0-25	Sb_1	8.5	1.2	0.1	26.2	0
C133/2	25-50		8.0	0.7	0.2	27.7	1
C133/3	50-100		8.5	2.6	0.1	29.8	0
C135/1	0-25	Sb_1	8.5	1.6	0.5	30.4	2
C135/2	25-50		8.5	2.4	1.3	29.5	5
C135/3	50-100		8.5	7.8	3.5	32.2	11
C137/1	0-25	Sf	8.2	1.5	0.2	31.8	1
C136/2	25-50		8.2	1.9	0.3	30.0	1
C137/3	50-100		8.3	1.9	0.3	28.6	1
C139/1	0-25	Sb_{2s}	8.8	0.6	0.6	33.5	2
C139/2	25-50		8.8	2.2	1.1	34.6	3
C139/3	50-100		8.2	5.3	-	34.2	0
C139/4	100-150		8.3	7.0	2.6	30.3	9
C139/5	150-200		8.2	6.4	-	28.2	0
C141/1	0-25	Sd_2	8.8	0.8	0.9	21.2	0
C141/2	25-50		8.7	0.6	0.6	37.0	2
C141/3	50-100		8.2	3.0	0.2	36.8	1
C143/1	0-25	Sot_2	8.5	1.5	0.4	31.1	1
C143/2	25-50		8.7	1.1	0.6	33.4	2
C143/3	50-100		8.6	1.4	0.6	30.5	2
C145/1	0-25	Sb_{1s}	8.5	1.2	0.3	31.1	1
C145/2	25-50		8.5	1.0	0.4	25.2	2
C145/3	50-100		8.4	3.3	1.9	34.2	6
C147/1	0-25	Sb_1	9.0	0.6	0.9	33.5	3
C147/2	25-50		9.0	1.1	0.7	33.5	2
C147/3	50-100		8.7	3.3	1.1	34.9	3
C149/1	0-25	Sl_2	8.1	2.7	0.1	32.5	0
C149/2	25-50		8.0	4.3	0.6	32.2	2
C149/3	50-100		8.4	7.7	1.8	31.4	6
C149/4	100-150		8.8	8.7	5.5	32.4	17
C149/5	150-200		8.6	11.7	8.2	31.5	26
C151/1	0-25	Sb_1	8.6	1.5	0.2	30.3	1
C151/2	25-50		8.6	0.6	0.4	29.4	1
C151/3	50-100		8.2	2.8	0.2	32.3	1
C155/1	0-25	Sd_1	8.6	0.8	0.6	35.3	2
C155/2	25-50		8.7	1.1	1.8	32.6	6

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C155/3	50-100	Sd_1	8.2	2.9	2.2	33.9	6
C157/1	0-25	Sb_2	8.2	1.7	0.3	32.1	1
C157/2	25-50		8.0	3.1	0.1	34.3	0
C157/3	50-100		8.1	5.7	1.0	34.0	3
C159/1	0-25	Sd_2	8.4	0.6	0.3	35.4	1
C159/2	25-50		8.5	0.8	0.7	35.2	2
C159/3	50-100		8.5	1.2	1.0	36.8	3
C159/4	100-150		8.1	4.8	1.5	38.6	4
C159/5	150-200		8.1	4.5	0.9	35.5	2
C161/1	0-25	Sb_2	8.6	1.4	0.6	35.4	2
C161/2	25-50		8.9	1.2	2.6	33.8	8
C161/3	50-100		8.9	2.2	4.8	35.8	13
C163/1	0-25	Sb_1	8.3	1.3	0.2	25.6	1
C163/2	25-50		8.4	2.7	0.2	27.0	1
C163/3	50-100		8.0	1.3	0.2	25.7	1
C165/1	0-25	Sb_1	8.3	1.5	0.5	32.5	2
C165/2	25-50		8.7	1.3	1.3	29.1	4
C165/3	50-100		8.4	3.3	2.1	31.0	7
C167/1	0-25	Sb_2	8.4	1.3	0.6	35.7	2
C167/2	25-50		8.6	1.0	1.4	36.0	4
C167/3	50-100		8.6	2.7	3.4	36.5	9
C169/1	0-25	Sb/Sd	8.4	1.1	0.3	38.7	1
C169/2	25-50		8.6	1.2	0.6	34.8	2
C169/3	50-100		8.5	2.1	2.0	37.5	5
C169/4	100-150		8.2	5.0	1.8	33.0	6
C169/5	150-200		8.2	6.6	0.9	30.4	3
C171/1	0-25	Sd_2	8.6	0.7	0.2	29.0	1
C171/2	25-50		8.5	0.8	0.6	29.6	2
C171/3	50-100		8.8	1.3	1.1	29.5	4
C173/1	0-25	Sd_2	8.3	0.9	0.3	35.6	1
C173/2	25-50		8.3	1.4	0.7	32.7	2
C173/3	50-100		8.4	0.8	0.8	33.7	2
C175/1	0-25	Sd_2	8.5	0.6	0.4	35.0	1
C175/2	25-50		8.6	0.7	0.7	35.5	2
C177/1	0-25	Sot_2	8.5	2.4	0.1	19.2	1
C177/2	25-50		8.4	1.1	0.1	21.4	1
C177/3	50-100		8.3	2.0	0.3	23.8	1
C181/1	0-25	Sb_2	8.6	0.6	0.4	37.6	1
C181/2	25-50		8.5	0.7	0.9	35.6	3
C181/3	50-100		8.1	2.9	0.4	36.8	1
C183/1	0-25	Sb_{2s}	8.7	0.8	0.6	34.1	2
C183/2	25-50		8.8	0.6	1.8	34.6	5
C183/3	50-100		8.5	1.6	2.4	32.9	7
C185/1	0-25	Sb_1	8.5	2.3	0.4	30.1	1
C185/2	25-50		8.7	1.9	2.8	32.1	9
C185/3	50-100		8.7	-	2.7	31.6	9
C187/1	0-25	Sb_2	8.6	0.7	0.6	36.9	2
C187/2	25-50		9.0	0.9	3.1	32.6	10
C187/3	50-100		8.4	5.5	2.0	35.0	6

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C189/1	0-25	Sb_2	8.2	1.8	0.4	33.7	1
C189/2	25-50		8.2	4.2	1.2	35.0	4
C189/3	50-100		8.5	8.4	2.7	34.0	8
C189/4	100-150		8.2	7.8	0.0	26.3	0
C189/5	150-100		8.5	8.4	3.5	32.5	11
C191/1	0-25	Sl_2	8.7	0.8	0.5	33.7	2
C191/2	25-50		8.3	3.1	2.8	30.7	9
C191/3	50-100		8.2	6.3	2.5	32.4	8
C193/1	0-25	Sb_2	8.6	-	0.2	25.8	1
C193/2	25-50		8.7	-	0.6	25.8	2
C193/3	50-100		8.4	3.3	0.3	29.7	2
C195/1	0-25	BM	8.0	-	0.2	16.3	1
C195/2	25-50		8.0	1.2	0.1	18.4	1
C195/3	50-100		8.2	1.3	0.3	19.4	2
C197/1	0-25	Sb_1	8.2	1.1	0.3	20.3	1
C197/2	25-50		8.2	3.9	1.5	21.5	7
C197/3	50-100		8.3	8.9	2.5	21.9	11
C199/1	0-25	Sb_2	8.4	-	0.5	33.0	2
C199/2	25-50		8.6	-	1.2	31.2	4
C199/3	50-100		8.5	3.2	3.4	34.1	10
C199/4	100-150		8.4	8.9	1.4	32.3	4
C199/5	150-200		8.1	4.0	1.0	37.7	3
C201/1	0-25	Sb_2	8.2	1.0	0.6	35.6	2
C203/1	0-25	Sd_{2-3}	8.2	0.6	0.4	36.1	1
C203/2	25-50		8.4	0.9	0.7	35.2	2
C203/3	50-100		8.5	2.8	3.9	37.0	10
C205/1	0-25	Sd_2	8.3	0.7	0.6	32.0	2
C205/2	25-50		8.7	0.8	1.4	36.0	4
C205/3	50-100		8.7	1.5	2.8	36.6	8
C207/1	0-25	Sd_2	8.2	1.1	0.3	37.4	1
C206/2	25-50		8.2	1.7	0.4	34.7	1
C207/3	50-100		8.0	8.9	0.6	29.1	2
C209/1	0-25	Sb_{2s}	8.2	1.6	0.3	32.1	1
C209/2	25-50		8.2	1.3	0.3	33.2	1
C209/3	50-100		7.9	3.4	0.4	32.9	1
C209/4	100-150		8.2	1.6	0.6	18.2	3
C209/5	150-200		8.9	1.1	1.3	18.9	7
C211/1	0-25	Sb_2	8.2	0.8	0.2	27.3	1
C211/2	25-50		8.2	0.9	0.2	28.1	1
C211/3	50-100		8.0	2.2	0.3	31.0	1
C213/1	0-25	Sot_2	8.0	1.6	0.2	31.3	1
C213/2	25-50		7.9	3.1	0.2	32.0	1
C213/3	50-100		8.0	4.4	0.1	28.0	1
C215/1	0-25	Sd_1	8.1	1.7	0.3	32.5	1
C215/2	25-50		8.2	1.4	0.5	31.8	2
C215/3	50-100		8.3	2.3	1.4	31.4	5
C217/1	0-25	Sd_3	8.2	1.2	0.5	35.8	1
C217/2	25-50		8.2	1.4	0.7	35.3	2

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C217/3	50-100	Sd_3	8.4	1.0	0.8	33.1	3
C219/1	0-25	Sot_2	8.1	1.6	0.3	25.0	1
C219/2	25-50		8.4	0.8	0.5	25.7	2
C219/3	50-100		8.6	1.5	0.9	24.8	3
C219/4	150-200		8.2	5.1	1.0	21.3	5
C221/1	0-25	Sd_2	7.2	1.6	0.4	37.9	1
C221/2	25-50		8.0	1.6	0.6	35.1	2
C221/3	50-100		8.0	3.3	0.5	35.7	1
C223/1	0-25	Sb_1	8.3	0.8	0.6	35.2	2
C223/2	25-50		8.5	2.2	2.5	33.6	8
C233/3	50-100		8.4	6.3	6.1	32.6	19
C226/1	0-25	Sb_1	8.3	0.8	0.3	16.6	2
C225/2	25-50		8.2	3.5	0.6	33.2	2
C225/3	50-100		8.3	6.6	1.3	30.8	4
C227/1	0-25	Sd_2	8.4	1.8	0.4	29.3	2
C227/2	25-50		8.4	1.7	0.9	30.6	3
C227/3	50-100		8.3	5.6	3.3	28.8	11
C229/1	0-25	Sl_2	8.4	1.0	0.1	38.6	0
C229/2	25-50		8.5	1.0	0.3	28.5	1
C229/3	50-100		8.3	5.0	1.3	26.6	5
C229/4	100-150		8.3	8.0	2.8	27.8	10
C229/5	150-200		8.5	10.0	4.2	32.6	13
C231/1	0-25	Sd_2	8.4	1.5	0.5	34.5	2
C231/2	25-50		8.7	1.2	0.8	35.6	2
C231/3	50-100		8.5	2.8	2.4	34.3	7
C233/1	0-25	Sd_1	8.4	1.6	0.7	32.3	2
C233/2	25-50		8.6	1.6	1.1	34.0	3
C233/3	50-100		8.5	2.2	2.2	34.8	6
C235/1	0-25	Sl_2	8.2	5.3	0.9	30.3	3
C235/2	25-50		8.4	7.6	1.9	27.4	7
C235/3	50-100		8.6	9.0	3.7	29.9	13
C242/1	0-25	Sd_2	8.4	1.4	0.3	27.4	1
C242/2	25-50		8.4	1.1	0.4	31.6	1
C242/3	50-100		8.6	0.9	0.6	33.7	2
C244/2	25-50	Sd_2	8.6	0.9	0.3	27.7	1
C244/4	100-150		8.7	0.8	0.9	32.4	3
C244/5	150-200		8.7	1.1	1.2	32.4	4
C246/2	25-50	Sb_1	8.5	1.1	0.7	26.0	3
C248/1	0-25	Sd_1	8.6	1.9	0.3	32.5	1
S248/2	25-50		8.7	1.2	0.5	32.7	2
C252/1	0-25	Sd_2	8.4	1.5	0.4	36.7	1
C254/1	0-25	Sd_2	7.9	1.0	0.3	33.7	1
C254/2	25-50		8.1	0.5	0.5	34.5	1
C254/3	50-100		8.1	1.2	0.7	32.9	2
C254/4	100-150		8.2	1.3	1.0	34.4	3
C254/5	150-200		7.8	3.5	0.4	33.0	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C256/1	0-25	Sb_2	8.3	0.8	0.4	35.5	1
C256/2	25-50		8.5	0.7	0.9	33.5	3
C256/3	50-100		8.5	0.9	1.4	36.3	3
C258/1	0-25	Sb_2	8.3	0.7	0.3	31.5	1
C258/2	25-50		8.4	0.7	0.6	31.8	2
C258/3	50-100		8.3	0.9	1.0	31.3	3
C260/1	0-25	Sd_3	8.3	0.9	0.2	29.2	1
C260/2	25-50		8.3	0.9	0.2	29.7	1
C260/3	50-100		8.4	0.5	0.2	30.3	1
C262/1	0-25	Sd_3	8.2	1.3	0.5	32.9	1
C262/2	25-50		8.3	0.6	0.4	30.0	1
C262/3	50-100		8.2	0.7	0.5	32.4	1
C265/1	0-25	Sd_3	8.2	0.8	0.2	30.2	1
C265/2	25-50		8.4	0.9	0.4	29.3	1
C265/3	50-100		8.5	0.8	0.8	32.1	3
C265/4	100-150		8.2	2.4	0.9	34.0	3
C265/5	150-200		7.9	3.4	0.6	32.6	2
C267/1	0-25	Sm	8.5	1.4	0.4	16.4	2
C267/2	25-50		8.6	2.9	1.4	15.6	9
C267/3	50-100		8.4	6.3	1.8	23.2	8
C269/1	0-25	Sm	7.7	0.9	0.2	23.7	1
C269/2	25-50		8.0	0.4	0.3	21.7	1
C269/3	50-100		8.2	0.7	0.1	16.3	1
C271/1	0-25	Sd_1	7.8	1.1	Nil	6.5	0
C271/2	25-50		8.2	1.3	0.1	6.4	0
C271/3	50-100		8.1	1.1	0.1	9.3	1
C273/1	0-25	Jsfx	8.3	0.8	0.1	29.4	0
C273/2	25-50		8.3	1.0	0.3	28.7	1
C273/3	50-100		8.0	4.0	0.5	29.6	2
C275/1	0-25	Jsfx	8.4	0.8	0.3	33.4	1
C275/2	25-50		8.5	0.6	1.0	30.8	3
C275/3	50-100		8.4	1.4	1.6	32.5	5
C277/1	0-25	Jsfx	8.2	1.0	0.3	35.5	0
C277/2	25-50		8.2	1.0	0.5	31.6	2
C277/3	50-100		8.3	1.6	1.3	32.1	4
C279/1	0-25	Sd_2	8.3	1.0	0.4	36.0	1
C279/2	25-50		8.2	0.8	0.7	33.6	2
C279/3	50-100		8.2	1.3	0.5	35.5	1
C279/4	100-150		8.2	1.6	1.1	31.6	4
C279/5	150-200		8.4	4.0	1.1	32.1	3
C281/1	0-25	Jsfx	7.9	0.6	0.5	30.8	1
C281/2	25-50		9.0	0.8	2.6	31.7	8
C281/3	50-100		9.5	2.2	5.7	31.7	18
C283/1	0-25	Sd_{1-2}	8.3	1.3	0.1	30.9	0
C283/2	25-50		8.4	0.6	0.4	31.2	1
C283/3	50-100		8.4	0.5	0.5	32.7	2
C285/1	0-25	Sb_1	8.3	0.6	0.3	31.5	1
C285/2	25-50		8.5	0.9	0.5	32.1	2
C285/3	50-100		8.3	3.2	0.3	29.0	1
C289/1	0-25	Sb_1	8.5	0.7	0.4	32.0	1

BORE ANALYSIS RESULTS

Bore/ Sample No.	Depth (cm)	Mapping Unit	pH 1:2½ Soil Water Suspension	ECe mmhos/cm	Ex. Na. me/100g	C.E.C. me/100g	ESP
C289/2	25-50	Sb_1	8.3	1.2	0.7	30.4	2
C289/3	50-100		8.0	4.4	0.8	31.9	3
C291/1	0-25	Sl_2	8.3	1.1	0.3	30.8	1
C291/2	25-50		8.1	3.1	0.4	30.0	1
C291/3	50-100		8.1	4.6	0.4	28.9	1
C293/1	0-25	Sb_2	8.5	0.8	0.2	30.7	1
C293/2	25-50		8.5	0.5	0.4	28.8	1
C293/3	50-100		8.6	1.0	0.8	29.1	3
C295/1	0-25	Sb_2	8.6	0.5	0.5	31.0	2
C295/2	25-50		8.7	0.9	1.3	29.5	4
C295/3	50-100		8.3	3.9	1.3	33.9	4
C297/1	0-25	Sb_2	8.3	1.2	0.3	31.3	1
C297/2	25-50		8.2	1.2	0.3	32.6	1
C297/3	50-100		8.2	3.3	0.2	33.5	1
C299/1	0-25	Sb_2	8.5	0.5	0.3	36.3	1
C299/2	25-50		8.4	1.1	0.6	32.6	2
C299/3	50-100		8.1	3.2	0.9	29.2	3

E

Infiltration and Hydraulic Conductivity

E.1 INFILTRATION

Surface infiltration tests were carried out using the double ring infiltrometer method at eleven sites in the survey area. An additional two sites were tested during the Reconnaissance Study also fell within the present survey area.

Triplicate sets of infiltration rings were driven into the ground to at least 15 cm depth at test sites. Readings were carried out over a 2 day period (3 days in one case) and an approximately constant head of 150—200 mm was maintained between readings.

Calculated infiltration rates and cumulative infiltration are presented in Table E.1. These results are summarised and discussed in Section 2.6.1. Plots of cumulative infiltration against elapsed time are illustrated in Figure 2.3.

E.2 HYDRAULIC CONDUCTIVITY TESTS

Soil saturated hydraulic conductivity was mainly assessed by the auger hole method (e.g. USBR, 1953). As no stable water table was encountered the 'pour in' as opposed to the 'pump out' method was employed. A total of 42 tests were carried out at 22 sites (these figures include 3 tests at 2 sites carried out in the Reconnsissance Survey) in the survey area using this method. In addition attempts were made to measure vertical hydraulic conductivity by siting infiltration rings at the bottom of soil profile pits at three sites.

E.2.1 Auger Hole Method

The 'pour in' auger hole method measures horizontal saturated hydraulic conductivity by determining the rate of water addition required to maintain a constant head of water in an auger hole of known dimensions.

In the present investigation an auger hole was excavated to the required depth using a Jarret auger of approximately 12 cm diameter. The hole was lined with gravel to prevent collapse on wetting and measured quantities of water were added over measured time intervals to maintain a constant water head in a central observation pipe. Accurate measurement of water levels within the central pipe was facilitated by use of an electrical contact breaker apparatus. Volume additions of water were standardised leaving time for permeation as the only variable. A constant rate of water addition was normally achieved after 3 to 4 hours when the tests were concluded. A few tests were carried out over time periods of up to six hours to check if any further significant decrease occurred. In the relatively few cases where a constant rate was not achieved during the test period graphs of rate of water addition against elapsed time were plotted and the constant rate achieved under saturated conditions was estimated by visual extrapolation of the resulting curve.

The hydraulic conductivity (K) of the soil layers tested was calculated according to the formulae of Boersma (1965). The actual formula used depends on the presence or absence of an effective 'impermeable layer' below the soil layer tested. As a rule of thumb, on underlying soil layer was judged to be impermeable if its hydraulic conductivity was less than one tenth of the hydraulic conductivity of the layer tested.

The formulae used to calculate 'K' are as follows:

Case 1 Where Tu > 3h.

$$K = \frac{[\text{logn}\,(\frac{h}{r} + \sqrt{(\frac{h}{r})^2 - 1}) - 1] \times Q \times 240}{2\pi h^2}$$

Case 2 Where 3h > Tu >h

$$K = \frac{[\;3\,\text{logn}\,\frac{h}{r}\;] \times Q \times 240}{\pi h\,(h + 2\,Tu)}$$

Where: K = Hydraulic Conductivity (mm/day)
h = Depth of auger hole — Depth to maintained water level (cm)
r = Radius of auger hole
Tu = Depth of impermeable layer — Depth of maintained water level (cm)
Q = Constant rate of water addition (ml/hr)

The results of the auger hole hydraulic conductivity tests are given in Table E.2 and are summarised and discussed in Section 2.6.3.

E.2.2 Subsoil Infiltration Tests

Inner infiltration rings (30 cm diameter) were sited at the bottom of soil profile pits (2 m depth) at three sites to measure vertical hydraulic conductivity and to compare results with those of the auger hole tests. Readings were taken over a three day time period and rings were topped up as necessary. Rates of water infiltration were approximately constant after 24 to 48 hours. The results are presented in Table E.3.

Profile No:	A377	Date: 27.2.1979
Soil Unit:	Sd_1	FAO/UNESCO Classification: Chromic Vertisol Irrigated Land Class: III Wsf

Location: Line 5, 1.7 km east of base line.

Topography: Shallow depression on margin of larger depressional area.

Microrelief: Gilgai M2

Surface Features: Pale grey, dry and hard, common shell fragments.

Profile Drainage: Poor

Vegetation and Land Use: Open savanna shrubland with *Dalbergia* spp., *Withania* spp., *Acacia zanzibarica*. Land Use Class: U

Depth (cm)	Horizon Description
0 - 10	Dark greyish brown (2.5Y4/2) clay with weak-moderate medium subangular blocky structure, tending to platy; dry, hard; low organic matter; common fine vertical cracks; common fine-very fine pores; many fine-medium roots; common shell fragments. Clear smooth boundary to:
10 - 25	Dark greyish brown (2.5Y4/2) clay with moderate medium prismatic structure, breaking into weak medium subangular blocky; slightly moist, very firm; very low organic matter; common fine vertical cracks; common fine-very fine pores; common fine-coarse roots; few small calcium carbonate nodules; common shell fragments. Clear smooth boundary to:
25 - 75	Dark greyish brown (10YR4/2) clay with few black manganese stains and a moderate coarse prismatic structure, breaking into moderate coarse angular blocky; slightly moist, very firm; common fine-coarse vertical cracks (up to 2 cm wide); few fine-very fine pores; common fine-coarse roots; common weakly developed slickensides; few white calcium carbonate nodules; common shell fragments. Gradual smooth boundary to:
75 - 125	Dark greyish brown (10YR4/2) clay with few fine distinct yellowish brown mottles and a weak coarse wedge structure with occasional prismatic aggregate near cracks; slightly moist, extremely firm; common medium vertical cracks (2 cm wide); few fine-very fine pores; few fine-medium roots; common slickensides, common small calcium carbonate nodules, increasing with depth; few shell fragments. Diffuse boundary to:
125 - 200	Greyish brown (10YR5/2) clay with few fine distinct brownish yellow mottles and weak medium angular blocky structure; moist, very firm, common fine cracks; few fine-very fine pores; few fine roots; common patches of semi hard - hard carbonate; maganese stains on root channels; few shell fragments.

Profile Pit No. A377

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-25	3	33	22	42	C(l)
P2	25-75	2	29	22	47	C
P3	75-125	2	29	22	47	C
P4	125-200	1	30	27	42	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	20	0.03	7.8	1.0	15.7	4.1	0.4	1.8	22.0	27.3
P2	2.2	0.06	7.8	2.8	19.5	10.4	0.9	1.1	31.9*	27.3
P3	21	0.09	8.0	2.1	15.2	11.8	1.5	1.0	29.5	27.0
P4	22	0.98	7.8	8.7	16.6	6.9	2.4	0.7	26.6	25.8

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	1	3.2	1.7	3.5	0.6	4.5	4.4	4.5	0.8	2.5	81
P2	3	11.2	13.6	10.6	0.2	8.3	12.5	2.4	1.1	1.2	-
P3	6	3.8	3.6	8.2	0.2	11.5	7.0	2.4	1.1	4.3	-
P4	9	33.8	39.5	51.5	0.4	54.4	61.7	2.5	1.8	8.5	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-25	92.4	0.09	0.8	9	1.9
P2	25-75	79.2	0.04	0.5	12	0.5

Profile No:	C009	Date: 15.1.1979
Soil Unit:	Sd 1	FAO/UNESCO Classification: Chromic Vertisol Irrigated Land Class: III Wsf
Location:	0.75 km east of base line on line 20	
Topography:	Western depression on Shabelle floodplain. c0.1% NW.	
Microrelief:	Gilgai M2	
Surface Features:	Brownish grey, self mulching, common cracks.	
Profile Drainage:	Poor	
Vegetation and Land Use:	Shrubland and thicket with *Acacia nilotica* dominant. Land Use Class: U.	

Depth (cm)	Horizon Description
0 - 15	Dark greyish brown (2.5Y4/2) clay with moderate medium subangular blocky structure; dry, slightly hard, low organic matter, common fine vertical and few fine horizontal cracks; many tubular pores; common fine roots; few small cutans; abundant shell fragments. Gradual smooth boundary to:
15 - 38	Dark greyish brown (2.5Y4/2) clay with moderate medium prismatic breaking to moderate medium subangular blocky structure; slightly moist, extremely firm; common fine vertical and few fine horizontal cracks; few fine inped pores; common fine roots; common weak slickensides; abundant shell fragments. Gradual smooth boundary to:
38 - 92	Dark greyish brown (2.5Y4/2) clay with strong very coarse prismatic structure breaking into medium prismatic peds; slightly moist, extremely firm; common vertical cracks (to 3 cm across); few fine-medium inped pores; common fine roots; common well developed slickensides; few very fine calcium carbonate concretions; common fine shell fragments. Gradual smooth boundary to:
92 - 180	Dark greyish brown (2.5Y4/2) clay with few fine faint brown mottles and massive structure; few fine pores; few fine roots to 150 cm depth; many fine soft calcium carbonate concretions; many shell fragments: few clay cutans.

Profile Pit No. C009

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-15	3	11	33	53	C
P2	15-38	2	8	27	63	C
P3	38-92	3	8	26	63	C
P4	92-180	0	8	31	61	C
P5	180-275	3	5	31	61	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	23	0.04	7.6	1.0	26.8	8.4	0.5	1.5	37.2*	34.6
P2	30	0.01	7.9	1.2	22.7	10.1	0.9	0.8	34.5*	33.6
P3	23	0.01	8.1	0.9	20.0	8.9	0.8	0.7	30.4	34.0
P4	19	0.35	7.8	3.6	13.5	5.0	1.1	1.1	20.7	35.1
P5	23	0.66	7.8	4.2	38.8*	14.8	0.6	1.0	55.2*	35.6

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	1	4.2	2.4	1.2	0.3	2.6	4.0	2.5	0.7	0.7	-
P2	3	5.2	2.4	3.4	0.2	4.5	7.5	3.0	0.8	1.7	-
P3	2	3.3	1.5	3.7	0.1	3.8	2.8	3.0	1.9	2.4	89
P4	3	32.5	16.5	14.4	0.3	5.1	46.7	1.0	2.6	2.9	59
P5	2	21.2	10.1	17.1	0.3	7.7	40.8	3.0	2.3	4.3	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-15	68.6	0.07	0.8	11	1.2
P2	15-38	67.0	0.06	0.7	12	0.7

* Due to breakdown of Calcium or Magnesium Carbonate - Disregard.

Profile No:	C238	Date: 10.2.1979
Soil Unit:	Sd_2	FAO/UNESCO Classification: Pellic Vertisol Irrigated Land Class:

Location: On Trace line 13, 200 m from western end.

Topography: Broad flat floored depression on western edge of floodplain.

Microrelief: Gilgai (M2)

Surface Features: Grey self mulching surface, breaking into granular aggregates; common shell fragments.

Profile Drainage: Poor - Very Poor.

Vegetation and Land Use: Mixed *Acacia*/non thorny shrubland, including *Dalbergia* spp., *A.nilotica*, *Dobera glabra*. Land Use Class: F2.

Depth (cm)	Horizon Description
0 - 15	Dark grey (2.5Y4/1) clay with common fine distinct dark brown mottles and moderate medium subangular blocky structure; slightly moist, very firm; moderate organic matter; few fine vertical and horizontal cracks; many fine tubular pores; common fine-medium roots; common very fine calcium carbonate concretions; few shell fragments; strong reaction to hydrochloric acid. Gradual smooth transition to:
15 - 38	Dark greyish brown (2.5Y3-4 /2) clay with moderate medium prismatic structure breaking into moderate fine-medium subangular blocky; slightly moist, very firm; low organic matter; common fine vertical cracks; few fine pores; common fine-medium roots; patchy weak cutans; common fine amorphous calcium carbonate; common fine shell fragments. Strong reaction to HCl. Gradual smooth transition to:
38 - 74	Dark grey (2.5Y4/1) clay with moderate coarse prismatic structure breaking into moderate medium subangular blocky; slightly moist, extremely firm; common medium vertical cracks; few fine pores; common fine-medium roots; common moderately developed cutans and slickensides; few ferromanganese coated calcium carbonate concretions; strong reaction to hydrochloric acid. Gradual smooth boundary to:
74 - 115	Clay, as above, but with weak medium angular blocky structure.
115 - 190	Dark greyish brown (2.5Y4/2) clay with few brown mottles along fossil root channels and weak medium angular blocky structure; moist, extremely firm; very few fine vertical cracks; few fine pores; few fine roots; many fine ferromanganese coated calcium carbonate concretions; many patches amorphous calcium carbonate; few shell fragments; strong reaction to hydrochloric acid.

Profile Pit No. C238

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-15	7	14	26	53	C
P2	15-38	5	16	18	61	C
P3	38-74	4	12	21	63	C
P4	74-115	5	11	21	63	C
P5	115-190	4	10	31	55	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	19	0.22	7.6	4.3	25.6	8.4	0.4	2.1	36.5*	33.4
P2	21	0.0	7.7	3.2	21.9	10.0	0.2	1.4	33.5*	32.4
P3	21	0.05	7.9	3.4	26.4	19.0	1.5	1.1	48.0*	34.6
P4	20	0.10	7.8	7.2	27.3	20.1	5.0	1.2	53.6*	34.2
P5	18	1.06	8.0	6.3	50.6*	11.6	1.1	1.2	64.5*	31.9

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 Cl	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	1	36.2	14.9	17.1	1.2	10.9	35.0	4.5	4.1	3.4	-
P2	1	27.5	11.8	9.7	0.5	10.9	40.8	3.0	1.8	2.2	-
P3	4	13.9	12.3	10.0	0.2	14.1	15.8	4.0	1.6	2.8	-
P4	15	35.0	27.5	52.9	0.3	35.2	50.0	3.0	2.3	9.5	-
P5	3	28.8	28.5	47.2	0.4	12.8	70.8	2.5	4.8	8.8	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-15	70.0	0.15	1.7	11	3.2
P2	15-38	61.8	0.08	0.7	9	0.8

* Disregard due to breakdown of Calcium or Magnesium Carbonate.

Profile No: C178 Date: 4.2.1979

Soil Unit: Sd_3 FAO/UNESCO Classification: Pellic Vertisol
Irrigated Land Class: VI SWF

Location: On Trace line 24, 4.5 km from western end.

Topography: Flat - in large depression

Microrelief: Only slight gilgai (M1), tending to M2 in uncultivated areas.

Surface Features: Pale grey, dry and crusted breaking to subangular blocky/crumb aggregate; many shell fragments.

Profile Drainage: Very Poor.

Vegetation and Land Use: Mixed cropping of sorghum and sesame. Good growth (sorghum more than 2 m high). Land Use Class: C.

Depth (cm)	Horizon Description
0 - 15	Dark greyish brown (10YR4/2) clay with moderate medium subangular blocky breaking to strong fine crumb at surface; slightly moist, firm; common medium vertical and common fine horizontal cracks; common fine inped and interstitial pores; common fine roots; many fine white calcium carbonate concretions; many fine shell fragments. Gradual smooth boundary to:
15 - 36	Dark grey (5Y4/1) clay with strong medium prismatic structure; moist, very firm; common medium vertical and common fine horizontal cracks; common fine inped pores; common fine roots; many fine calcium carbonate concretions; many fine shell fragments. Gradual smooth boundary to:
36 - 75	Dark grey (5Y4/1) clay with strong coarse prismatic structure; moist, extremely firm; common medium vertical and few fine horizontal cracks; common fine inped pores; common fine roots; common strongly developed slickensides; common clay cutans; many very fine calcium carbonate concretions; many shell fragments. Strong reaction to hydrochloric acid. Gradual smooth boundary to:
75 - 130	Dark grey (5Y4/1) clay with moderate medium-fine subangular blocky structure; moist, extremely firm; few medium vertical cracks; common fine inped pores; common fine roots; common strongly developed slickensides and cutans; many very fine calcium carbonate concretions; many shell fragments. Strong reaction to HCl. Gradual smooth boundary to:
130 - 200	Dark greyish brown (2.5Y4/2) clay with weak-medium subangular blocky structure; moist; extremely firm; few fine inped pores; rare very fine roots; no slickensides; many very fine hard calcium carbonate concretions and occasional fine powdery calcium carbonate; many fine shell fragments; strong reaction to hydrochloric acid.

Profile Pit No. C178

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-15	2	15	35	48	C
P2	15-36	2	17	31	50	C
P3	36-75	2	15	30	53	C
P4	75-130	2	15	28	55	C
P5	130-200	1	18	33	48	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	24	0.03	7.7	0.7	34.2*	9.8	0.3	1.2	45.5*	30.0
P2	24	0.02	7.9	0.7	19.9	7.3	0.8	0.9	28.9	30.0
P3	27	0.01	8.0	1.2	16.6	6.9	0.9	0.8	25.2	30.6
P4	25	0.05	7.9	3.5	20.2	9.4	0.8	1.0	31.4*	30.7
P5	23	1.14	7.7	7.3	70.5*	7.4	1.5	0.9	80.3	30.1

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	1	2.8	1.5	1.1	0.2	4.5	0.5	4.0	0.9	0.8	-
P2	3	3.0	0.9	2.1	0.2	3.5	2.3	2.5	1.3	1.5	96
P3	3	3.5	2.1	4.2	0.2	5.4	5.4	4.0	1.6	2.5	82
P4	3	12.1	5.0	10.6	0.4	15.4	23.7	2.5	1.7	3.6	-
P5	5	32.5	14.9	18.5	0.5	44.8	45.8	2.5	3.2	3.8	-

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-15	74.6	0.07	0.7	10	1.9
P2	15-36	77.8	0.07	0.6	9	1.6

* Due to breakdown of Calcium Carbonate Disregard.

Profile No:	C263	Date: 22.2.1979
Soil Unit:	Sdw	FAO/UNESCO Classification: Pellic Vertisol Irrigated Land Class: VI SWF
Location:	On Trace line No. 4, 5.0 km from western end.	
Topography:	Large flat depression	
Microrelief:	Smooth and even MO.	
Surface Features:	Dry hard dark grey, slightly self mulching, shallow irregular cracks.	
Profile Drainage:	Very Poor.	
Vegetation and Land Use:	Previously cropped with sorghum and sesame. Land Use Class: Cf	

Depth (cm)	Horizon Description
0 - 15	Dark grey (2.5Y4/1) clay with moderate medium subangular blocky structure breaking to medium crumb; dry, slightly hard; low organic matter; common fine vertical cracks; common fine inped pores; common fine-medium roots; common fine shell fragments; few very fine calcium carbonate concretions. Clear smooth boundary to:
15 - 40	Dark grey (5Y4/1) clay with moderate coarse prismatic structure breaking to moderate medium subangular blocky; slightly moist, very firm; common fine vertical and few fine horizontal cracks; few fine pores; common fine-medium roots; common soft very fine calcium carbonate concretions; common fine shell fragments. Gradual smooth boundary to:
40 - 90	Dark grey (5Y4/1) clay with weak-moderate medium subangular blocky structure; moist, extremely firm; common very fine vertical and horizontal cracks; few fine pores; common very fine roots; common very fine calcium carbonate concretions; common fine shell fragment; few weak slickensides and few weak cutans. Gradual smooth boundary to:
90 - 145	Dark grey (5Y4/1) clay with very weak subangular blocky structure with wedge shaped aggregates; very moist, slightly plastic; rare very fine pores; few weak cutans; many very fine shells and shell fragments; small patches powdery calcium carbonate. Gradual smooth boundary to:
145 - 200	Dark grey (5Y4/1) clay with rare fine yellowish brown mottles and very weak subangular blocky structure; very moist, plastic; rare very fine pores; patchy clay skins; many very fine shells and shell fragments; few patches of powdery calcium carbonate.

Profile Pit No. C263

Particle Size Analysis

Sample No.	Depth (cm)	Particle Size Analysis (%) Coarse Sand	Fine Sand	Silt	Clay	Texture
P1	0-15	2	16	29	53	C
P2	15-40	2	16	27	55	C
P3	40-90	1	22	22	55	C
P4	90-200	1	32	16	51	C

Chemical Analysis

Sample No.	Total Carbonate %	Gypsum %	pH (paste)	EC mmhos S.E.	Exchangeable Cations (me /100g) Ca	Mg	Na	K	TEB me%	CEC me%
P1	28	0.03	7.7	1.1	26.8*	8.4	0.4	1.9	37.5*	29.2
P2	30	0.02	8.1	0.6	26.2*	8.1	0.7	1.5	36.5*	28.2
P3	2.5	0.01	8.2	0.7	16.5	6.5	0.8	1.6	25.4	27.9
P4	27	0.17	7.7	2.4	11.8	4.6	0.0	0.6	17.0	30.8

Chemical Analysis (contd)

Sample No.	ESP %	Soluble Cations me/1 Ca	Mg	Na	K	Soluble Anions me/1 C1	SO_4	HCO_3	B.in SE. (ppm)	SAR	BS (%)
P1	1	5.7	2.3	2.2	0.4	6.4	4.7	2.4	0.8	1.1	-
P2	2	2.8	0.7	2.0	0.2	2.6	2.0	3.5	0.8	1.5	-
P3	3	2.9	1.0	2.6	0.2	3.8	2.7	3.5	1.0	1.9	91
P4	0	16.8	7.3	5.8	0.4	3.8	25.2	3.0	1.8	1.7	55

Topsoil Chemical Fertility Analysis

Sample No.	Depth (cm)	Total P mg %	Total N mg %	Organic Carbon %	C/N Ratio	Available P (ppm)
P1	0-15	92.0	0.08	1.6	20	2.95
P2	15-40	87.4	0.06	1.0	17	2.05

* Disregard due to breakdown of Calcium Carbonate.

Profile No.: C287 **Date:** 27.2.1979

Soil Unit: SI_1 FAO/UNESCO **Classification:** Calcaric Fluvisol
Irrigated Land Class: III tex

Location: 700 m from western end of trace line 5

Topography: Broad flat levee alongside Farta Tukuule

Microrelief: Even

Surface Features: Brown with slight crusting, breaking into granular/crumb aggregates

Profile Drainage: Moderately well

Vegetation and: Land Use: Medium shrubland dominated by *Dobera glabra*

Depth (cm)	Horizon Description
0– 12	Dark yellowish brown (10YR 3/4) silty clay loam with moderate medium subangular blocky structure; dry, slightly hard; low organic matter; few fine vertical cracks; many fine tubular pores; common fine roots. Clear smooth boundary to:–
12– 30	Dark yellowish brown (10YR 3/4) heavy silty clay loam with moderate fine-medium subangular blocky structure breaking to fine crumb; slightly moist, friable; common fine vertical cracks; many fine tubular pores; common fine roots; common very fine powdery calcium carbonate. Gradual smooth boundary to:–
30– 60	Brown (10YR 4/3) light silty clay with few dark manganese stains and moderate medium-coarse prismatic structure breaking to moderate medium subangular blocky; common fine vertical cracks; common fine-coarse pores; common fine roots; few patches powder carbonate. Diffuse boundary to:–
60–140	Dark yellowish brown (10YR 4/4) light clay with few manganese stains and moderate medium prismatic structure breaking to moderate fine-medium angular blocky; slightly moist, very firm; common fine vertical and horizontal cracks; common fine tubular pores; few fine-medium roots; many crystalline calcium carbonate and few gypsum concentrated along ped faces. Gradual smooth boundary to:–
140–170	Dark greyish brown (10YR 4/2) clay with common medium distinct reddish brown mottles, common manganese stains and weak-medium wedge/angular blocky structure; slightly moist, very firm; few fine vertical cracks; few fine pores; few fine-medium roots; common powdery carbonate and gypsum; common weak slickensides. Gradual smooth boundary to:–
170–180	Brown (10YR 5/3) light clay; massive; dry, very hard; common fine pores; common powdery carbonate.

Profile No.:	A302	**Date:** 10.2.1979
Soil Unit:	SI_2	FAO/UNESCO **Classification:** Calcaric Fluvisols Irrigated Land Class: III wtx
Location:	On trace line 13, 1.25 km from western end	
Topography:	On crest of levee alongside Farta Tukuule	
Microrelief:	Even M0	
Surface Features:	Grey brown, dry hard; slight wash	
Profile Drainage:	Imperfect	
Vegetation and: Land Use:	Mixed *Acacia* non-thorny shrubland, including *A. nilotica, Dalbergia spp., Thespesia spp., Dobera Glabra.* Land Use Class U.	

Depth (cm)	**Horizon Description**
0– 10	Brown (10YR 4/3) silty clay with weak medium subangular blocky structure; slightly moist, firm; low organic matter; common fine vertical cracks; common medium to fine pores; common fine-medium roots; few fine soft calcium carbonate. Clear smooth boundary to:–
10– 60	Brown (10YR 4/3) clay with weak coarse prismatic structure breaking to weak medium platy; slightly moist, firm; common fine vertical cracks; few fine pores; common fine to coarse roots; common weak cutans; common calcium carbonate concretions. Diffuse boundary to:–
60–125	Brown (10YR 4/3) clay with few fine faint grey mottles and moderate medium angular blocky structure; slightly moist, very firm; few fine vertical cracks; very few fine pores; few fine roots; many clay cutans and small slickensides; common soft calcium carbonate; lower boundary marked by layer of snail shells. Clear smooth boundary to:–
125–155	Grey (2.5Y 5/1) clay with common medium distinct strong brown mottles and weak coarse angular blocky structure; moist, very firm; few fine vertical and diagonal cracks; few very fine pores; few fine roots; common crystalline calcium carbonate and ferromanganese coated carbonate nodules; few gypsum. Gradual smooth boundary to:–
155–190	Grey (2.5Y 5/1) clay with common medium-coarse distinct-prominent brown and strong brown mottles and weak coarse subangular blocky structure; moist, very firm; few fine vertical cracks; few fine pores; few very fine roots; many crystalline calcium carbonate; few patches of gypsum.

N.B. – The subsoil of this profile is not typical. More recent levee deposits have been deposited over a surface which was probably an old depression. The interface is marked by a distinctive layer of complete gastropod snail shells.

Profile No.:	C035	**Date:** 24.1.1979
Soil Unit:	Sb_1	FAO/UNESCO **Classification:** Calcaric Fluvisol Irrigated Land Class : II w
Location:	On trace line 22	
Topography:	Flat cover floodplain, near margin of low levee	
Microrelief:	Even	
Surface Features:	Yellowish brown, dry and hard; irregular cracks	
Profile Drainage:	Imperfect	
Vegetation and: Land Use	Cultivated with sorghum. Class C	

Depth (cm	**Horizon Description**
0– 15	Brown (10YR 4/3) silty clay loam with strong fine angular blocky structure breaking to fine crumb; dry, slightly hard; common fine vertical and many fine horizontal cracks; few fine-medium tubular pores; abundant fine roots; common very fine calcium carbonate concretions. Gradual smooth boundary to:–
15– 36	Brown (10YR 4/3) clay with strong medium subangular blocky structure; dry, slightly hard; common fine cracks; few fine pores; common fine roots; common very fine calcium carbonate concretions. Gradual smooth boundary to:–
36– 73	Brown (10YR 4/3) clay with moderate medium subangular blocky structure; dry, slightly hard; common fine cracks; few fine tubular pores; common fine roots; common very fine calcium carbonate concretions. Gradual smooth boundary to:–
73–128	Dark greyish brown (10YR 4/2) clay with common fine faint dark brown mottles and moderate medium subangular blocky structure; moist, extremely firm; few fine pores; common fine roots; many very fine ferromanganese coated calcium carbonate concretions.
128–190	As above, also including some soft calcium carbonate and gypsum.

Profile No.:	A337	**Date:** 16.2.1979
Soil Unit:	Sb_2	FAO/UNESCO **Classification:** Chromite Vertisol Irrigated Land Class: II sw
Location:	On trace line 16, 1.95 km from western end	
Topography:	Flat cover floodplain	
Microrelief:	Slight gilgai (M1)	
Surface Features:	Grey brown hard surface with slight crusting. Occasional small 'sink holes'	
Profile Drainage:	Poor	
Vegetation and: Land Use:	Bush regrowth with *Dalbergia, Dobera glabra, Acacia nilotica.* Land Use Class F2.	

Depth (cm)	**Horizon Description**
0– 10	Brown (10YR 4/3) light clay with moderate medium subangular blocky structure and faint laminar substructure; slightly moist, firm; low organic matter; common fine vertical cracks; common fine pores; many fine-common roots; few shell fragments. Clear smooth boundary to:—
10– 40	Brown (10YR 4/3) clay with moderate coarse prismatic structure, breaking into weak medium subangular blocky; slightly moist, firm; common fine-medium vertical cracks; common fine-very fine pores; common fine-medium roots; patches small slickensides; few ferromanganese coated calcium carbonate nodules; common shell fragments. Gradual smooth boundary to:—
40– 95	Brown (10YR 4/2.5) clay with few fine faint grey mottles and weak-medium coarse platy to angular blocky structure; common medium vertical and diagonal cracks; few fine pores; few fine-medium roots; common small slickensides; few soft calcium carbonate; common shell fragments. Gradual smooth boundary to:—
95–120	Dark greyish brown (10YR 4/2) clay with many coarse faint dark grey mottles and few dark manganese stains; very weak coarse wedge structure; moist, extremely firm; common medium vertical and few fine horizontal cracks; rare very fine pores; few fine calcium carbonate; common shell fragments. Diffuse boundary to:—
120–200	Dark grey (2.5Y 4/1) clay with common medium distinct strong brown mottles; weak to moderate angular blocky wedge structure; moist, extremely firm; common fine vertical cracks; few fine-very fine pores; common shell fragments; common amorphous calcium carbonate.

Profile No.:	A416		**Date:** 6.3.1979
Soil Unit:	Sb_{2s}	FAO/UNESCO	**Classification:** Chromic Vertisol Irrigated Land Class : II sw

Location: On western base line

Topography: Cover floodplain near boundary with western depression

Microrelief: M1–2 Gilgai

Surface Features: Brownish grey self mulching with granular and subangular blocky aggregates.

Profile Drainage: Poor

Vegetation and: Land Use: Mixed *Acacia* and non-thorny shrubland

Depth (cm)	**Horizon Description**
0– 10	Dark greyish brown (10YR 4/2) silty clay with moderate medium subangular blocky structure, slightly moist, firm; low organic matter; common fine vertical cracks; common fine-medium pores; many fine-medium roots; few shell fragments. Clear boundary to:–
10– 35	Dark greyish brown (10YR 4/2) clay with moderate coarse prismatic structure breaking to weak medium subangular blocky; slightly moist, very firm; common fine coarse vertical cracks (to 1 cm wide), few fine horizontal cracks; few fine pores; common fine-medium roots; common fine calcium carbonate concretions. Clear smooth boundary to:–
35– 80	Dark brown (10YR 3/3) clay with weak-moderate very coarse prismatic structure, breaking to moderate medium wedge; common fine-medium vertical and few fine diagonal and horizontal cracks; few fine-very fine pores; common fine-medium roots; common slickensides; common fine calcium carbonate concretions. Gradual smooth boundary to:–
80–120	Dark brown (10YR 3/3) clay with common dark manganiferous mottles and very weak coarse subangular blocky structure; moist, extremely firm; few fine vertical cracks; few very fine pores; few fine roots; common fine calcium carbonate concretions. Gradual smooth boundary to:–
120–155	Brown (10YR 4/3) silty clay with common medium distinct yellowish brown mottles and weak medium-fine subangular blocky structure; moist, very firm; few-common fine pores; few fine roots; common crystalline calcium carbonate and hard nodules. Gradual wavy boundary to:–
155–200	Yellowish brown (10YR 5/4) light silty clay loam with few medium faint strong brown mottles and weak medium subangular blocky structure common fine pores; rare fine roots; few crystalline calcium carbonate.

Profile No.:	C179	**Date:** 4.2.1979
Soil Unit:	Sb_{2s}	FAO/UNESCO **Classification:** Chromic Vertisol Irrigated Land Class: II sw
Location:	On trace line 24, 1.5 km from western end	
Topography:	Flat cover floodplain	
Microrelief:	Slight gilgai, M1	
Surface Features:	Grey brown, slightly self mulching	
Profile Drainage:	Poor	
Vegetation and: Land Use:	Cultivated with sorghum (Class C)	

Depth (cm)	**Horizon Description**
0– 15	Dark greyish brown (10YR 4/2) silty clay with moderate fine subangular blocky breaking to strong fine crumb structure; dry, slightly hard; few fine vertical cracks; common fine interstitial pores; common fine roots. Gradual smooth boundary to:–
15– 34	As above, only with weak-moderate medium subangular blocky structure.
34– 70	Dark greyish brown (10YR 4/2) clay with moderate medium subangular blocky structure; slightly moist, very firm; few-common medium vertical cracks; few fine pores; common fine-medium roots; common fine calcium carbonate concretions. Gradual smooth boundary to:–
70–122	Dark greyish brown (10YR 3.5/2) light silty clay with moderate medium-coarse subangular blocky structure; slightly moist, very firm; few fine vertical cracks; few fine pores; common fine-medium roots; many fine white calcium carbonate concretions. Gradual smooth boundary to:–
122–145	Brown (10YR 4/3) silty clay loam with weak-moderate medium subangular blocky structure; moist, very firm; few fine pores; common fine-medium roots; many fine white calcium carbonate concretions and patches of amorphous calcium carbonate.
145–200	Brown (10YR 4/3) clay with weak-moderate medium subangular blocky structure; moist, extremely firm; few fine pores; few fine-medium roots; common patches amorphous calcium carbonate and many hard ferro-manganese coated nodules.

Profile No.:	C288	**Date:** 27.2.79
Soil Unit:	Sd_1	FAO/UNESCO **Classification:** Chromic Vertisol Irrigated Land Class: III Wsf
Location:	700 m from western end of trace line 26	
Topography:	Small depressions. Slope c.1 per cent E	
Microrelief:	Slight gilgai M1	
Surface Features:	Brownish grey, slightly self mulching with subangular blocky aggregates	
Profile Drainage:	Poor	
Vegetation and: Land Use	Mixed *Acacia* and non-thorny shrubland	

Depth (cm)	**Horizon Description**
0– 12	Dark greyish brown (10YR 4/2) clay with moderate medium subangular structure breaking to weak medium platy; dry, slightly hard; few fine vertical cracks; many fine tubular pores; common fine-medium roots; few powdery calcium carbonate. Clear wavy boundary to:–
12– 30	Dark greyish brown (2.5Y 4/2) clay with moderate medium subangular blocky structure; slightly moist, very firm; common fine vertical cracks; common fine-medium tubular pores; common fine-medium roots; few small slickensides; many shell fragments; few powdery carbonate. Gradual smooth boundary to:–
30– 70	Dark greyish brown (2.5Y 4/2) clay with moderate medium coarse prismatic structure breaking to medium wedge; slightly moist, very firm; common fine-medium vertical cracks (to 1 cm wide); few fine-medium pores; common fine roots; common slickensides; few fine carbonate nodules and powdery deposits. Clear smooth boundary to:–
70–130	Dark greyish brown (2.5Y 4/2) clay with weak medium wedge/prismatic structure; moist, extremely firm; few fine vertical cracks; few fine pores; common fine roots; common shell fragments; few patches powdery carbonate. Gradual smooth boundary to:–
130–200	As above, with weak medium angular blocky structure and common powdery carbonate.

Profile No.:	A299	**Date:** 5.2.1979
Soil Unit:	Sd_2	FAO/UNESCO **Classification:** Pellic Vertisol Irrigated Land Class: VI SWF
Location:	On western base line; 100 m south west of start of Line 33	
Topography:	Broad depression along west side of floodplain. Slope c.0.5 per cent	
Microrelief:	Gilgai (M2)	
Surface Features:	Grey, self mulching, breaking into granular aggregates; common sink holes	
Profile Drainage:	Very poor	
Vegetation and: Land Use	*Acacia nilotica* thicket. Class U	

Depth (cm)	**Horizon Description**
0– 15	Dark grey (2.5Y 4/1) clay with moderate medium-coarse subangular blocky structure; slightly moist, very firm; low organic matter; common fine vertical and few fine horizontal cracks; few fine tubular pores; common fine-medium roots; common shell fragments. Gradual smooth boundary to:–
15– 55	Dark grey (2.5Y 4/1) clay with moderate very coarse prismatic structure breaking to weak-medium angular blocky; common vertical and few diagonal cracks (to 1 cm wide), few fine horizontal cracks; few fine tubular pores; common fine-medium roots; many shell fragments. Diffuse boundary to:–
55–140	As above, with structure tending to coarse platy and wedge rather than angular blocky; few slickensides.
140–230	Dark grey (2.5Y 4/1) clay with few fine distinct strong brown mottles and moderate coarse wedge structure; moist, extremely firm; few fine vertical cracks; few fine pores; rare fine roots; many well defined slickensides; few crystalline calcium carbonate; few gypsum.

Profile No.: A378 **Date:** 27.2.1979

Soil Unit: Sd_2 FAO/UNESCO **Classification:** Pellic Vertisol
Irrigated Land Class: VI SWF

Location: On trace line 17Y, 500 m from western end

Topography: Lower slope site in western depression area. Slope 0.5 per cent

Microrelief: Gilgai. M2

Surface Features: Grey hard surface with common 'sink holes', irregular shallow cracks, scattered shell fragments.

Profile Drainage: Very poor

Vegetation and Land Use: *Acacia nolotica* thicket

Depth (cm)	Horizon Description
0– 12	Dark grey (2.5Y 4/1) clay with weak-medium subangular blocky structure; dry, slightly hard; low organic matter; few fine cracks; common very fine pores; common fine roots; common fine calcium carbonate nodules; many shell fragments. Clear smooth boundary to:–
12– 60	Dark grey (5Y 4/1) clay with weak-moderate coarse angular blocky structure tending to slight wedge; slightly moist, very firm; few fine cracks; few common fine pores; few fine-medium roots; few weakly developed slickensides; few calcium carbonate concretions; many shell fragments. Diffuse boundary to:–
60–100	Dark grey (5Y 4/1) clay with few fine distinct yellowish brown mottles and weak coarse wedge structure; slightly moist, extremely firm; few very fine vertical and diagonal cracks; few fine pores; few fine roots; common well developed slickensides; few fine calcium carbonate nodules; many shell fragments. Diffuse boundary to:–
100–200	Clay as above, slightly more massive, gypsum crystals present.

Profile No.:	C237	**Date:** 10.2.1979
Soil Unit:	Sot_1	FAO/UNESCO **Classification:** Calcaric Regosol Irrigated Land Class VI STex
Location:	On trace line 12, 1.5 km east of base line.	
Topography:	Raised terrace area. 1 per cent slope down to broad depression (Sd_1)	
Microrelief:	Slightly uneven due to erosion	
Surface Features:	Pale greyish brown with sandy wash	
Profile Drainage:	Imperfect	
Vegetation and Land Use:	Dominantly non-thorny shrubland. Class U	

Depth (cm)	**Horizon Description**
0– 15	Dark brown (10YR 3/3) silty clay loam with moderate fine subangular blocky structure; slightly moist, firm; low organic matter; few fine tubular pores; common fine-few medium roots; common very fine calcium carbonate concretions. Clear smooth boundary to:–
15– 30	Brown (10 YR 4/3) silty clay with moderate medium subangular blocky breaking to fine subangular blocky structure; slightly moist, firm; common fine vertical cracks; common medium-fine tubular pores; common fine-medium roots; common fine calcium carbonate concretions, including few ferromanganese coated. Gradual smooth boundary to:–
30– 64	Brown (10 YR 4/3) clay with moderate medium angular blocky structure; slightly moist, very firm; few fine-medium cracks; common very fine tubular pores; common fine-medium roots; common weak cutans; fine sand movement through cracks and root channels; common fine calcium carbonate. Gradual smooth boundary to:–
64–110	Brown (10YR 4/3) clay with weak medium angular blocky structure; slightly moist, very firm; few fine vertical cracks; few medium tubular pores; common fine roots; common weak cutans; common very fine calcium carbonate concretions and patches of carbonate 1–2 cm across. Clear wavy boundary to:–
110–175	Light brown (7.5YR 6/4) clayey gravel; structureless; slightly moist; common very fine pores; few fine roots; abundant hard calcium carbonate nodules; few old termite chambers; intact fossil snail shells. Gradual wavy boundary to:–
175–200	Brown (10YR 5/3) gravelly clay with many white calcareous mottles; structureless; slightly moist; few very fine pores; few fine roots.

Profile No.: C286 **Date:** 27.2.1979

Soil Unit: Som FAO/UNESCO **Classification:**Calcaric Regosol
Irrigated Land Class: IV swte

Location: 6.8 km from western end of trace line 5

Topography: Old meander complex. Slightly uneven due to dissection by small channels

Microrelief: Slightly uneven (erosion and surface wash)

Surface Features: Pale greyish brown hard crusted surface, becomes powdery on breaking. Common surface wash

Profile Drainage: Imperfect

Vegetation and: Land Use: Dense shrubland with *Acacia zanzibarica* dominant

Depth (cm)	Horizon Description
0— 17	Very dark greyish brown (2.5Y 3/2) fine sandy clay loam with few fine strong brown mottles along root channels; weak medium subangular blocky structure; dry, slightly hard; very low organic matter; few fine vertical cracks; many very fine pores; common fine roots; few fine calcium carbonate nodules. Clean smooth boundary to:—
17— 43	Dark greyish brown (2.5Y 4/2) fine sandy clay with weak medium prismatic structure breaking to moderate medium subangular blocky; dry very hard; common fine vertical cracks; common fine pores; common fine roots; many calcium carbonate nodules and few patches of amorphous calcium carbonate. Gradual smooth boundary to:—
43— 70	Dark greyish brown (2.5Y 4/2) fine sandy clay with common fine faint yellowish brown mottles and very weak medium subangular blocky structure; dry, very hard; common fine pores; few fine roots; many ferromanganese coated calcium carbonate nodules; common patches amorphous calcium carbonate. Gradual smooth boundary to:—
70—108	Dark greyish brown (2.5Y 4/2) clay with common medium distinct yellowish brown mottles and massive structure; dry, very hard; few fine vertical cracks with fine sand along surfaces; common fine pores; few fine roots; few small termite chambers; many patches amorphous calcium carbonate and many ferromanganese coated nodules. Gradual smooth boundary to:—
108—200	Light olive brown (2.5Y 5/4) clay with few fine faint brown mottles and massive structure; dry, very hard; few fine vertical cracks; few fine pores; many ferromanganese coated calcium carbonate nodules; few fine gypsum.

Profile No.: C240 **Date:** 16.2.1979

Soil Unit: S1/Sd FAO/UNESCO **Classification:** Calcaric Fluvisol
Irrigated Land Class: III wf

Location: 750 m from eastern end of trace line 17Y

Topography: Shallow depression near eastern edge of Shabeelle floodplain

Microrelief: Gilgai M2

Surface Features: Brown, self mulching, breaking into subangular blocky aggregates

Profile Drainage: Imperfect

Vegetation and Land Use: *Acacia nilotica* thicket

Depth (cm)	Horizon Description
0– 18	Brown (10YR 4/3) silty clay loam with moderate medium subangular blocky breaking to fine platy structure; dry, slightly hard; low organic matter; few fine vertical cracks; many fine pores; many fine-medium roots; few fine calcium carbonate. Clear wavy boundary to:–
18– 40	Brown (10YR 4/3) heavy silty clay loam with moderate medium subangular blocky structure; slightly moist, firm; few fine vertical cracks; many fine pores; many fine roots; many fine calcium carbonate concretions Gradual smooth boundary to:–
40– 90	Brown (10YR 4/3) light clay with few fine faint yellowish brown and grey mottles; moderate medium-coarse prismatic structure breaking to moderate medium subangular blocky; slightly moist, firm; common fine vertical cracks; many fine pores; common fine roots; many fine calcium carbonate concretions. Gradual smooth boundary to:–
90–114	Dark yellowish brown (10YR 3/4) light clay with common medium distinct dark brown and strong brown mottles and moderate medium subangular blocky structure; moist, firm; few fine vertical cracks; many fine-medium pores; common fine roots; common shell fragments. Diffuse boundary to:–
114–190	Dark grey (2.5Y 4/1) clay with common medium distinct dark brown mottles and very weak coarse subangular blocky structure; moist, extremely firm; few fine remnant cracks; no pores; shell fragments concentrated down cracks.

TABLE C.1 LABORATORY ANALYSIS OF MOISTURE RETENTION PROPERTIES

Profile Pit Sample No.	Depth (cm)	BD (g/cc)	% Moisture (by voloume) retained at tension of (bars) 0	0.1	0.33	1.0	15	A P (%)	AWC (%)	EAWC (%)
A364/W1	25-29	1.26	56.3	46.9	44.1	41.6	32.5	9.4	14.4	5.3
A364/W2	50-54	1.48	39.1	38.3	37.0	35.5	31.1	0.8	7.2	2.8
A377/W1	17.21	1.39	54.3	47.5	44.8	41.8	30.6	6.8	16.9	5.7
A377/W2	37-41	1.51	47.7	46.8	45.4	43.9	37.0	0.9	9.8	2.9
A379/W1	15-19	1.33	55.2	53.2	48.9	45.2	31.9	2.0	21.3	8.0
A379/W2	25-29	1.40	57.2	51.4	49.4	47.3	35.3	6.1	16.1	4.1
C263/W1	16-20	1.40	59.2	57.0	55.4	52.9	36.8	2.2	20.2	4.1
C263/W2	43-47	1.35	52.6	51.3	50.1	48.2	35.9	1.3	15.4	3.1

BD = Bulk Density
AP = Aeration Porosity (Moisture retained between 0 and 01 bars).
AWC = Available Water Capacity (Moisture retained between 0.1 and 15 bars).
EAWC = Easily Available Water Capacity (Moisture retained between 0.1 and 1.0 bars).

TABLE E.1 **Infiltration Test Results**

Test No.	$1^{\dagger}$		$2^{\dagger}$		3		4		5		6		7	
Site No.	A058		B035		C009		C038		A300		C178		C238	
Soil Mapping Unit	Sb_2		Sl_2		Sd_1		Sb_1		Sb_{2s}		Sd_3		Sd_2	
Time Elapsed hrs. min	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)
Day 1 0.05	–	–	–	–	–	–	–	–	–	–	11	132	17	208
0.10	–	–	–	–	–	–	–	–	–	–	19	100	31	168
0.15	34	136	–	–	29	116	27	108	27	109	–	–	–	–
0.20	–	–	–	–	–	–	–	–	–	–	26	38	47	94
0.30	49	59	27	54	46	68	44	69	44	68	–	–	–	–
0.40	–	–	–	–	–	–	–	–	–	–	34	25	71	71
0.45	61	48	–	–	62	65	–	–	–	–	–	–	–	–
1.00	–	–	42	30	75	53	65	41	59	30	–	–	–	–
1.20	–	–	–	–	–	–	–	–	–	–	40	9	97	40
1.30	91	41	–	–	–	–	–	–	–	–	–	–	–	–
2.00	109	35	67	25	119	44	94	29	82	22	–	–	–	–
2.20	–	–	–	–	–	–	–	–	–	–	46	6	133	35
3.00	139	30	93	26	155	36	130	36	101	19	–	–	–	–
3.20	–	–	–	–	–	–	–	–	–	–	51	4	163	30
4.00	180	41	116	22	189	34	160	30	115	15	–	–	–	–
4.20	–	–	–	–	–	–	–	–	–	–	56	5	191	28
5.00	202	24	135	20	221	31	191	32	133	18	–	–	–	–
5.20	–	–	–	–	–	–	–	–	–	–	–	–	222	31
6.00	228	26	157	22	253	32	222	31	147	14	–	–	–	–
7.00	253	25	–	–	–	–	–	–	–	–	–	–	–	–
8.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Day 2 0.00*	458	–	296	–	448	–	420	–	237	5	214	–	435	–
1.00	462	21	310	11	473	24	451	31	247	11	218	5	447	12
2.00	477	15	316	9	490	17	471	20	256	8	222	4	458	11
3.00	492	15	325	9	507	17	486	15	264	8	226	4	474	15
4.00	508	15	334	9	526	19	506	20	273	9	229	3	490	16
5.00	522	15	344	9	545	18	518	12	rain		233	4	509	19
6.00	–	–	355	10	563	18	537	19			237	4	525	16
7.00	–	–	364	10	–	–	–	–			241	3	–	–
Day 3 0.00*			533	–										
1.00			567	14										
2.00			579	12										
3.00			592	12										
4.00			603	12										
5.00			614	10										

* Accounts for overnight infiltration.

† Carried out during reconnaissance survey.

[1] Figures are means of triplicate readings

[2] Figures are uncorrected for evaporation losses

ΣI = Cumulative Infiltration

$\frac{dI}{dt}$ = Infiltration Rate

TABLE E.1 (Cont'd)

Test No.	8		9		10		11		12		13	
Site No.	A301		C239		A364		C263		A379		A377	
Soil Mapping Unit	Sl_1		Sl_2		Sb_1		Sdw		Sb_2		Sd_1	
Time Elapsed hrs. min	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)	ΣI (mm)	$\frac{dI}{dt}$ (mm/hr)
Day 1 0.05	16	188	—	—	—	—	—	—	—	—	—	—
0.10	30	172	—	—	—	—	—	—	—	—	—	—
0.15	—	—	51	204	34	135	22	88	37	147	15	60
0.20	39	56	—	—	—	—	—	—	—	—	—	—
0.30	—	-	83	127	52	72	32	39	50	52	23	33
0.40	60	126	—	—	—	—	—	—	—	—	—	—
0.45	—	—	—	—	—	—	—	—	63	53	—	—
1.00	78	26	124	83	71	38	47	30	73	41	33	20
1.20	—	—	—	—	—	—	—	—	—	—	—	—
1.30	—	—	—	—	—	—	—	—	—	—	—	—
2.00	130	52	192	68	107	36	72	24	101	27	51	17
2.20	—	—	—	—	—	—	—	—	—	—	—	—
3.00	180	50	253	56	136	30	87	16	125	24	66	16
3.20	—	—	—	—	—	—	—	—	—	—	—	—
4.00	233	52	310	66	162	25	107	20	145	20	82	15
4.20	—	—	—	—	—	—	—	—	—	—	—	—
5.00	—	—	368	58	185	23	122	15	166	22	98	17
5.20	—	—	—	—	—	—	—	—	—	—	—	—
6.00	—	—	426	58	211	27	137	15	186	20	113	15
7.00	—	—	—	—	—	—	—	—	207	21	—	—
8.00	414	45	—	—	—	—	—	—	—	—	—	—
Day 2 0.00*	645	—	560	—	329	—	327	—	359	—	247	—
1.00	660	15	597	37	358	29	337	10	436	11	256	9
2.00	677	17	626	29	376	18	348	11	447	10	264	8
3.00	706	29	643	17	393	17	357	9	457	10	271	7
4.00	733	27	664	21	408	22	368	11	466	9	279	8
5.00	756	23	694	20	426	18	376	9	476	13	288	9
6.00	—	—	709	29	442	16	—	—	486	10	296	8
7.00	—	—	—	—	—	—	—	—	497	11	—	—

* Accounts for overnight infiltration.

† Carried out during reconnaissance survey.

[1] Figures are means of triplicate readings

[2] Figures are uncorrected for evaporation losses

ΣI = cumulative infiltration.

$\frac{dI}{dt}$ = infiltration rate.

TABLE E.2 Summary of Hydraulic Conductivity Data

Site	Soil Unit	Test H1 Depth (cm)	Test H1 Texture	Test H1 H.C. (mm/day)	Test H2 Depth (cm)	Test H2 Texture	Test H2 H.C. (mm/day)	Test H3 Depth (cm)	Test H3 Texture	Test H3 H.C. (mm/day)
A058	Sb_2	40–103	C(l)	12.0	140–205	C	9.0	–	–	–
A299	Sd_2	55–100	C	3.0	140–190	C	1.9	–	–	–
A300	Sb_{2s}[1]	50–105	C	2.9	150–205	C	5.8	–	–	–
A301	Sl_1	100–160	SiC(l)	71.0	160–200	SiC	24.0	–	–	–
A302	Sl_2	10– 60	C	37.0	125–160	C	8.9	155–190	C	11.2
A337	Sb_2	50– 90	C	4.4	–	–	–	–	–	–
A364	Sb_1	55–110	C	10.1	150–190	C	6.7	–	–	–
B035	Sl_2	30– 70	C(l)	20.0	–	–	–	–	–	–
C009	Sd_1	50–100	C	2.6	150–200	C	0.6	–	–	–
C035	Sb_1	50–105	C	7.4	150–205	C	4.0	–	–	–
C038	Sb_1	55–105	C	9.9	150–205	C/SiC	6.0	–	–	–
C178	Sd_3	36–130	C	4.3	130–200	C	2.9	–	–	–
C179	Sb_2	110–150	SiCl/SiC	14.0	150–200	C	4.6	–	–	–
C238	Sd_2	38–118	C	3.3	115–190	C	2.8	–	–	–
C239	Sl_2	50– 85	C(l)	36.5	150–205	C	4.4	–	–	–
C240	Sl/Sd_1	45– 90	C(l)	98.0	125–170	C	3.2	–	–	
C263	Sdw	45– 90	C	17.1	145–200	C	0.0	–	–	–
C287	Sl_1	33– 73	SiC(l)/C(l)	29.3	117–162	C(l)/C	21.9	–	–	–
C288	Sd_1	70–130	C	4.3	130–200	C	1.0	–	–	–
A377	Sd_1	45– 90	C	3.8	–	–	–	–	–	–
A379	Sb_2	20– 80	C	12.5	115–200	C	3.0	–	–	–
A416	Sb_{2s}	50– 95	C	4.5	145–190	SiCL(l)	220.0	–	–	–

[1] Lighter subsoil not encountered in test bore.

TABLE E.3 Subsoil Infiltration Test Results

Site	Soil Unit	Texture	Final Infiltration Rate (mm/day)
C038	Sb_1	Silty Clay	4,632
C288	Sd_1	Clay	1,332
A378	Sd_2	Clay	15

With the possible exception of site A378 these recorded values are significantly higher than expected, both from direct field observations and from auger hole measurements (soil morphology in the layers tested did not suggest such a large difference between vertical and horizontal conductivity). During the course of the subsoil infiltration tests it was apparent that considerable lateral seepage occurred as the floors of the profile pits were saturated with water when the later test readings were taken. For this reason we consider the results of these tests invalid.

F

Laboratory Methods

F.1 ROUTINE METHODS USED FOR BORE SAMPLES

F.1.1 Electrical Conductivity of Saturation Extract

Distilled water was added to a known weight of soil with stirring until the saturation point was reached then measured and the result expressed in mmhos/cm.

F.1.2 Exchangeable Sodium

Four g of soil were extracted by shaking with 20 ml of N ammonium acetate solution, buffered at pH 8.4 to prevent dissolution of calcium carbonate. Exchangeable sodium was measured in the extract by atomic absorption spectroscopy using strontium chloride as an ionisation buffer.

F.1.3 Cation Exchange Capacity - Bascombe's Method

Four g of soil were extracted by shaking with 20 ml of N ammonium acetate 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 equal to the difference between the amount of magnesium added and the amount remaining in solution.

F.1.4 Exchangeable Sodium Percentage

Exchangeable sodium percentage (ESP) was calculated from the exchangeable sodium and the cation exchange capacity.

F.1.5 pH of Saturation Paste

Distilled water was added to a sample of soil, with stirring, until the saturation point was reached. The paste was allowed to stand for two hours to reach equilibrium. The pH of this paste was then measured to the nearest 0.1 pH unit using a Pye pH meter with combined glass/calomel electrode.

F.1.6 Gypsum Content

The gypsum content was calculated as the difference between the calcium concentration in the saturation extract and the calcium concentration obtained at a higher soil : water ratio (usually 1:5 but 1:50 or greater for high gypsum values).

F.2 ADDITIONAL METHODS USED IN DETAILED ANALYSIS OF PROFILE PIT SAMPLES

F.2.1 Particle Size and Analysis

40 g of soil were dispersed by shaking overnight with sodium hexametaphosphate/ sodium carbonate solution. The suspension was then transferred to a one litre cylinder, made up to volume and stirred. A Bouyoucos hydrometer was used to take readings after the following settling times:

(a) 46 seconds, to give silt plus clay content;

(b) 6½ hours, to give clay content.

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

F.2.2 Exchangeable Cations

4 g of soil were extracted by shaking with 20 ml of normal ammonium acetate solution buffered at pH 8.4.

Calcium and magnesium were determined by atomic absorption spectroscopy using strontium chloride as a releasing agent to overcome interference by aluminium or phosphate.

Potassium and sodium were also determined by using atomic absorption methods, using strontium chloride as an ionisation buffer.

F.2.3 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.

F.2.4 Soluble Anions in Saturation Extract

(a) Carbonate and Bicarbonate

An aliquot 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 stablised gel. The opaque suspension was then measured using a nephelometer.

F.2.5 Carbonates

Content of calcium and magnesium carbonates was calculated from volumetric measurement of carbon dioxide released on addition of acid (Calcimeter method).

F.2.6 Hot Water Soluble Boron

A weighed sample of soil was extracted, by boiling under reflux for five minutes, with twice its weight of distilled water. The suspension obtained was centrifuged to obtain a clear extract. Boron was detemined in this extract by the curcumin method. Results were expressed as ppm boron in the soil.

F.2.7 Total Phosphorus

A weighed finely ground sample of the soil was digested with perchloric acid. After digestion the sample was centrifuged to obtain a clear extract.

Phosphorus was determined colorimetrically using the vanadate-molybdate method.

F.2.8 Available Phosphorus

Five grains of soil were extracted with 0.02 normal sulphuric acid (100 ml) by shaking for thirty minutes. Phosphorus was determined in the extract by the reduced molybdenum blue method.

F.2.9 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 a mixed indicator of bromocresol green/methyl red. 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.

F.2.10 Organic Carbon Content - Walkley-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 that only 77 per cent of the organic carbon present had been oxidised.

F.2.11 Total Sulphur

The soil sample was refluxed with a reducing mixture of hydriodic, hydrocholoric and hypophosphorous acids. The hydrogen sulphide evolved was absorbed in a solution of sodium hydroxide. The alkaline solution was then reacted with a standard volume of potassium iodide solution. Excess iodine was titrated against thiosulphate using starch as an indicator. The difference between this titration and the titration obtained when the known standard volume of iodine/potassium iodide was titrated directly against the thiosulphate was used to calculate the sulphur present in the sample.

F. 2.12 Moisture Retention Characteristics

Soil samples were collected in the field using a special core sampling device. The dry weight of the undisturbed soil in the core was determined and the bulk density calculated.

Subsequently, the cores were saturated with water, placed in a porous plate apparatus, and subjected to a pressure of 1/10 of an atmosphere. When the moist sample and pressure reached equilibrium water ceased to flow from the pressure chamber. The sample was then removed and weighed to determine the moisture content.

The determinations were repeated at pressures of 1/3 and 1 atmospheres.

The samples were then transferred to the high pressure chamber, and the soil moisture content determined when in equilibrium with a pressure of fifteen atmospheres.

G

Daily Rainfall Statistics for 1978

Meteorological Stations

Jilib (Alessandra)	0°30'N	42°46'E	Altitude 24m.
Jilib State Farms	0°29'N	42°46'E	Altitude 19m. (approx.)
Jubbo Sugar Project	0°25'N	42°42'E	Altitude 20m.*

*Permanent Meteorological Station. Figures from January to July recorded at 'Temporary Office Site'.

Daily Rainfall Statistics 1978

Month: January				Month: February			
Day	Alessandra	State Farm	JSP	Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0	1	0.0	0.0	0.0
2	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	3	0.0	0.0	0.0
4	0.0	0.0	0.0	4	0.0	0.0	0.0
5	0.0	0.0	0.0	5	0.0	0.0	0.0
6	0.0	0.0	0.0	6	0.0	0.0	0.0
7	0.0	0.0	0.0	7	0.0	0.0	0.0
8	0.0	0.0	0.0	8	0.0	0.0	0.0
9	0.0	0.0	0.0	9	0.0	0.0	0.0
10	0.0	0.0	0.0	10	0.0	0.0	0.0
11	0.0	0.0	0.0	11	0.0	0.0	0.0
12	0.0	0.0	0.0	12	0.0	0.0	0.0
13	0.0	0.0	0.0	13	0.0	0.0	trace
14	0.0	0.0	0.0	14	0.0	0.0	0.0
15	0.0	0.0	trace	15	0.0	0.0	0.0
16	0.0	0.0	0.0	16	0.0	0.0	0.0
17	0.0	0.0	0.0	17	0.0	0.0	0.0
18	0.0	0.0	0.0	18	0.0	0.0	trace
19	0.0	0.0	0.0	19	0.0	0.0	0.0
20	0.0	0.0	0.0	20	0.0	0.0	0.0
21	0.0	0.0	0.0	21	0.0	0.0	0.0
22	0.0	0.0	0.0	22	0.0	0.0	0.0
23	0.0	0.0	0.0	23	0.0	0.0	0.0
24	0.0	0.0	0.0	24	0.0	0.0	0.0
25	0.0	0.0	0.0	25	0.0	0.0	0.0
26	0.0	0.0	0.0	26	0.0	0.0	0.0
27	0.0	0.0	0.0	27	0.0	0.0	1.1
28	0.0	0.0	0.0	28	0.0	0.0	0.0
29	0.0	0.0	0.0	29	0.0	0.0	0.0
30	0.0	0.0	0.0	30	0.0	0.0	0.0
31	0.0	0.0	0.0	31	0.0	0.0	0.0
Total	0.0	0.0	0.0	Total	0.0	0.0	1.1

Daily Rainfall Statistics 1978

Month: March

Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	2	6.5
4	6.7	4	18.2
5	20.0	14	6.0
6	45.0	50	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0
9	0.0	0.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	5	1.7
14	0.0	0.0	trace
15	0.0	0.0	0.0
16	2.0	13	trace
17	5.0	0.0	3.0
18	6.0	15	0.0
19	0.0	0.0	0.0
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.0	0.0	0.0
23	0.0	0.0	0.0
24	0.0	0.0	0.0
25	0.0	0.0	trace
26	0.0	0.0	0.0
27	0.0	0.0	0.0
28	0.0	0.0	0.0
29	0.0	0.0	0.0
30	0.0	0.0	0.0
31	0.0	0.0	trace
Total	84.7	103	35.4

Month: April

Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.7
4	0.0	0.0	0.0
5	5.0	13	1.7
6	0.0	0.0	0.0
7	2.0	14	30.0
8	11.0	18	28.8
9	7.0	10	2.0
10	7.0	6	0.0
11	6.0	30	0.8
12	1.0	3	1.0
13	55.0	165	53.2
14	0.0	0.0	0.0
15	8.0	39	1.6
16	0.0	0.0	0.0
17	0.0	10	0.0
18	7.0	0.0	0.0
19	0.0	0.0	2.0
20	0.0	9	13.0
21	10.2	30	28.4
22	21.5	0.0	0.0
23	0.0	0.0	trace
24	0.0	0.0	0.0
25	2.1	0.0	0.0
26	0.0	0.0	0.0
27	0.0	7	4.0
28	0.5	8	15.3
29	8.1	11	1.6
30	2.3	17	14.1
31	0.0	0.0	0.0
Total	153.7	390	198.2

Daily Rainfall Statistics 1978

Month: May

Day	Alessandra	State Farms	JSP
1	18.2	6	7.5
2	2.5	0.0	0.0
3	1.5	31	64.6
4	13.6	3	0.0
5	0.0	22	44.8
6	48.3	0.0	0.0
7	1.3	31	2.4
8	9.8	0.0	0.0
9	0.0	18	7.2
10	78.0	29	23.5
11	16.3	10	4.7
12	9.0	8	4.6
13	0.0	8	0.0
14	0.0	0.0	0.4
15	0.0	0.0	0.5
16	0.0	0.0	0.0
17	0.0	0.0	0.4
18	0.0	0.0	0.7
19	1.1	0.0	0.2
20	0.0	0.0	7.0
21	1.7	0.0	0.0
22	1.4	0.0	1.9
23	5.6	0.0	0.2
24	5.4	27	44.1
25	10.6	0.0	1.1
26	0.0	0.0	0.0
27	1.0	0.0	0.0
28	0.0	10	5.9
29	2.6	0.0	0.2
30	1.0	0.0	0.0
31	0.0	0.0	0.5
Total	**228.9**	**203**	**222.3**

Month: June

Day	Alessandra	State Farms	JSP
1	0.5	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	0.0	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0
9	0.0	0.0	0.0
10	0.0	0.0	0.6
11	0.0	0.0	0.1
12	0.0	0.0	0.0
13	0.0	0.0	1.6
14	0.2	0.0	0.0
15	2.7	0.0	3.8
16	0.4	0.0	2.3
17	1.1	0.0	0.0
18	0.8	0.0	0.0
19	0.0	0.0	0.0
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.0	12	10.6
23	2.8	10	5.7
24	5.5	11	5.8
25	14.5	7	1.0
26	2.1	0.0	2.2
27	1.9	15	0.5
28	2.8	2	2.4
29	1.5	0.0	1.2
30	2.0	0.0	1.8
31	0.0	0.0	
Total	**38.8**	**57**	**39.6**

Daily Rainfall Statistics 1978

Month: July				Month: August			
Day	Alessandra	State Farms	JSP	Day	Alessandra	State Farms	JSP *
1	0.0	0.0	1.8	1	0.0	0.0	0.0
2	2.8	0.0	0.0	2	0.0	0.0	0.0
3	0.0	6	1.4	3	0.0	0.0	0.0
4	0.5	0.0	0.0	4	0.0	0.0	0.0
5	0.0	5	0.0	5	0.0	0.0	0.0
6	0.0	0.0	0.0	6	0.0	0.0	0.0
7	0.0	0.0	0.2	7	0.0	0.0	0.0
8	1.0	0.0	0.5	8	0.5	0.0	0.0
9	0.8	4	0.6	9	0.0	0.0	0.0
10	15.0	18	1.9	10	0.0	0.0	0.0
11	6.0	7	6.3	11	0.0	0.0	0.0
12	0.3	5	13.2	12	0.0	0.0	0.0
13	0.0	0.0	0.0	13	0.0	0.0	0.6
14	0.0	0.0	0.5	14	0.0	0.0	0.0
15	0.0	0.0	0.0	15	0.0	0.0	0.0
16	0.0	0.0	0.2	16	0.0	0.0	0.5
17	0.0	0.0	0.0	17	0.7	0.0	0.5
18	0.0	0.0	0.0	18	0.5	0.0	0.0
19	0.0	0.0	2.0	19	0.0	0.0	0.0
20	0.0	3	1.9	20	0.0	0.0	0.0
21	2.5	4	2.0	21	0.0	0.0	0.0
22	2.0	4	0.0	22	0.0	0.0	0.0
23	0.3	0.0	0.0	23	0.0	0.0	0.0
24	0.0	0.0	0.0	24	0.0	0.0	0.0
25	0.0	0.0	0.0	25	0.0	0.0	0.0
26	0.0	0.0	0.0	26	0.0	8	2.7
27	0.0	0.0	0.0	27	1.5	0.0	0.0
28	0.0	0.0	0.0	28	0.0	0.0	0.0
29	0.0	0.0	0.0	29	0.0	0.0	0.0
30	0.0	0.0	0.0	30	0.0	0.0	0.0
31	0.0	0.0	0.0	31	0.0	0.0	0.0
Total	32.1	56	32.5	Total	3.2	8	4.3

* Transfer to 'Permanent Meteorological Station'.

Daily Rainfall Statistics 1978

Month: September

Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	0.0	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0
9	0.0	0.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	0.0	0.0	0.0
15	0.2	0.0	0.0
16	0.0	0.0	0.0
17	0.0	0.0	0.0
18	0.0	0.0	0.0
19	0.0	0.0	0.0
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.0	0.0	0.0
23	0.0	0.0	0.0
24	0.0	0.0	0.0
25	0.0	0.0	0.0
26	0.0	0.0	0.0
27	0.0	0.0	0.0
28	0.0	0.0	0.0
29	0.0	0.0	0.0
30	0.0	0.0	0.0
31	0.0	0.0	0.0
Total	0.2	0.0	0.0

Month: October

Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.5
6	0.0	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0
9	0.0	0.0	0.0
10	0.0	0.0	0.0
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	0.0	0.0	0.0
15	0.0	0.0	0.0
16	0.0	0.0	0.0
17	0.0	0.0	0.0
18	0.0	0.0	0.0
19	0.0	0.0	0.0
20	0.0	0.0	7.0
21	0.0	0.0	0.0
22	0.0	0.0	0.0
23	0.0	0.0	8.5
24	0.0	0.0	5.1
25	3.0	0.0	5.0
26	0.0	0.0	2.7
27	6.6	5	46.4
28	4.4	0.0	0.0
29	0.0	0.0	3.0
30	20.3	10	3.8
31	2.8	24	19.1
Total	37.1	39	101.4

Daily Rainfall Statistics 1978

Month: November

Day	Alessandra	State Farms	JSP
1	41.5	8	10.0
2	1.0	11	0.0
3	14.2	0.0	0.0
4	0.0	18	13.8
5	2.0	22	3.5
6	47.0	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	8.4
9	22.5	0.0	0.0
10	0.0	77	13.2
11	2.0	10	0.0
12	35.5	0.0	0.0
13	0.0	18	14.8
14	0.0	15	1.3
15	1.1	20	28.5
16	0.0	0.0	0.0
17	2.3	0.0	0.6
18	0.0	0.0	0.0
19	0.0	0.0	1.1
20	0.0	0.0	1.9
21	11.3	0.0	7.3
22	5.5	25	3.2
23	8.5	5	37.4
24	0.2	34	18.5
25	17.6	10	0.0
26	12.0	0.0	0.0
27	0.0	0.0	0.0
28	0.0	0.0	0.0
29	0.0	0.0	0.0
30	1.4	0.0	0.0
31	0.0	0.0	0.0
Total	225.6	273	163.5

Month: December

Day	Alessandra	State Farms	JSP
1	0.0	0.0	0.0
2	0.0	28	37.1
3	6.0	25	42.1
4	15.5	0.0	0.0
5	13.5	0.0	1.2
6	10.4	0.0	0.0
7	0.0	0.0	0.0
8	0.5	15	9.7
9	6.0	15	7.9
10	0.9	8	7.5
11	0.4	15	20.4
12	0.4	30	37.0
13	10.3	5	0.0
14	0.0	0.0	10.6
15	19.5	0.0	0.6
16	0.0	0.0	0.0
17	0.0	0.0	0.0
18	0.0	0.0	0.0
19	0.0	0.0	0.0
20	0.0	0.0	0.0
21	0.0	0.0	0.0
22	0.0	0.0	0.0
23	0.0	0.0	0.0
24	0.0	0.0	0.0
25	0.0	0.0	0.0
26	0.0	0.0	0.0
27	0.0	0.0	0.0
28	0.0	0.0	0.6
29	0.0	0.0	0.0
30	0.0	0.0	0.0
31	0.0	0.0	0.0
Total	83.4	141	174.1