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ROSEIRES SOIL SURVEY

REPORT No. 5

THE NILE
FROM KHARTOUM TO KAREIMA

SOILS AND ENGINEERING RECONNAISSANCE

HUNTING TECHNICAL SERVICES LTD.
4 ALBEMARLE STREET
LONDON, W.1

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON .. W.C.1

SEPTEMBER 1964

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MINISTRY OF AGRICULTURE

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ERRATA

Reference in Text	Correction
Letter of transmittal 3rd Para.3rd line	For Kahushiya read Kabushiya
Acknowledgements 3rd Para.2nd line	For Bori read Bari
References. 1st	For The Republic of Sudan read The Republic of the Sudan.
Chapter 1	
1.5.6th line	For Caltropis read Calotropis
1.9.2nd Para. 4th line	For sandy clay read sandy clay loam.
1.13.3rd Para.(ii) 2nd line	For encrouching read encroaching
4th Para.2nd line	For for read of.
Chapter 2	
2.2 (i) 2nd line	For occuring read occurring
2.34 3rd line	For Figure 6 read Figure 6b.
2.52	For System read Systems
2.54 6th line	For Gossypiurm read Gossypium
Chapter 3	
3.31 2nd line	For hexamotaphosphate read hexametaphosphate.
" 5th line	Delete and
3.51 2nd Para. 4th line	For samples read sampled.
Chapter 4	
4.111 4th Para. 3rd line	For salinty read salinity
4.2 12th Para. last line	For cambic read cambric
Table 4.21 9th line	For Orthustnet read Orthustent
Chapter 5	
5.7 1st Para. 6th line	For supplu read supply
Page 44. last Para. line 3	For it read if
" 47 Para.1. line 6	For avilable read available
" 47 Para.4. line 3	For approved read proved
" 59 Table 6.2	For Medissa read Medisisa

Reference in Text			Correction
Appendix 1			
Page 5. 0-1 cm			For course read coarse
Appendix 2			
Page 1.	2005	110-200cm	E.S.P. For 235 read 100
Page 3.	2062	0 -100cm	" For 104 read 100
"	2087	0 -15cm	Sat.% For 198 read 20
"	2092	0 -30cm	" For 254 read 25
Page 4	2106	0 -150cm	" For 204 read 20
"	"	150 -200cm	" For 192 read 19
"	2112	0 -74cm	Coarse Sand. For 81 read 8
"	2117	0 -75cm	" " For 41 read 4
Page 6	2160	10 -60cm	E.S.P. For 110 read 100

Dr. R. Smith

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Lion House
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12302

YOUR REF.----------

OUR REF. ----------

11th December, 1964.

H.E. The Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY REPORT NO. 5.

We have pleasure in submitting our Report No. 5 for the Roseires Soil Survey Project, the study of which was entrusted to us by the Contract dated September, 1962.

The Report, which is accompanied by an album of maps, contains the results of the reconnaissance soil and engineering survey carried out along the Main Nile on both banks between Khartoum and Kareima. In the Contract this area is described as Area 4 and is specified to include both banks of the Nile from Khartoum to the Third Cataract (north of Dongola). We have already submitted to you, on 15th October 1963, our Report No. 3 which covered the northern part of Area 4 from Kareima to the Third Cataract. Report No. 5 covers the remainder of Area 4 and so the reconnaissance surveys to the north of Khartoum are concluded.

We would like to point out that the 20 metre isopotamon has not been established for a number of sections, mainly between Kahushiya and Abu Hamed. This work was curtailed, after consultation with the Director of Agriculture, so that the reconnaissance engineer could devote the remainder of the field season, mid March to mid May 1964, on location of pump sites and survey of canal headreaches for possible project areas. If you should consider it necessary the establishment of the 20 metre isopotamon could be completed during the 1964/65 season after the reconnaissance engineers complete the field work in Area 5b (White Nile Rabak to Melut).

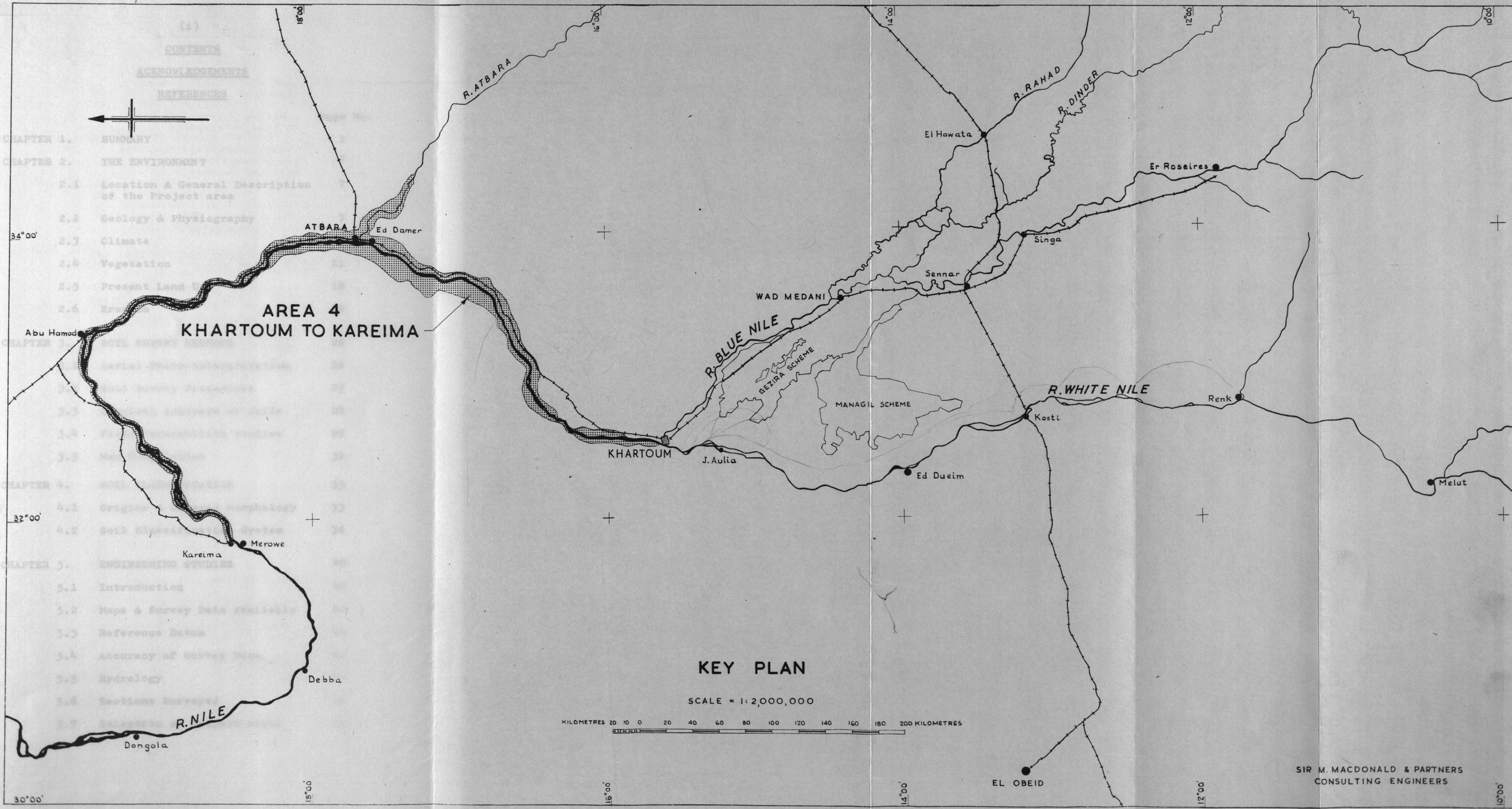
A detailed list of the projects and areas recommended for semi-detailed soil survey is given in the summary of the report. We have recommended that a total area of 271,000 feddans be covered by the semi-detailed soil survey. Of these 67,000 feddans are comparatively more difficult to irrigate.

The necessary agricultural and soil studies were undertaken on our behalf by Messrs. Hunting Technical Services Ltd. under the direction of Dr. Robert Smith, Consultant in charge of the soil surveys. Dr. Smith will be available in Khartoum for discussions on this Report if required by you.

We are, Excellency,

Your obedient Servants

SIR M. MACDONALD & PARTNERS.



KEY PLAN

SCALE = 1: 2,000,000

KILOMETRES 20 10 0 20 40 60 80 100 120 140 160 180 200 KILOMETRES

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS

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ACKNOWLEDGEMENTS

The compilation of a report of this nature cannot be completed without reference to the many organisations and individuals, both in the Sudan and the United Kingdom, who have assisted us either by providing information, advice or facilities. Among the many who have assisted us in this way are the following, to whom our thanks are due.

Sudan Government:

The many members of both administrative and technical staff in the Ministry of Agriculture, including the Permanent Secretary to the Minister, the Chief Research Officer, the Senior Inspector of Agriculture, Northern Province and many of his staff; Members of the Ministry of Irrigation and Hydro-Electric Power, the Geological Survey Department, the Agricultural Bank and officers of the local administrations and police.

University of Khartoum:

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Messrs. Agricultural Services (Sudan) Ltd.

The analyses of all the soil samples were carried out in the Khartoum laboratory of Messrs. Agricultural Services (Sudan) Ltd.

Zeidab Syndicate

The General Manager and the Assistant Manager of the Zeidab Estate.

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CHAPTER I

SUMMARY

1.1 The reconnaissance soils and engineering survey of the southern part of Area 4, Khartoum to Kareima, covered a gross area of nearly one million feddans of land located mostly in the Shendi, Berber and Abu Hamed Districts of Northern Province but including smaller areas in Khartoum and Kassala Provinces.

1.2 The project lands form a narrow and discontinuous strip of flood plain and alluvial terrace on both banks of the Main Nile from Khartoum downstream to the Fourth Cataract, a distance by river of about 755 kilometres. Also included is a narrow strip of land on both banks of the river Atbara extending 75 kilometres upstream from its junction with the Main Nile.

1.3 The upper limit of survey is defined by contract as the 20 metre isopotamon. Our survey shows that there is no irrigable land above this level. In fact, the dissected platform of sandstones and granite-gneisses is usually encountered below the 20 metre isopotamon and rock outcrops are often found beside the river as in the long reach between the 4th and 5th cataracts where areas of arable land are minimal.

1.4 The project area lies partly within the semi-desert region and partly within the desert region of the Sudan.

North of Berber the rainfall is negligible (Abu Hamed averages 17 mm per year) and the summers are very hot and dry as the southerly winds do not bring rain to the region. The winters are cooler but are characterized by strong drying northerly winds which cause serious sand drift from the north east.

South of Berber the rainfall increases steadily. Atbara receives an annual average of 72 mm. mostly in July and August, whilst Shendi receives 135 mm. and Khartoum 164 mm. mostly in July, August and September.

1.5 In the desert zone north of Berber vegetation is virtually absent except along the river. Further south, with increased rainfall some vegetation is found on the higher dry, terrace; scattered Acacia ehrenbergiana bushes throughout the area, Panicum turgidum on sandy sites, Caltropis procera near villages, Acacia mellifera near Shendi and occasionally Capparis decidua, Corchorus depressus and Aristida species. Riparian vegetation is much more varied and plentiful. Common tree species are Acacia albida, A. Seyal, A. arabica, A. tortilis and Hyphaene thebaica. Other common species are Cadaba rotundifolia, Salvadora persica, Demostachya bipinnata, Indigofera oblongifolia, Ziziphus spina-Christi, Euphorbia granulata and Capparis decidua.

1.6 The total population in the area between Sabaloka Gorge and Abu Hamed is about 500,000 people. There are three larger urban centres :-

Atbara (population 36,200)

Berber (11,000) and Shendi (11,000).

There is some industrial development at Atbara which is headquarters of the Sudan Railway and possesses a cement factory. Otherwise the population of the towns and villages and the nomads of the area are dependent for a livelihood on irrigable farming and/or grazing in the south.

1.7 Except for negligable areas of rainfed catch cropping in the south, all the farmland is under one of the forms of irrigation described below :-

Seluka cultivation is carried out on the moist silt on banks and islands of the Nile and Atbara after subsidence of the annual flood. The chief crop grown is dura.

Saqia cultivation, powered by oxen, is carried out on lands close to the river. There are 2,023 feddans of saqia cultivation on the Nile in the Shendi-Berber districts and 219 feddans on the Atbara (up to 75 km. from Atbara town). The chief crops grown are wheat, barley lubia, lucerne, fasulia and ful musri in the winter season, dura and lucerne in the summer season and dura, lubia and maize in the flood season. There are also some orchard lands.

Private Pump Schemes (about 500), with perennial, restricted orflood licences, irrigate 45,820 feddans in the Shendi district and 44,677 feddans in the Berber district. The largest private pump schemes are the Zeidab concession and Fadlab concession, both of which grow medium staple cotton as the chief cash crop.

Government Pump Schemes at Gandetto, Kitiab, Aliab and El Bauga irrigate a gross area of almost 18,000 feddans. Water rates are charged according to the crops grown :- wheat, Egyptian beans, fasulia, lubia, dura, maize, orchards (perennial), clover or vegetables.

Basin Irrigation varies somewhat from year to year depending on the height of the flood. In an average year about 47,500 feddans is irrigated in the following basins :- Hugna (2,000). Medisisa (500), Wad Hamid (9,000), Salawa (5,000), S yal (3,000), Surfur (6,000), Kelli (7,000), Taiyiba and Guweir (10,000) and El Basabir (5,000). The basins are administered by the Northern Province authorities while Ministry of Irrigation and H.E. Power is responsible for the operation and maintenance of the inlet and outlet canals and cross banks where present. Food crops are grown in the basins after the flood waters have subsided.

1.8 The soil survey was carried out according to the specifications of the agreement of 27th September, 1962. After elimination of obviously unsuitable lands by air photo-interpretation and preliminary field inspection the density of soil observations on the selected lands was one site for

each 2.500 feddans. At 45 selected representative sites throughout the project area, soil profiles were examined in 2 metre deep pits and samples were taken for laboratory examination as follows :- mechanical analysis, pH on 1:5 suspension and soil paste, electrical conductivity on soil paste, exchangeable sodium and cation exchange capacity; exchangeable sodium percentage (E.S.P.) was calculated from the two last analyses. Field permeability tests were carried out at representative sites.

1.9 The soil survey shows that the soils of Area 4 South, are similar to the soils of Area 4 North, (Kareima to the Third Cataract), but are different in origin and morphology from those of the Gezira area. Whereas the Gezira soils are mostly Vertisols (cracking clays) the soils of Area 4 South, are Entisols (stratified soils without natural genetic horizons). Because of the arid environment these Entisols belong to the sub-order of Ustents. The Ustents are then further sub-divided into sandy soils. (Psammustents) and loamy soils (Orthustents).

The Orthustents are moderately to slightly calcareous, stratified soils with an appreciable silt component. The textures generally fall in the range of loamy sand, sandy loam, sandy clay, loam, clay loam, and sandy clay. Gravels and stones are frequent in soils of the upper (older) terraces but are generally absent on the flood plain and lower (younger) terraces. The soils may be saline or non-saline. Appreciable exchangeable sodium is present at many of the sample sites and the soil reaction varies from slightly to strongly alkaline.

The soils are classified as follows :-

Orthustent Sub-Group	Characteristics
Orthic	non saline, non alkali, loamy soils.
Psammustentic	with a sandy horizon.
Calcorthidic	with a highly calcareous horizon.
Natrargidic	alkali loam.
Vertic	non saline, non alkali clay.
Natrargidic Vertic	alkali clay.
Lithic	stony or rocky within 50 cm.

Psammustent Sub-Group	Characteristics
Oxic	sand or loamy sand to at least 70 cm.
Orthustentic	with a loamy horizon below 50 cm.
Lithic	occasional stones or rock outcrops.

1.10 In addition to the Entisols there are a few sites that are tentatively classed as belonging to the soil order of Aridisols. These are high alkali sites classed as Natrargids.

1.11 The engineering survey was concerned with establishing the 20 metre isopotamon and the nature of the position of major topographic obstacles where these were encountered between the 20 metre level and the river.

The position of the 20 metre isopotamon was established by office and field studies, using as a basis, the cross sections at approximately 4 kilometre intervals established by the 1951-52 survey of the Sudan Survey Department which covered the ground up to the 15 metre isopotamon.

1.12 In addition to establishing the 20 metre isopotamon, the reconnaissance engineer, by field and office studies using aerial photography, located possible pump sites for project areas. Short lengths of canal head reach were surveyed and preliminary canalisation layouts were prepared for each area.

When the soil survey was completed and it was found that the limit of suitable soils, as defined by the reconnaissance soil survey, did not extend beyond the 15 metre isopotamon, work ceased on establishing the 20 metre isopotoman and emphasis was given to the survey of possible pump sites and canal lines.

1.13 The land suitability classification is concerned with agricultural, engineering and land tenure considerations.

Registered lands, where fully developed by private enterprise, were excluded from our soil survey and land suitability classification, as were the lands of the government pump projects some of which are privately owned and some of which are government lands. Our soil survey and land suitability classification is confined to the undeveloped registered lands, Government lands of the basins (partly developed) and the undeveloped river terraces.

Agricultural aspects of land suitability were confined to the physical bases of potential agricultural production. As in Area 4 North, topographic and soils limitations were the chief limiting factors. Topographic limitations are of three types :-

i) Gullied lands of the upper terraces which suffer from run-off from the rocky tablelands above them.

ii) Sand dunes, often unstable, in the basins of Shendi district and encrouching from the desert in Berber District.

iii) Uneven terrain associated with old river channels especially in the basins and lower terraces.

Soils limitations may be physical such as excessive sandiness near flattened dunes, the presence for excessive stones and gravel as on the upper terraces, or bad soil structure as in the Natrargid soils of the lower terraces near Shendi and Ed Damer. Chemical limitations are due to fairly widespread alkalinity (high E.S.P.) and occasional high salinity; because of the coarser texture and higher permeability of these soils it is considered that reclamation would be possible in most places.

1.14 The lands recommended for semi-detailed survey and land suitability classification in Area 4 South, have been divided into two categories described as favourable lands and difficult lands as shown in Table 1.141.

Table 1.141 Areas Recommended for semi detailed survey

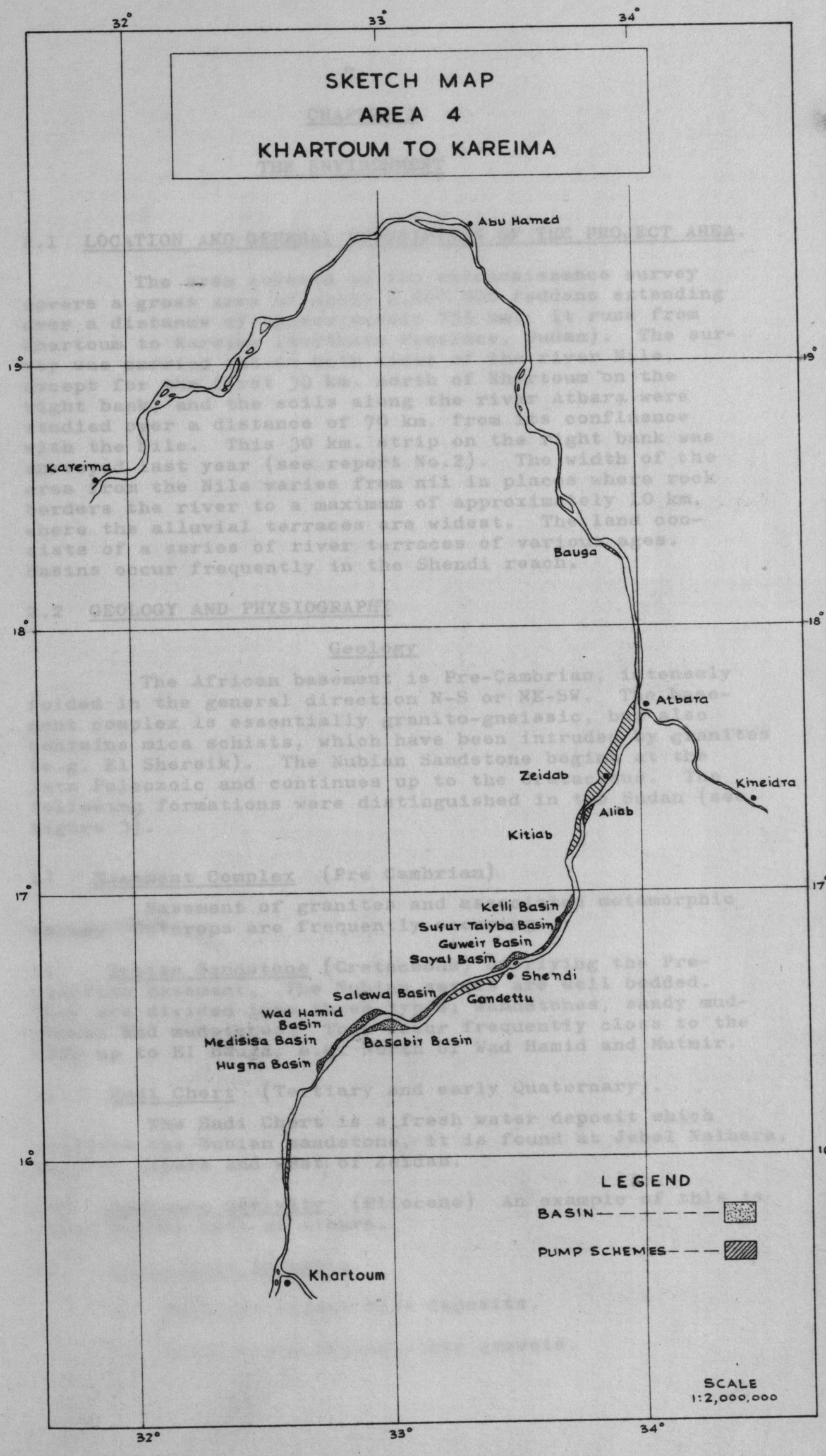
I Favourable Lands

Serial No.	Locality	Area (Feddans)
a1	Hugna Basin	2,800
a2	Medisisa-Wad Hamed Basins	18,000
a3	Salawa-Habashi Basins	10,500
a4	Sayal Basin	3,800
a5 & a6	Guweir-Kelli Basins and Kitiab south extension.	57,300
a7	Kitiab west	1,000
a8	Aliab west	2,900
a9	Zeidab NW extension	4,300
b10	El Bauga extension	10,000
a11	Basabir - Wad ban Naga Basins	16,000
a12	Kabushiya area	11,400
a13	Mutmir-Aliab strip	3,200
a14	Aliab West north extension	1,200
b15	Atbara town south	6,000
b16	Adabia area	6,800
b17	Hassa area	8,500
b18	Atbara river, left bank opposit Kineidra.	22,000
b19	Atbara river, right bank at Kineidra	18,100
	Category I total area	203,800

II Difficult Lands

Serial No.	Locality	Area (Feddans)
a20	Wad Hamid west extension	13,500
a21	Shendi higher terrace	37,500
b22	Shendi SW sandy area	6,600
b23	Taragma area	6,100
c24	Atbara River right bank between cross sections 7 & 9.	3,500
	Category II total area	67,200

Grand Total Categories I and II 271,000 feddans


SKETCH MAP
AREA 4
KHARTOUM TO KAREIMA
32°
33°
34°
19°
18°
17°
16°
Abu Hamed
Kareima
Bauga
Atbara
Zeidab
Kineidra
Aliab
Kitiab
Kelli Basin
Sufur Taiyba Basin
Guweir Basin
Sayal Basin
Shendi
Salawa Basin
Gandettu
Wad Hamid Basin
Medisisa Basin
Basabir Basin
Hugna Basin
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CHAPTER 2

THE ENVIRONMENT

2.1 LOCATION AND GENERAL DESCRIPTION OF THE PROJECT AREA.

The area covered by the reconnaissance survey covers a gross area of about 1,000,000 feddans extending over a distance of approximately 755 km. It runs from Khartoum to Kareima (Northern Province, Sudan). The survey was carried out on both sides of the river Nile, except for the first 30 km. north of Khartoum on the right bank, and the soils along the river Atbara were studied over a distance of 70 km. from its confluence with the Nile. This 30 km. strip on the right bank was surveyed last year (see report No.2). The width of the area from the Nile varies from nil in places where rock borders the river to a maximum of approximately 10 km, where the alluvial terraces are widest. The land consists of a series of river terraces of various ages. Basins occur frequently in the Shendi reach.

2.2 GEOLOGY AND PHYSIOGRAPHY

Geology

The African basement is Pre-Cambrian, intensely folded in the general direction N-S or NE-SW. The basement complex is essentially granito-gneissic, but also contains mica schists, which have been intruded by granites (e.g. El Shereik). The Nubian Sandstone begins at the late Paleozoic and continues up to the Cretaceous. The following formations were distinguished in the Sudan (see Figure 3).

i) Basement Complex (Pre Cambrian)

Basement of granites and associated metamorphic rocks. Outcrops are frequently occuring.

ii) Nubian Sandstone (Cretaceous) overlying the Pre-Cambrian basement. The Nubian series are well bedded. They are divided into three types; sandstones, sandy mudstones and mudstones. They occur frequently close to the Nile up to El Bauga, e.g. North of Wad Hamid and Mutmir.

iii) Hudi Chert (Tertiary and early Quaternary).

The Hudi Chert is a fresh water deposit which overlies the Nubian sandstone, it is found at Jebel Nalhara, east of Atbara and west of Zeidab.

iv) Volcanic Activity (Pliocene) An example of this is Jebel Nakhra West of Atbara.

v) Quaternary Deposits

a) Holocene recent Nile deposits.

b) Pleistocene Palaeolithic gravels.

Physiography

The Nile valley between Khartoum and Abu Hamed extends over a distance of approximately 580 km. and the Nile follows the NE-SW and NW-SE faults in the Basements complex. The fall of the Nile between these two towns is approx. 65 m. Where the rocks of the Basement complex are more resistant to erosion the 5th, cataract, approximately 120 kilometres north of El Bauga, at Granita and Sabaloka Gorge approximately 80 km. north of Khartoum, occur.

In both places the river bed is braided. It is shallow in the dry season at the 5th cataract but at Sabaloka Gorge, the depth is usually about 20 metres.

Rather broad terraces occur on both sides of the river, where the river crosses the Nubian series; but not always at the same level on both sides. In general three terraces occur, including the recent floodplain. At Jebel El Nakhra a 4th terrace has been discovered by Berry (1963).

Basins occur on both sides of the river, especially in the Shendi area; but also further north, for example at Hudeiba. These basins are mostly former river courses and are seldom flat and level. The area between the pump scheme and the Nubian sandstones at El Bauga is also probably an old river channel. A dissected levee has been recognised north of Shendi, on the east bank. On the west bank of the Nile between Khartoum and Sabaloka is a narrow silt terrace approximately 1 kilometre in width. On the other side the terraces are broad, but are decreasing in width North of Qubba. In the Sabaloka Gorge (basement complex) a very high silt terrace has been recognised (findings of L. Berry, University of Khartoum). Fixed or moving dunes of the qoz type occur on the higher terraces on both sides of the river. Most of these dunes are derived from the Nubian series; between El Guweir and Kitiab dunes occur in the basins. They are derived both from the Nubian series and water borne sand. The active dunes in the northern part of the area consist of fine to very fine sand. A good example is the barchans approximately 25 km. North of Kurgos.

Undulating gravel ridges, derived from the Nubian series, were found on both sides of the river.

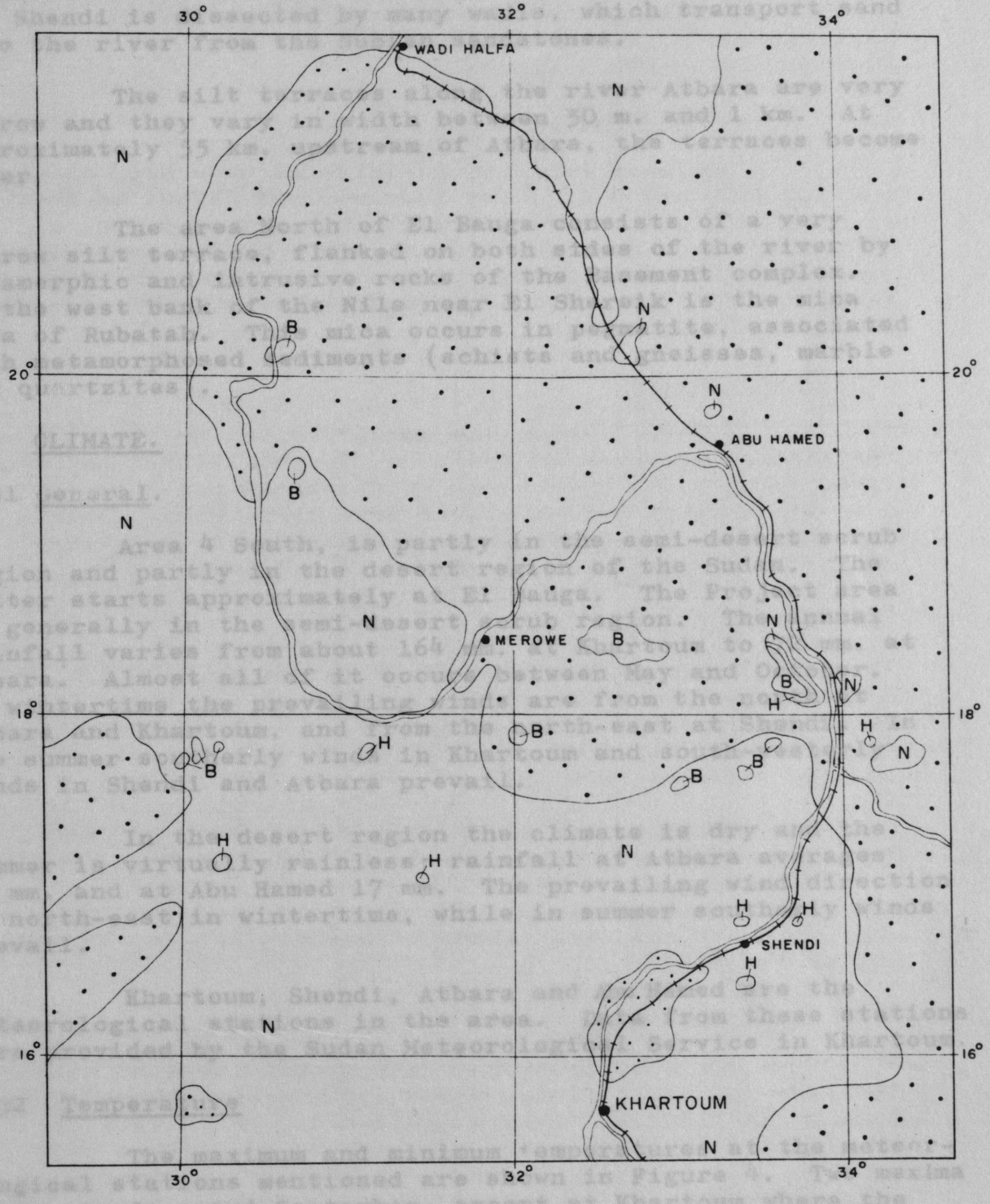
Neolithic sites, in the form of gravel mounds, were distinguished on the West as well as on the East bank of the river on the higher terraces only e.g. West of Maknia.

South of Atbara is a pre-Paleolithic terrace.

North of Atbara the terraces are narrow and much more eroded than south of Atbara, due to the contribution of the Atbara river, which has a brief and strong river flood.

GEOLOGICAL MAP OF NORTHERN SUDAN

SCALE 1:4,000,000



Hudi Chert – Middle Tertiary ..... H

Nubian Series, Mesozoic ..... N

Lavas, Tertiary ..... B

Basement Complex .....

A full sequence of formations at Jebel Nakhra, consisting of lavaflow, gravels, Hudi Chert and Nubian sandstones, was discovered by Berry (1963). The alluvial plain north of El Bauga varies in width from 100 to 1,000m, flanked by metamorphic rocks on both sides of the river. Topography of the lower silt terraces is in general quite flat with occasional sand dunes or a sandy layer. The higher terraces are more eroded. The area between Sabaloka and Shendi is dissected by many wadis, which transport sand into the river from the Nubian sandstones.

The silt terraces along the river Atbara are very narrow and they vary in width between 50 m. and 1 km. At approximately 55 km. upstream of Atbara, the terraces become wider.

The area North of El Bauga consists of a very narrow silt terrace, flanked on both sides of the river by metamorphic and intrusive rocks of the Basement complex. On the west bank of the Nile near El Shereik is the mica area of Rubatab. This mica occurs in pegmatite, associated with metamorphosed sediments (schists and gneisses, marble and quartzites).

2. CLIMATE.

2.31 General.

Area 4 South, is partly in the semi-desert scrub region and partly in the desert region of the Sudan. The latter starts approximately at El Bauga. The Project area is generally in the semi-desert scrub region. The annual rainfall varies from about 164 mm. at Khartoum to 72 mm. at Atbara. Almost all of it occurs between May and October. In wintertime the prevailing winds are from the north at Atbara and Khartoum, and from the north-east at Shendi. In the summer southerly winds in Khartoum and south-westerly winds in Shendi and Atbara prevail.

In the desert region the climate is dry and the summer is virtually rainless: rainfall at Atbara averages 72 mm. and at Abu Hamed 17 mm. The prevailing wind direction is north-east in wintertime, while in summer southerly winds prevail.

Khartoum, Shendi, Atbara and Abu Hamed are the meteorological stations in the area. Data from these stations were provided by the Sudan Meteorological Service in Khartoum.

2.32 Temperature

The maximum and minimum temperatures at the meteorological stations mentioned are shown in Figure 4. Two maxima occur, in June and September, except at Khartoum where the maxima are in May and October. There is a slight drop in temperature in August, due to the influence of the moist southern winds. (This decreases from Khartoum northwards). The lowest temperatures occur in January throughout the area.

2.33 Rainfall

The rainfall varies considerably from year to year; the average decreasing rapidly from Khartoum to Atbara. At Khartoum and Shendi, most of the rain falls in July, August and September, while at Atbara and Abu Hamed it falls in July and August. The rainfall at Abu Hamed is extremely low.

Occasional heavy showers of 25 - 100 mm. have been recorded. The mean monthly rainfall at the four stations is shown in Figure 5.

2.34 Relative Humidity

The mean relative humidity at 0600 hrs, 1200 hrs and 1800 hrs G.M.T. for Khartoum and Shendi is shown on Figure 6a and for Atbara and Abu Hamed on Figure 6. At Shendi there were no data available of the measurements at 1800 hours G.M.T. A humidity peak occurs in August at all the stations, and there is a small rise in December and January.

2.35 Evaporation

Figure 7 shows the annual variation in daily evaporation measured at Khartoum, Shendi, Atbara and Abu Hamed using Piche cylinders, which allows water to diffuse into air through porous plates from small glass flasks. The variation in evaporation at Khartoum is the largest, while the variation at Abu Hamed is smaller.

2.36 Cloud Amount

Cloud amount has been recorded at 0600 hrs. 12.00 and 1800 hrs. G.M.T. at Khartoum, Atbara and Abu Hamed and at 0600 hrs., and 1200 hrs. at Shendi. It is measured on a scale from 0 (no cloud) to 8 (100% cloud cover). The monthly averages from 1931-60 are shown in Table 2.36.

Khartoum has an average cloud cover of over 50% in July and August and less than 20% in December, January and February. It is remarkable that the average cloud cover in Shendi drops to 10% during the same months. In general there are more clouds at midday than in the morning and evening.

2.37 Wind Direction

The distribution of the prevailing wind direction is shown in the following Table 2.37 for Khartoum (1956-61), Shendi (1952-62) and Atbara (1951-60). There were no data available from Abu Hamed. At Khartoum and Atbara the prevailing wind blows from the north, during the months of October to May-June. Khartoum has a southern summer wind, while at Atbara south-westerly winds prevail. In the Shendi area a north-easterly wind blows during the months October to May, while in the summer months the prevailing wind is south-westerly.

2.38 Amount of Sunshine and Solar Radiation

Table 2.38 shows the amount of sunshine and solar radiation for Khartoum (1957-62). There were no data available for Shendi, Atbara and Abu Hamed. In the rainy season the amount of sunshine is the lowest.

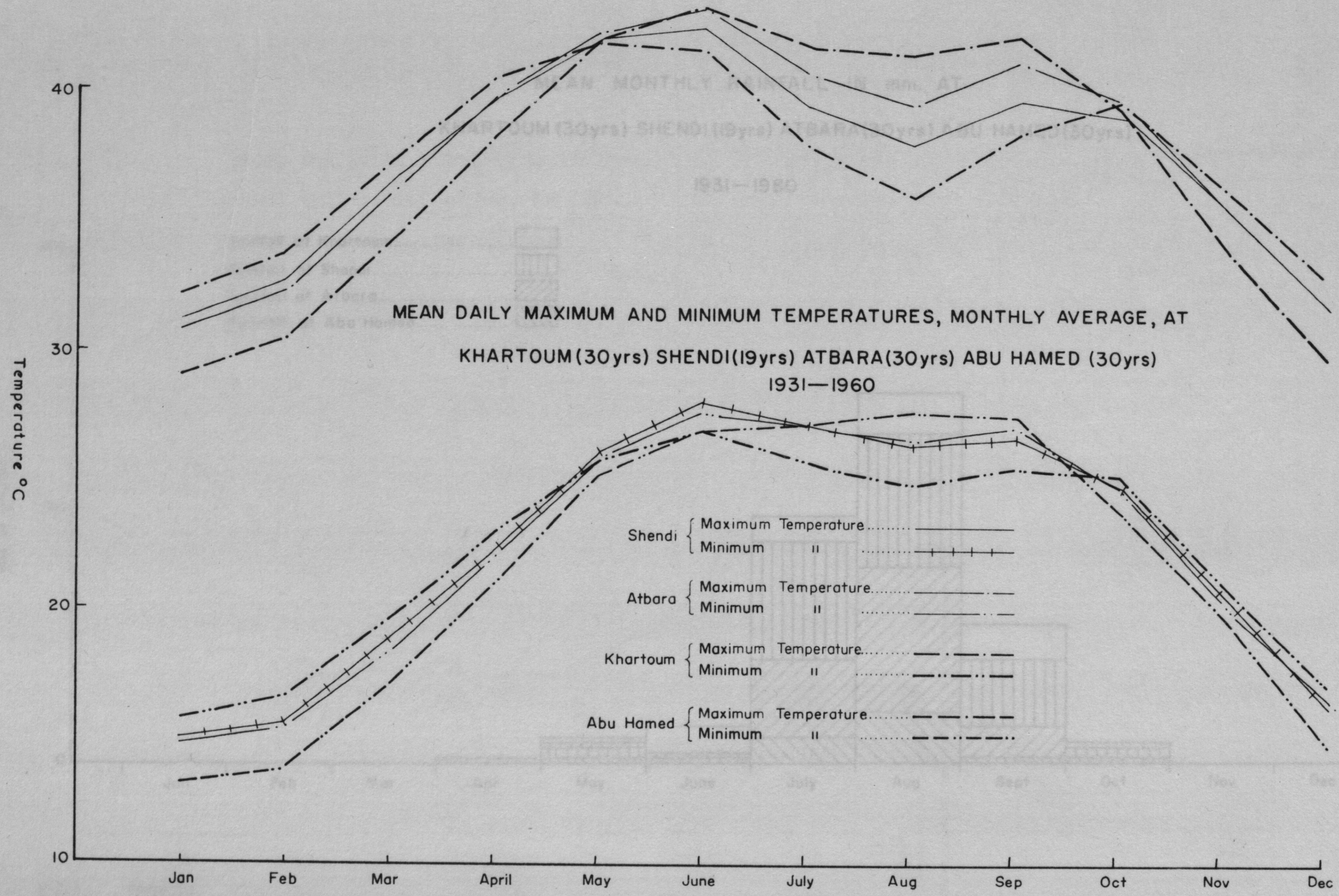

MEAN DAILY MAXIMUM AND MINIMUM TEMPERATURES, MONTHLY AVERAGE, AT
KHARTOUM (30yrs) SHENDI (19yrs) ATBARA (30yrs) ABU HAMED (30yrs)
1931—1960
Temperature °C
40
30
20
10
Jan
Feb
Mar
April
May
June
July
Aug
Sep
Oct
Nov
Dec
Shendi { Maximum Temperature
Minimum "
Atbara { Maximum Temperature
Minimum "
Khartoum { Maximum Temperature
Minimum "
Abu Hamed { Maximum Temperature
Minimum "

Figure 4

MEAN MONTHLY RAINFALL IN mm. AT

KHARTOUM (30yrs) SHENDI (19yrs) ATBARA (30yrs) ABU HAMED (30yrs)

1931—1960

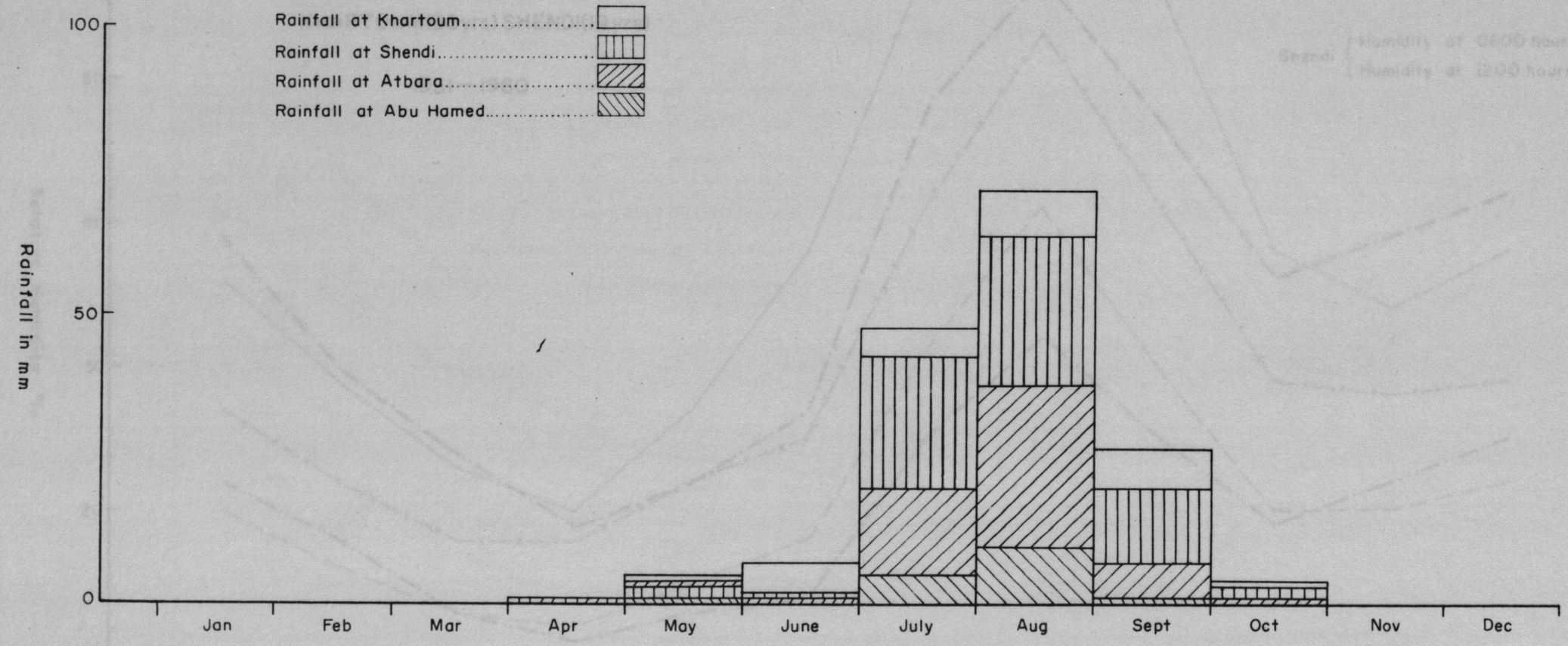


Figure 5

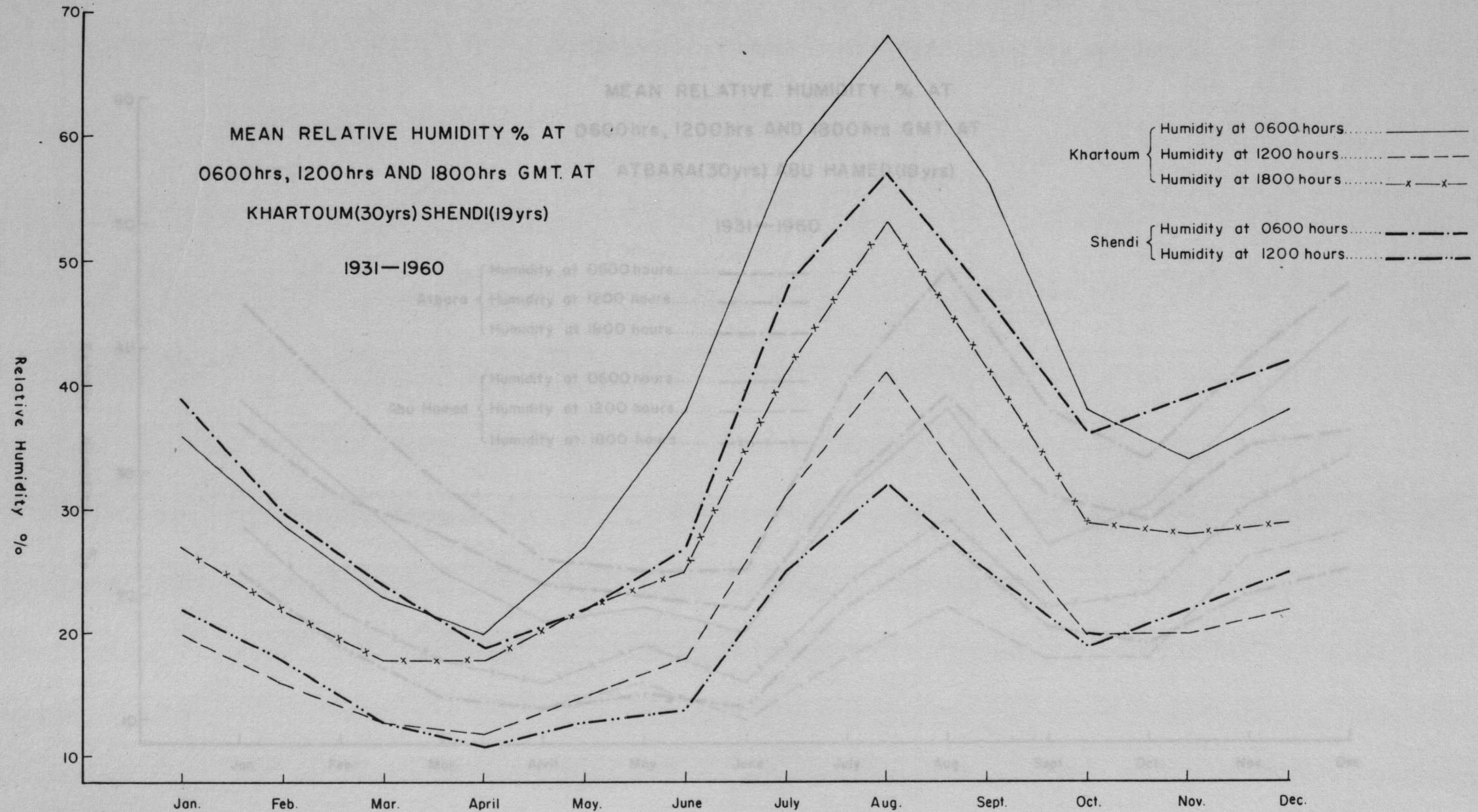

MEAN RELATIVE HUMIDITY % AT
0600hrs, 1200hrs AND 1800hrs GMT. AT
KHARTOUM(30yrs) SHENDI(19yrs)
1931—1960
Khartoum
Humidity at 0600 hours
Humidity at 1200 hours
Humidity at 1800 hours
Shendi
Humidity at 0600 hours
Humidity at 1200 hours
Relative Humidity %
70
60
50
40
30
20
10
Jan.
Feb.
Mar.
April
May.
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 6a

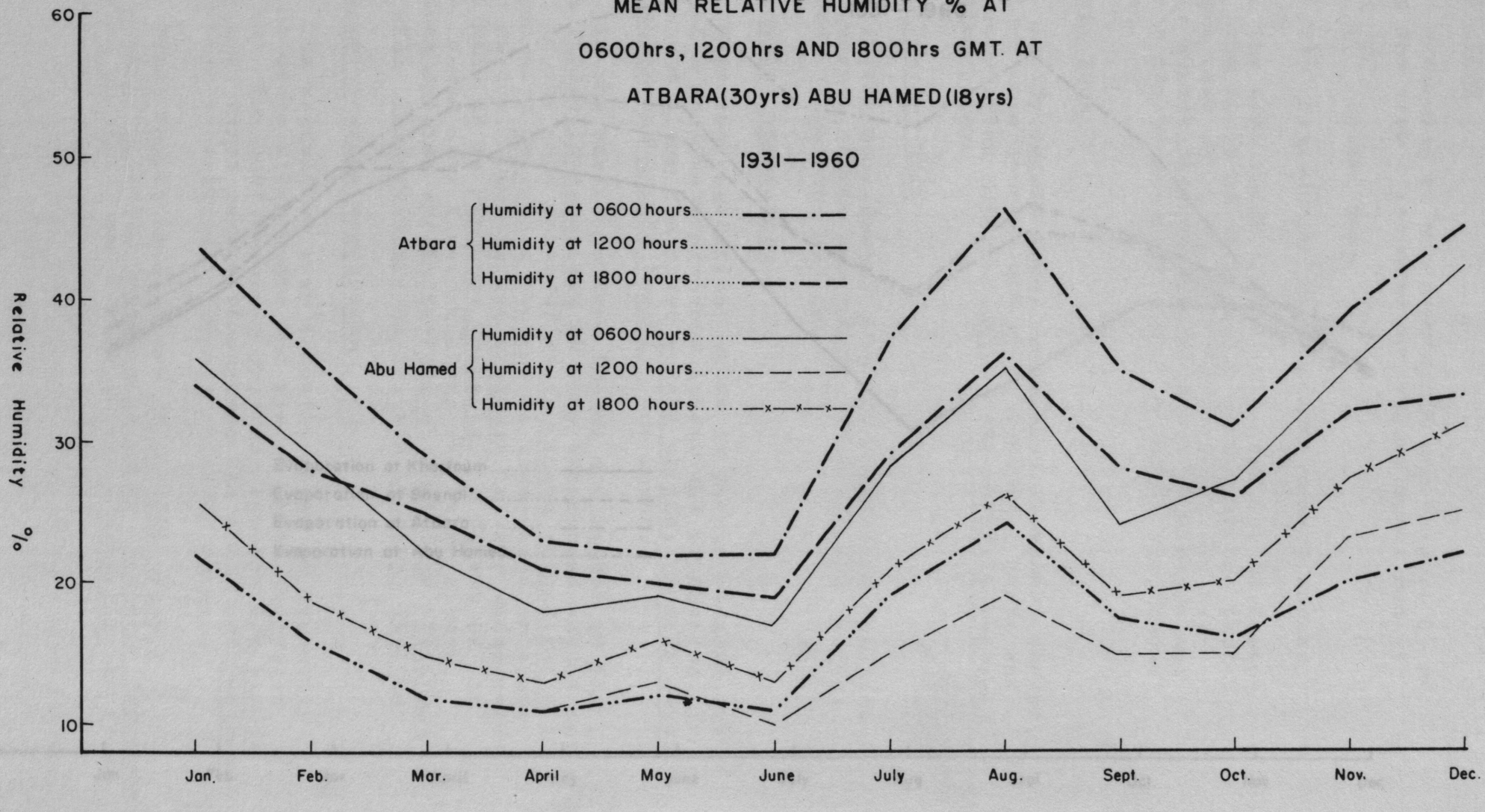
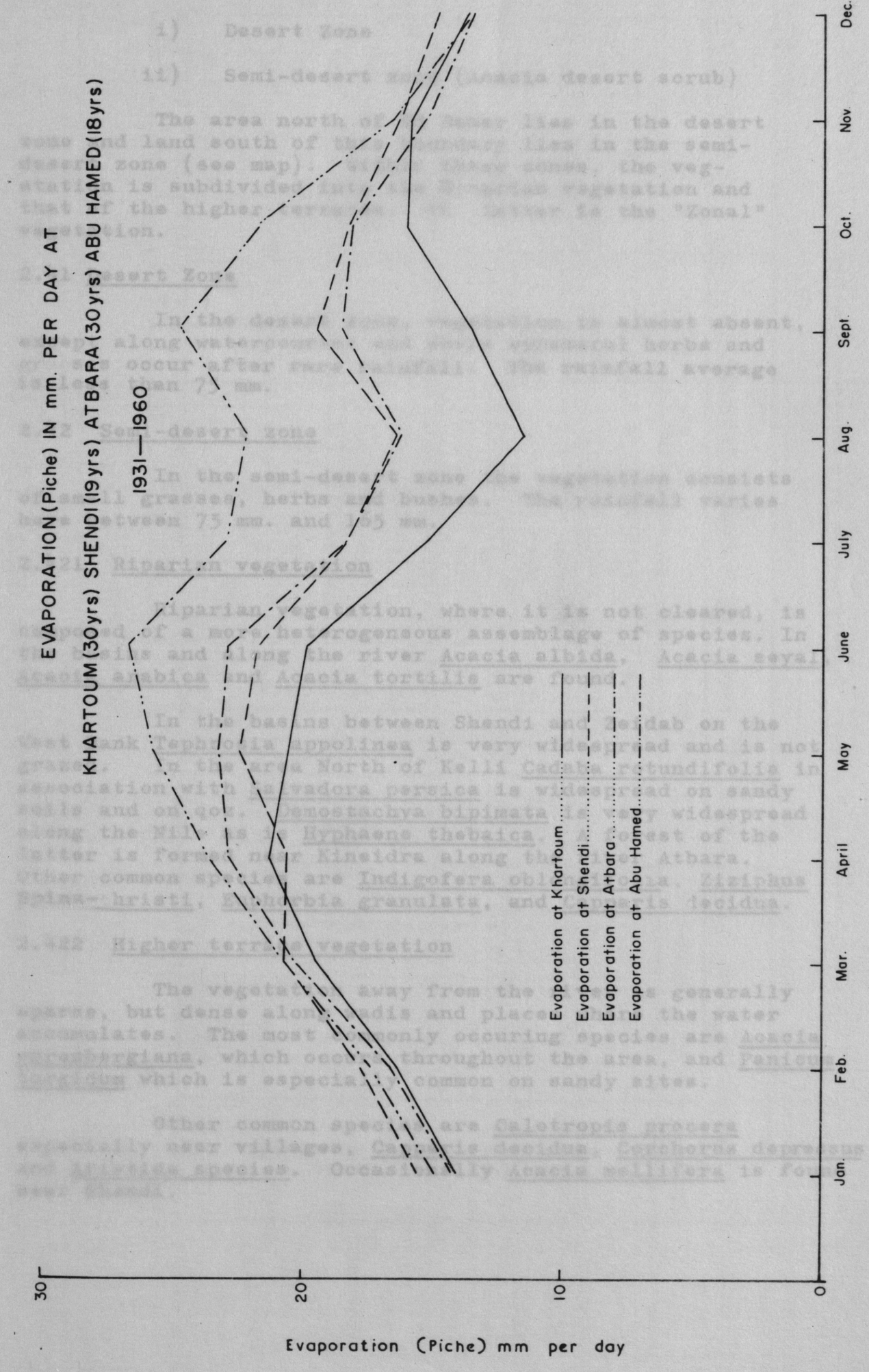

MEAN RELATIVE HUMIDITY % AT
0600hrs, 1200hrs AND 1800hrs GMT. AT
ATBARA(30yrs) ABU HAMED(18yrs)
1931—1960
Atbara
Humidity at 0600 hours
Humidity at 1200 hours
Humidity at 1800 hours
Abu Hamed
Humidity at 0600 hours
Humidity at 1200 hours
Humidity at 1800 hours
Relative Humidity %
60
50
40
30
20
10
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Figure 66

Figure 7


EVAPORATION (Piche) IN mm. PER DAY AT
KHARTOUM (30yrs) SHENDI (19yrs) ATBARA (30yrs) ABU HAMED (18yrs)
1931—1960
Evaporation at Khartoum
Evaporation at Shendi
Evaporation at Atbara
Evaporation at Abu Hamed
Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
0
10
20
30
Evaporation (Piche) mm per day

2. VEGETATION

According to the vegetation map (Figure 8) of the Sudan the area 4 includes two vegetational zones:

i) Desert Zone

ii) Semi-desert zone (Acacia desert scrub)

The area north of Ed Damer lies in the desert zone and land south of this boundary lies in the semi-desert zone (see map). Within these zones, the vegetation is subdivided into the Riparian vegetation and that of the higher terraces. The latter is the "Zonal" vegetation.

2.41 Desert Zone

In the desert zone, vegetation is almost absent, except along watercourses and where ephemeral herbs and grasses occur after rare rainfall. The rainfall average is less than 75 mm.

2.42 Semi-desert zone

In the semi-desert zone the vegetation consists of small grasses, herbs and bushes. The rainfall varies here between 75 mm. and 165 mm.

2.421 Riparian vegetation

Riparian vegetation, where it is not cleared, is composed of a more heterogeneous assemblage of species. In the basins and along the river Acacia albida, Acacia seyal, Acacia arabica and Acacia tortilis are found.

In the basins between Shendi and Zeidab on the West Bank Tephrosia appolinea is very widespread and is not grazed. In the area North of Kelli Cadaba rotundifolia in association with Salvadora persica is widespread on sandy soils and on qoz. Demostachya bipimata is very widespread along the Nile as is Hyphaene thebaica. A forest of the latter is formed near Kineidra along the river Atbara. Other common species are Indigofera oblongifolia, Ziziphus Spina-christi, Euphorbia granulata, and Capparis decidua.

2.422 Higher terrace vegetation

The vegetation away from the river is generally sparse, but dense along wadis and places where the water accumulates. The most commonly occuring species are Acacia ehrenbergiana, which occurs throughout the area, and Panicum turgidum which is especially common on sandy sites.

Other common species are Calotropis procera especially near villages, Capparis decidua, Corchorus depressus and Aristida species. Occasionally Acacia mellifera is found near Shendi.

Table 2.36 Cloud (0 = no cloud, 8 = 100% cloud cover). Monthly Average at 4 Representative Stations.

Month	Khartoum (30 years)			Shendi (19 years)		Atbara (30 years)			Abu Hamed (18 years)		
	0600 hrs.	1200hrs.	1800 hrs.	0600 hrs.	1200 hrs.	0600 hrs.	1200 hrs.	1800 hrs.	0600 hrs.	1200 hrs.	1800 hrs
January	1.4	1.6	1.0	0.4	0.4	1.0	1.0	0.5	1.2	1.3	1.1
February	1.6	1.4	1.0	0.4	0.5	1.0	1.1	0.6	1.2	1.3	1.1
March	1.9	1.9	1.4	0.9	0.8	1.3	1.3	0.7	1.5	1.6	1.0
April	2.0	2.0	1.3	0.9	0.8	1.0	1.1	0.7	0.1	1.2	1.0
May	2.6	2.7	2.0	1.3	1.6	1.3	1.7	1.1	1.4	1.7	1.3
June	3.2	3.2	2.4	1.1	1.3	1.9	2.1	1.2	1.7	1.6	1.1
July	4.6	4.8	4.2	2.7	3.4	2.9	3.5	3.0	2.7	3.0	2.3
August	5.1	4.8	4.2	2.8	3.0	3.5	3.7	3.0	3.2	3.1	2.5
September	4.4	3.9	3.3	2.2	2.3	3.0	3.1	2.1	3.1	2.6	2.1
October	2.0	2.8	1.9	0.8	1.7	1.0	1.6	0.9	0.7	1.1	0.8
November	1.3	1.4	0.7	0.4	0.5	0.9	1.1	0.5	1.0	1.5	0.8
December	1.5	1.6	0.9	0.6	0.6	1.0	1.2	0.6	1.5	1.6	1.0
Yearly Mean	2.6	2.7	2.0	1.2	1.4	1.6	1.9	1.2	1.7	1.8	1.6

Table 2.37a Wind Force & Direction, Monthly Trends for Khartoum, 1956 - 1961

MONTH	WIND DIRECTION															
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
January	16.42	4.50	0.72	0.18	0.02	0.02	0.02	0.05				0.07	0.27	3.87	22.51	50.45
February	13.21	3.95	0.81	0.05						0.05	0.05	0.20	0.59	5.78	22.87	50.71
March	14.38	5.26	1.37	0.67	0.22	0.05	0.05	0.05	0.05	0.18	0.09	0.45	1.21	4.84	22.47	47.25
April	10.81	5.81	3.03	1.55	0.42	0.46	0.46	1.02	0.74	0.42	0.86	2.27	3.73	9.81	25.79	30 81
May	7.73	5.35	3.18	2.82	1.28	1.50	1.68	4.35	4.23	3.29	2.60	4.53	4.48	9.27	18.21	20.97
June	1.85	2.62	1.71	2.08	1.97	2.41	3.43	17.82	15.39	13.66	9.31	8.05	3.54	4.61	5.12	4.14
July	0.61	0.38	0.61	0.78	1.01	2.04	4.39	26.17	23.70	15.14	10.62	6.83	2.08	1.68	1.37	1.12
August	0.29	0.27	0.51	0.92	0.94	1.70	4.19	26.19	26.73	18.62	9.88	4.79	0.90	0.87	0.69	0.87
September	2.15	1.76	2.04	2.27	2.25	3.08	4.05	14.98	14.65	11.55	9.75	9.05	3.84	3.63	5.65	6.11
October	7.59	7.50	6.00	6.25	2.63	2.83	2.36	4.14	3.05	2.65	1.95	2.63	2.89	7.89	18.35	19.04
November	11.25	6.43	2.92	0.49	0.11		0.05		0.02			0.16	1.07	7.22	24.26	45.90
December	12.91	4.82	1.61	0.49							0.07	0.13	0.76	5.71	28.43	44.91

Table 2.37b Wind Force and Direction, Monthly Trends for Shendi, 1952-1962.

MONTH	WIND DIRECTION							
	N	NE	E	SE	S	SW	W	NW
January	12.65	73.82	0.88	0.73		0.59	0.59	10.73
February	12.16	77.31	0.32	0.81		0.49		8.91
March	12.04	74.01	0.88	2.06	0.44	2.20	0.59	7.34
April	8.59	68.25	2.15	4.45	0.15	4.14	0.31	11.50
May	8.45	41.54	1.19	10.98	1.78	17.95	1.63	16.32
June	3.05	10.99	1.07	4.27	2.90	61.07	3.21	13.43
July	0.59	1.91	0.15	2.21	2.65	84.98	2.06	5.45
August	0.15	1.65		1.50	5.24	83.38	2.10	5.99
September	1.75	10.95	0.79	3.65	0.63	57.78	2.86	21.59
October	6.04	53.46	2.50	7.81	0.29	10.16	1.33	18.41
November	11.89	66.46	0.31	1.37	0.31	2.29	0.31	17.07
December	12.83	70.94	1.18	1.18		0.74	0.44	12.68

Table 2.37c Wind Force and Direction, Monthly Trends for Atbara, 1951-1960

MONTH	WIND DIRECTION															
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
January	15.35	7.21	3.99	2.05	0.22	0.18	0.16	0.07	0.05	0.09	0.09	0.11	0.16	0.43	7.97	60.81
February	15.61	7.83	3.05	3.43	0.69	0.36	0.15	0.16	0.03	0.13	0.19	0.33	0.33	0.83	7.50	58.15
March	17.28	5.90	2.52	2.69	0.72	0.54	0.22	0.22	0.18	0.27	0.27	0.42	0.43	1.15	7.00	57.54
April	13.95	8.07	5.77	6.37	1.82	1.27	1.11	0.82	0.43	0.42	0.66	1.05	1.22	1.70	8.86	41.70
May	10.26	6.97	4.77	7.35	3.91	2.84	2.51	3.10	2.03	2.01	2.51	2.01	1.61	2.94	9.23	27.80
June	4.71	2.44	1.97	3.25	1.76	1.82	1.61	4.13	6.28	7.56	8.94	8.11	4.51	4.96	9.56	17.00
July	1.12	0.32	0.30	0.25	0.28	0.66	1.09	6.32	15.89	18.97	16.21	11.37	3.98	3.24	5.63	6.83
August	1.03	0.34	0.31	0.77	0.58	0.78	1.51	6.68	19.11	22.74	17.57	9.01	2.29	2.02	3.82	4.65
September	1.82	1.33	1.64	4.08	2.82	2.99	2.90	6.86	12.18	12.99	11.75	8.44	2.74	2.54	4.36	11.32
October	8.63	8.04	8.45	16.53	6.06	4.85	2.84	1.49	1.06	1.10	1.05	1.51	1.10	1.84	5.07	21.91
November	11.72	7.96	5.83	5.83	1.00	0.36	0.29	0.14	0.15	0.24	0.37	0.93	1.00	1.97	12.82	45.29
December	11.63	7.04	4.34	3.52	0.51	0.39	0.15	0.09	0.03	0.04	0.15	0.43	0.51	0.87	8.93	59.15

Table 2.38

Amount of Solar Radiation and Sunshine
Mean Daily Totals Per Month

Station: Khartoum Observatory

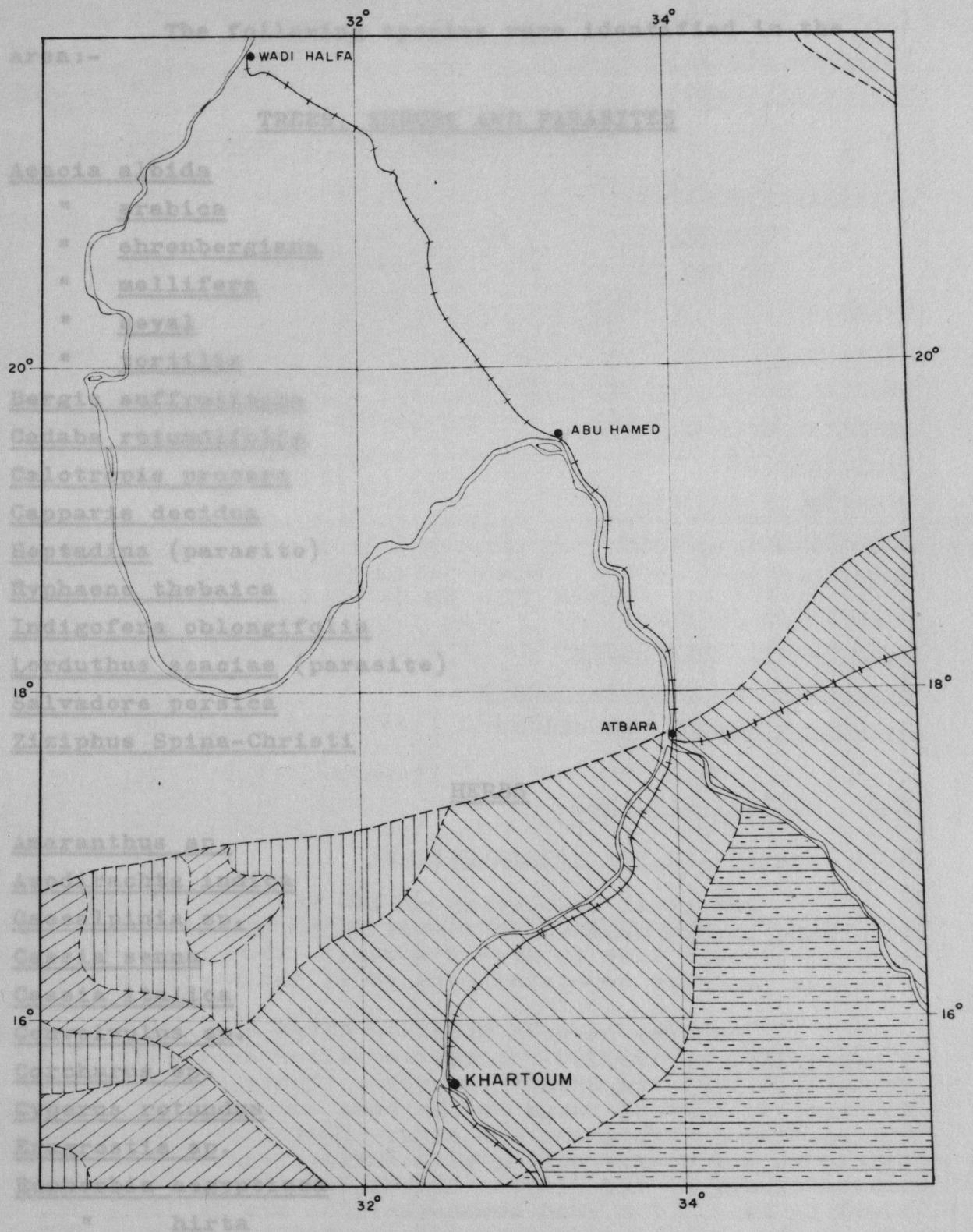
Lat: 15° 36'N Long: 32° 33'E Alt: 380 metres. A.M.S.L.

Month	1957		1958		1959		1960		1961		1962		Mean Monthly 1958 - 1962	
	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours	Radiation Cal/cm^2	Sunshine Hours
January	-	-	455.9	10.7	446.7	10.8	486.5	10.8	475.0	10.5	488.3	10.9	470.5	10.7
February	-	-	499.9	10.9	516.2	10.8	529.0	10.9	529.2	10.4	518.3	10.8	518.5	10.8
March	-	-	547.6	11.1	575.1	11.1	586.6	10.9	557.6	10.1	555.8	10.4	564.5	10.7
April	-	-	527.4	10.2	570.5	10.6	598.2	11.2	611.5	11.3	598.4	11.2	581.2	10.9
May	-	-	519.4	09.8	571.1	10.9	596.2	11.3	595.0	10.9	568.0	10.4	569.9	10.7
June	-	-	512.1	09.4	513.8	10.1	552.7	10.1	541.6	09.3	548.0	09.9	533.6	09.8
July	524.3	9.4	514.5	08.6	498.9	09.3	553.8	08.9	513.3	06.8	531.1	09.0	520.9	08.6
August	515.3	9.1	522.2	09.2	454.4	08.0	569.4	10.4	552.6	08.6	513.3	08.4	522.8	09.1
September	521.9	10.0	506.2	09.7	490.9	09.7	531.3	09.4	565.8	10.2	496.4	09.0	523.2	09.8
October	502.5	10.3	486.4	10.7	471.3	10.3	495.8	09.8	535.7	10.0	453.7	09.7	498.3	10.3
November	456.2	10.3	448.4	11.0	441.6	11.0	490.0	11.1	502.6	10.8	482.2	10.9	447.8	10.8
December	438.9	10.6	428.5	10.7	411.4	10.5	451.3	10.6	477.3	10.8	456.7	10.4	441.7	10.8

Figure 8

VEGETATION MAP OF NORTHERN SUDAN

SCALE 1:4,000,000



DESERT

SEMI DESERT

a. Acacia Tortilis – Maerua crassifolia Desert Scrub

b. Semi Desert grassland on clay

c. Semi Desert grassland on sand

d. Acacia Melliféra – Commiphora Desert Scrub

2.43 Lists of Identified Plants

The following species were identified in the area:-

TREES, SHRUBS AND PARASITES

Acacia albida
" arabica
" ehrenbergiana
" mellifera
" seyal
" tortilis
Bergia suffruticosa
Cadaba rotundifolia
Calotropis procera
Capparis decidua
Heptadina (parasite)
Hyphaene thebaica
Indigofera oblongifolia
Lorduthus acaciae (parasite)
Salvadore persica
Ziziphus Spina-Christi

HERBS

Amaranthus sp.
Azodirachta indica
Caesalpinia sp.
Cassia senna
Cassia italica
Convolvulus sp.
Corchurus sp.
Cyperus rotundus
Eragrostis sp.
Euphorbia aegyptiaca
" hirta
" granulata
" Indica
Fagonia cretica
Gynandropsis gynandra
Heliotropium aegyptiacum Lehm.
Lotus arabica L
Mallungo cerviana
Polygola acicularis
Polynomum salicifolium Brouss.
Rorippa indica (L) Hiern
Solanum jubiam

Striga hermonthica (parasite)
Tephrosia appollinea
Tragus racemorus
Tribulus terrestris
Trigonella Hamosa L

GRASSES

Aristida funiculata
" hordeacea
" mutabilis
Brachiana eruciformis
Cynodon dactylon
Dactyloctenium aegyptiacum
Demostachya bipimata
Digitaria sp.
Dinerba retroflexa
Echinochloa colonum
Ennopogon sp
Eragrostis tremula
Eragrostis cilianensis
Schoenefeldia gracilis Kunth
Sorghum virgatum ex. Willd.

2.5 PRESENT LAND USE

2.51 Population and Communications

The total population of the Northern Province according to the population census 1955/1956 is 873,059, of which over half live in Area 4 South. The Shendi-Berber reach is the most populated portion of the northern Sudan.

The area between Sabaloka Gorge and Abu Hamed has a population of 493,300. Large towns are Atbara (36,298), Berber (10,977) and Shendi (11,031). There are a few big villages such as El Bauga and Metemma and small villages are scattered throughout the area. There are many nomads living in the desert moving with their livestock in the dry season closer to the river. Shendi and Atbara are the principal markets. The road communications are fairly good, except the crossings of the wadis, which are sandy. The railway runs along the east side of the river up to Abu Hamed. In addition to railway and road there is air-transport from Khartoum to Atbara. From Khartoum up to Shendi there is no river-crossing. Between Shendi and El Bauga ferry communication between the two banks is quite good. (Crossings at Shendi, Kabushiya, Atbara and El Bauga). In Abu Hamed the difficulty is that the ferry only crosses the Nile to Mograt Island and there is no crossing between this island and the south bank.

It is very important to take into consideration the opening up of the area on both sides of the river by road. If there was a good road between Shendi and Khartoum, the latter town could have cheap fresh food from the Shendi reach.

2.52 Present System of Arable Cultivation

The present system of arable cultivation are as follows :-

2.521 Seluka Cultivation

As the Nile and the river Atbara flood subsides annually it leaves wide strips of moist and fertile silt. Dura is the most important crop grown in seluka cultivation. There are no data available for the area cultivated and no data about yields.

2.522 Saqia Cultivation

Approximately 2,023 feddans are cultivated by saqia in the Berber-Shendi district, but the saqias are being replaced more and more by motor pumps. Along the Atbara river, over a distance of 75 km, 219 feddans are irrigated by saqia. At low water level only a very small area can be irrigated. In the saqia lands 3 cultivation seasons are recognised:

1/ Shitwi (winter) from November to March

2/ Seifi (summer) from May to August

3/ Damira (flood) from August to November

Winter Season

Wheat and barley are mostly cultivated, but also lubia, lucerne, fasulia and ful masri.

Summer Season

Dura, lucerne are grown and fruit is harvested.

Flood Season

The flood season is the best cultivation season for the principal crops such as dura, lubia and maize.

Saqia land is all private land.

Reallocation and consolidation of fragmented land is necessary because at present individual holdings are split up in small scattered pieces as a result of subdivision on inheritance.

Pump Schemes

These can be divided into private and government pump schemes.

2.523A Private Pump Schemes

The development of the private schemes in the Shendi/Berber reach has been very rapid in the last ten years. Table 2.523 shows the increase in licenses. The increase of private schemes was most marked in the Berber district.

The largest private pump schemes are Zeidab concession and Fadlab concession.

The total area irrigated by pump schemes is 45,819.55 feddans in the Shendi district and 44,677 feddans in the Berber district.

Table 2.523 Numbers of Pump Licences in Berber and Shendi Dsitricts.

Year		'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63
No. of Licences	SHENDI	137	137	149	145	162	166	176	168	168	183	199
	BERBER		15	18	25	31	51	68	85	142	167	305

All pumps in the Sudan have to be licenced under the Nile Pumps Control (Regulations of 1951).

There exist three types of licence:

1/ Perennial Licence - which allows pumping throughout the year.

2/ Flood Licence - which allows pumping during the flood season, from 16th July to 31st of December.

3/ Restricted Licence - varies according to the district and the location on the river system, but mainly allows pumping from 15th July to 30th of November.

2.524 Government Pump Schemes

Four pump schemes are administered by the Government in the Shendi/Berber reach. Gandetto, Kitiab and El Bauga were started in 1917, while Aliab was started during the last world war.

Their gross areas range between 3,000 to 5,800 feddans and are shown in Table 2,524

Table 2.524 Government pump schemes in the Shendi/Berber - Districts

Scheme	Gross Area in Feddans		
	Govt. Land	Private Land	Total
Gandetto	2,300	900	3,200
Kitiab	5,000	800	5,800
Aliab	5,500	-	4,500
El Bauga	1,800	1,400	3,200
Totals	13,600	3,100	17,700

The government land is divided into tenancies of 10 feddans except in Gandetto which consists of irregular sized holdings (average 3 feddans) and the tenants pay a rent of 10 PT per feddan per year. In addition they pay water rates on various crops. The water rates are the same in all government schemes, 83.5 PT per feddan per watering. The cost of waterings for various crops per year are :-

Horticulture (gardens)	LS.	20:000
Clover	LS.	19:620
Winter vegetables	LS.	6:350
Wheat	LS.	6:350
Beans	LS.	4:890
Broad Beans (Egyptian Beans)	LS.	4:890
Lubia (Flood)	LS.	3:240
Dura (Flood)	LS.	3:200
Maize (Flood)	LS.	4:200
Maize (Summer)	LS.	4:890
Dura (Summer)	LS.	4:890

2.525 Basin Cultivation

Along the Nile between Sabaloka Gorge and Abu Hamed basins occur mainly in the Shendi area. Most of the basins have an inlet canal from the river and an outlet canal downstream and in addition cross banks (salibas) are constructed. The area irrigated each year depends on the height and overflow of the river, but many tenants have bought their own pumps in case of a low flood.

As soon as the area is dry enough to be cultivated the seeds of the various crops are sown.

The basins are administered by the Northern Province authorities while the Irrigation Department is responsible for the maintenance and operating of the flood irrigation system.

The most important basins are mentioned below :-

Basin	Approximate area (in Feddans)	
Hugna Basin	2,000	700 already converted to Pump Scheme
Medisisa	500	
Wad Hamid	9,000	
Salawa	5,000	
Sayal	3,000	
Sufur	6,000	
Kelli	7,000	
Tayiba and Guweir	10,000	
El Basabir	5,000	

The extent of the variation in areas flooded is given in Table 2.525.

Table 2.525 Areas of Land Flood Irrigated in Shendi Basins, 1944-1959.

Basin	AREA FLOODED IN FEDDANS.										
	MEAN 1944/55	HIGH 1946	LOW 1941	1952	1953	1954	1955	1956	1957	1958	1959
Hugna	830	2,000	-	1,400	30	1,700	700	1,000	750	700	2,000
Medisisa	410	1,000	-	400	10	800	200	400	500	500	1,000
Wad Hamid	8,570	10,000	3,350	8,800	9,600	9,400	9,000	9,000	9,500	9,500	9,200
Basabir	3,000	5,000	-	2,700	4,500	4,900	3,200	3,000	4,500	5,500	5,000
Salawa	5,580	7,200	2,150	5,400	6,000	7,000	6,500	5,500	7,600	6,000	1,600
Saiyal	2,680	3,200	550	2,600	3,000	3,200	2,900	2,200	2,900	3,000	3,200
Guweir	1,830	2,700	-	1,800	2,700	2,700	2,400	2,000	2,400	3,000	2,700
Tayiba	3,880	7,000	-	3,500	6,500	7,000	6,700	4,500	4,500	6,000	7,000
Kelli	5,900	13,000	-	4,400	8,660	11,500	10,000	7,000	7,000	7,000	8,000
Kimeir	1,650	3,000	-	2,000	3,000	3,000	2,500	1,500	2,500	3,000	3,000
TOTAL	34,330	54,100	6,050	33,000	44,000	51,200	44,100	36,100	42,150	44,200	48,100

2.53 The Main Crops

The following crops are grown in various seasons in the Shendi/Berber reach.

Summer crops:	maize and dura
Flood crops:	maize, dura, lubia and beans
Winter crops:	Egyptian beans, beans, wheat, vegetables and onions, and in the Kurgous area ground-nuts.
Permanent crops:	Orchards and pasture.

2.54 Pests and diseases

The following list shows the main diseases affecting the crops in the area.

	Crops	Diseases
1/	Hibiscus esculentus (Bamia)	leaf curl (virus)
2/	Dolichos lablab (lubia)	powdery mildew (fungus) mosaic (virus)
3/	Gossypiurm spp (cotton)	leaf curl, boll rot
4/	Garden crops (fruit)	folliocellosis or mottled leaves
5/	Portulaca olereca (regla)	white blister or white rust (fungus)
6/	Vicia faba (Ful musri)	powdery mildew (fungus)
7/	Phaseolus vulgaris (Fasulia)	curly top (virus) blast
8/	Lycopersicon esculentus (tomatoes)	leaf curl (virus)
9/	Pisum satibum (Baslla)	powdery mildew
10/	Members of the Cucurbitaeceae	powdery mildew

There is also considerable bird damage. The following species are considered to be the most destructive:

House sparrow - Passer domesticus (Linn)

Destructive pest of grain, beans and fruit.

Golden sparrow - Auripasser luteus (Licht)

These birds are in diffuse colonies in small thorn bushes especially in the area south of Atbara.

Egyptian Goose - Alopochen aegyptiacus (Solater)

They occur in the area between Shendi and Dongola where they do much damage to wheat. They both eat the newly sown seed and graze the young shoots.

2.55 Fertilisers

Cultivators use cattle manure when they have three or more cows. The application per feddan is unknown and irregular.

Ammonium sulphate is commonly used. The normal application being about 50 kg. per feddan and this would cost L.S. 1.050. The fertilisers are bought from the Agricultural Bank of the Sudan.

In the gardens the applications of cattle manure are 20 kilos per 1 - 5 years and chemical fertilisers ½ kg. per 6 months/tree.

The yield per feddan would be higher if the cultivator made more intensive use of his land e.g. applying more fertilisers and paying more attention to adequate watering.

2.56 Livestock

The large majority of cattle, sheep, goats and camels are owned by the nomads. Large herds of camels are frequently seen in the north. Ed Damer is the main market for camels and livestock. Sheep and goats are most commonly found in the Shendi area.

The Government policy is to dig wells in the desert, where the nomadic herds can drink thus avoiding trouble with the riverside people.

The riverside cultivators keep some cattle for milk, meat and saqia operations, and a few sheep and goats.

2.6 EROSION

The main agencies of erosion in the Northern Province are :-

i) Water erosion

ii) Wind erosion

2.61 Water erosion

Fluvial erosion along the Nile is severe. The river is continuously eroding old silt islands and forming new ones elsewhere. Downstream of the confluence of the Nile and the Atbara, the erosion becomes more severe.

South of Shendi where rainfall is higher many wadis dissecting the area emphasise this problem very clearly. These wadis transport much sand and damage cultivation along the river. Protective dykes, such as those at Zeidab, can be constructed, but the expenditure is high.

2.62 Wind Erosion

Traffic and grazing are the factors most damaging to vegetation cover and soil surface structure. As long as there is a thin raincrust on the soil surface wind erosion is restricted, but as soon as the surface is disturbed, deflation starts. Tracks of cars and animals and even places where camels have rolled, are dangerous spots and become scoured during windstorms.

There are several places in the Northern Province where sand is menacing pump schemes. These include the Abu Hamed area, where Barchans are encrouching on agricultural land and at Hudeiba research farm, where severe sand movement is observed.

CHAPTER 3

SOIL SURVEY METHODS

3.1 AERIAL PHOTO-INTERPRETATION

3.11 Procedures

The aerial photo-interpretation of area 4 South was carried out using a Wild mirror stereoscope in the office and a pocket stereoscope in the field. The latter was used mainly for field orientation and to obtain accurate boundaries in conjunction with direct field checks, where delineation was difficult. It was not possible to separate soil types, except in the case of sand dunes and in the basins, where a dendritic pattern occurs. The photo-interpretation procedure during the field work was :-

A reconnaissance in the field with mosaics.

Preliminary photo-interpretation map, drawn on the mosaics or on the maps of 1:100,000.

Visiting sites on an overall grid system of 1 to each 10.5 square kilometres and field checks of the boundaries.

Final photo-interpretation mapping.

Bare rock, stony areas and sand dunes were excluded from the grid system by preliminary photo-interpretation. Much of the area was driven through and inspected in the normal course of navigation from one grid site to another.

3.12 Land types

The following land types were distinguished during photo-interpretation:

i) Active floodplain

ii) Older terraces

iii) Rocky areas

In these land types the area was delineated according to relief, colour tone and colour texture, vegetation and erosion.

Relief

As the area is relatively flat the relief has posed the biggest problems. It was not possible to delineate micro-relief; but the edges of the alluvial terraces, sand dunes, gravel ridges and rocks showed a sharp change in relief.

Colour tone and colour texture

The quality of the aerial photographs must be taken into consideration because the colour tone and colour texture differ very often between photographs. Colour is particularly important in flatter areas, and thus careful printing is essential. Whitish coloured patches are in general sandy areas, which can also be distinguished by relief.

It was very difficult to find any correlation between colour and soils. However, with dark grey it was found, that the soil is very often alkaline, but these could also occur where soils are wet or moist as in basins and streambeds.

Erosion

Alternating white/grey streaks are often found on the slopes. These are due to erosion. The white/grey streaks are those where the gravel has been washed out, while the darker streaks are gravel. Other erosion features are V and U shaped gullies in the gravel ridges, rocky areas and wadis.

Vegetation

It appears that the more vegetation occuring in an area, the higher the proportion of sand.

Two species have been identified during the photo analysis. Acacia tortilis, which appears as a round shaped dark dot and the Dom Palm, appearing in the form of a star.

A useful indicator for topography was the villages, which are located on the higher ground.

All information has been checked at the beginning of the survey and used in other areas by deduction and interpolation.

3.13 Aerial Photographs

The aerial photographs of the area 4 South, were flown by the Sudan Survey Department, for the Roseires Soil Survey Project in 1961-1963 at scale 1:25,000. The focal length was 15 cm.

The mosaics for the area between Khartoum and Atbara were compiled by B.K.S. Air Limited at an approximate scale of 1:50,000. For the area north of Atbara, use was made of an earlier photography as the new photography did not cover the area.

It is very important to have recent photo cover of the area to be surveyed. A good example is the cover of the River Atbara, flown in November, 1963, where the surface features have not altered between the flying of the photographs and the soil survey.

3.2 SOIL SURVEY PROCEDURES

The reconnaissance survey was commenced in November 1963 and completed in February 1964. A preliminary study was made of the maps and mosaics, together with a field trip, in October, by the Consultant in charge and the soil Surveyor, to establish some idea of the terrain.

In order to ensure the required density of one site per 2,500 feddans, a 10.5 square kilometre grid was marked out on the base maps or the mosaics. One site has been investigated within each square of the grid. The sites were selected within the grid to cover as wide a range as possible of the landforms that could be differentiated on the photographs. On the high terraces, where flat areas alternated with sandy layers and dunes, it was necessary to follow a rigid grid system. Otherwise only flat areas without a sandy layer would be chosen and a wrong impression obtained.

The following investigations were carried out :-

i) Pits were dug to a depth of 2 metres at selected sites representative of the different soil types found in the area. Approximately 1 in 5 of the total sites were sampled at the rate of one sample per horizon described, but generally not exceeding three per pit.

ii) Bores were dug to a depth of 2 metres and the profile described. These were not sampled.

iii) All the obviously unsuitable areas such as hilly and rocky areas, sand dunes, sloping gullied land etc., were eliminated by aerial photo-interpretation. In doubtful cases, such as gravelly and stony areas, sites were visited before a decision was made. A total of 205 bores and 45 pits was investigated. Pit 2009 was not sampled because of too much stone and gravel. 123 samples were taken for the following laboratory analyses :-

Mechanical analysis (International fractions)

pH on soil paste and 1:5 suspension.

Salinity test (E.C. on saturation extract)

Soluble sodium in saturation extract.

Cation exchange capacity (C.E.C.)

Soluble and exchangeable sodium in ammonium acetate.

3.3 CHEMICAL ANALYSES OF SOILS

The following methods were used by Agricultural Services (Sudan) Ltd. in making the determinations:

3.31 Mechanical Analysis : Bouyoucos Hydrometer Method

40 grams soil soaked with 25 ml. water and 11 ml. of 10 per cent sodium hexamotaphosphate solution overnight; next morning despersed in electric stirrer for 10 minutes, transferred to 1 litre measuring cylinder, shaken and hydrometer and readings taken after 4 minutes, 2 hours and 7 hours. With every reading the temperature is recorded and corrections made for temperature and dispersing agent content. The readings are also corrected for moisture content, when required, by performing separate moisture determination.

To get good results the soil samples must be washed out several times with alcohol.

3.32 pH

Potentiometric determination using glass electrode on saturation extract, soil paste or 1:5 extract as required.

3.33 Electrical Conductivity

By using a Solubridge on saturation extract.

3.34 Soluble Sodium in Saturation Extract

Appropriately diluted saturation extract is analysed on flame-photometer for Sodium.

3.35 Exchangeable Sodium

12.5g of soil are soaked in 50 ml. of normal ammonium chloride, left for one hour and then leached a few times (about four) by decantation. The soil is then transferred into the filter and leached with successive portions of normal ammonium chloride when drained. Leaching is continued until 250 ml. of filtrate are collected. The filtrate (5 ml.) is diluted 20 times and sodium read off on flamephotometer against 10 ppm. sodium standard containing the same amount of ammonium chloride. Zero is set with 0.05 N. ammonium chloride. From these readings the sum of soluble plus exchangeable sodium is calculated. By subtracting the soluble sodium from saturation extract data the net figure for exchangeable sodium is obtained.

Exchangeable Sodium percentage is the result of the calculations of $\frac{\text{Exchangeable sodium} \times 100}{\text{C.E.C.}}$

3.4 FIELD PERMEABILITY STUDIES

3.41 Method

Field permeability tests were carried out at 20 pit sites. Two tests were made at 7 pit sites bringing the total of tests made to 27. It was not possible to make more field permeability tests due to cracks, stones, gravels or too many Carbonate concretions.

The method was adapted from the type "A" test, described in the Earth Manual, United States Bureau of Reclamation, 1951, as used by Hunting Technical Services Ltd., in their Kirkuk (Iraq) and Pangani (Tanganyika) projects.

Apparatus

2 jerry cans	Clean gravel
2" Jarret auger	Stopwatch
10 m. rubber tubing	250 cc graduated cylinder
1 screw clamp	50 cc " "
1 tap	
2m. measuring tape	

3.42 Procedure

The tests were carried out in or beside the 2m pits dug throughout the area of this soil survey, whose textural layers had previously been defined and described. Horizons of more than 30 cm. depth had to be used as the method is unreliable where the length of the test section is less than five times the diameter of the bore. The top of the horizon was cut back as a step in the pit and a hole bored in it vertically with the Jarret auger. After boring, the depth of the hole is measured in cm. A 1m. length auger tube was inserted and surrounded with gravel. The bottom is also covered with gravel. The top of the gravel is considered to be the top of the test section. Its depth below the top of the hole was measured and subtracted from the total hole depth to give h, the height of the test section.

Gravel is needed to prevent the hole collapsing when wetted and the auger tubing is needed to facilitate the introduction of the water. The hole is then filled to the top of the gravel with water from the jerry can through the rubber hose. The water tap or screw clamp on the hose is used to maintain the water surface at the level of the top of the gravel. During the permeability studies it is noticed that by using a water tap better results are obtained than by using a screw clamp. In general the test readings were made after approximately 30 min. as the soil is then more or less saturated. The rate of inflow is measured at 5 minutes intervals by catching the flow in graduated cylinder during 1 minute. When three similar test readings were made the test was considered as finished. From the final reading the permeability is deduced from the following formula.

$$K = \frac{864\ Q}{Cu.\ r.\ h.}$$

in which:

K = coefficient of permeability in m/day/unit hydraulic gradient.

Q = rate of steady inflow in ml/sec.

r = radius of bore in cm.

h = height of water column in cm.

Cu = coefficient of conductivity obtained from table 3.43.

The following sources of inaccuracy became apparent during the tests.

a. The height of the tap above the ground must be kept constant. If the water is poured into the cylinder from a higher level than into the auger hole, the head of the water is reduced and the flow becomes slower.

b. Invisible cracks.

c. Any changes in the position of the rubber water pipe may cause it to be pinched at some point and to cut off the flow.

3.43 Results

The correlation between hydraulic conductivity and the texture is shown in Table 3.43.

Four texture classes were classified upon:

I	10 - 20% Clay
II	20 - 30% Clay
III	30 - 40% Clay
IV	40 - 60% Clay

The lighter the soils the higher the hydraulic conductivity.

The increase of the permeability of the soils of class iv is probably due to invisible cracks, which would be more likely to be present at the higher clay percentage.

Table 3.43 Correlation Between Hydraulic Conductivity and Soil Texture

Class No.	Pit No.	% Sand	% Clay	Field Texture	Hydraulic conductivity m/day/unit gradient	
I	2030	81	13	Sandy Loam	0.0128	
	2031 a	79	11	Sandy Loam	0.358	Average
	2175 a	59	15	Sandy Loam	0.228	
	2175 b	59	15	Sandy Loam	0.195	0.176
	2178	62	17	Loam	0.0783	
II	2005	56	28	Silty Clay Loam	0.0136	
	2014	47	26	Silty Clay Loam	0.0367	
	2031 b	69	23	Silty Clay Loam	0.0360	Average
	2062	57	24	Silty Clay Loam	0.0148	
	2092	66	27	Sandy Clay Loam	0.102	0.104
	2100	71	22	Sandy Loam	0.00886	
	2154 b	58	29	Fine Sandy Loam	0.262	
	2190	48	29	Silt Loam	0.357	
III	2056	51	30	Silty Clay Loam	0.0466	
	2117 a	48	30	Silty Clay Loam	0.466	
	2160 a	39	35	Silty Clay Loam	0.113	Average
	2160 b	34	35	Silt Loam	0.0540	
	2164	58	31	Sandy Clay Loam	0.00212	0.0364
	2185	55	32	Silty Clay Loam	0.00363	
	2243 a	61	30	Loam	0.0226	
	2243 b	56	34	Sandy Clay	0.00330	
IV	2112 a	33	45	Silty Clay Loam	0.0755	
	2117 b	31	40	Silty Clay Loam	0.0715	
	2143	41	48	Silty Clay Loam	0.0106	Average
	2154 a	43	44	Sandy Clay Loam	0.117	
	2169	25	49	Clay	0.00824	0.0656
	2112 b	23	52	Silty Clay Loam	0.11	

3.5 MAP COMPILATION

3.51 The Base Maps

The base maps are compiled from the Mosaics dated 1963 covering the area between Khartoum and Atbara and from the Sudan Survey 1:100,000 maps dated 1951, overprinted with the cross-sections of the survey of irrigable areas, sheets 8 to 13, covering the Nile between Atbara and Abu Hamed.

The base maps were produced by Hunting Technical Services Ltd., at a scale 1:100,000. The investigated sites were marked on the maps as follows :-

△ 2001	-	2 metre pits, samples
O 2002	-	2 metre bore, not sampled
O (unnumbered)	-	miscellaneous sites visited

The sites were numbered from 2001 - 2251.

3.52 The Soil Maps

The classification of the individual sites was not marked on the soil maps. The soil boundaries were determined stereoscopically from the aerial photographs, and then transferred freehand on to the map and mosaics. The soil classification used is explained in Chapter 4.

3.53 The Land Suitability Maps

The areas recommended for semi-detailed investigation were transferred directly from the soil map.

CHAPTER 4

SOIL CLASSIFICATION

4.1 ORIGINS AND GENERAL MORPHOLOGY

The soils of the area are developed from the alluvial deposits of the Nile. These deposits can be divided into the active flood plain and older deposits forming river terrace. These alluvial deposits consist mainly of coarse textured materials brought by the seasonally fast flowing Blue Nile with some admixture of fine textured materials from the slow White Nile. The Atbara river contributes sand and some coloured minerals to the soils north of Atbara. Contributions from local sources, mainly from the Nubian series, consist of wind-blown sand or sand brought by wadis (and deposited downstream). In many places the soil contains wind-blown coarse sand and frequently gravels and stones derived from the Nubian series, especially on the surface. Kankars are frequent on the surface as well as throughout the profile.

4.11 Soils of the Recent Flood Plain

These immature soils vary in texture from coarse sand to clay and the distribution of textures is complex. This is due not only to the differences in depositional pattern but also to windblown sand and sheet erosion from higher terraces or hills. In general it appears that the textures are finer at the surface and become coarser at depth. The soils of the active flood plain belong to the order of the Entisols, of which the great groups Orthustents and Psammustents occur.

4.111 Loamy Soils (Orthustents)

The colours of the finer textured Orthustents are in general brown (10YR 4/3) to very dark greyish brown (10 YR 3/2) and sometimes yellowish brown (10YR 4/4). The coarser textured Orthustents are lighter coloured and mostly yellowish brown (10YR 5/4 - 10YR 5/8). Some manganese mottles and rusty coloured stains have been found in the subsoil.

The Orthustents are generally structureless or weakly structured in places where the soil is not affected by annual floods. The surface is slightly cracked except where the drainage conditions are poor. In some cases large cracks of approximately 5 cm, mostly infilled with sand, are frequent up to the depth of approximately 40 cm. Where the clay content of these soils is more than 40% they are classified as Vertic Orthustent. The consistency of these immature soils varies between loose and very hard.

Under field conditions the moisture content in the top horizons varies between dry and moist and becomes moist to wet with depth. The top horizons are in general rapidly or moderately moisture absorbent, while the underlying horizons are moderately or slowly moisture absorbent.

These soils are in general non saline or slightly saline, with E.C. ranging between approximately 0.25 to approximately 5 mmhos. in the first 50 cm. The salinty between 50 and 160 cm. is approximately ranging between 5 and 14 mmhos. Higher salinities are found along the edges and at the lowest places of the basins. This is due respectively to runoff from the higher terraces and to surface evaporation. It was not possible to make any correlation between E.C.'s and depth of horizons. Both E.C.'s and horizons very widely. (See chemical analyses in Appendix 2).

The E.S.P.'s range in the first 50 cm. between 1 and 40 and become higher with depth. In pit No.2062 E.S.P.'s of 100 occur throughout the profile. For detail see Chemical Analysis (Appendix 2).

Like alkalinity, the pH of soils varies within the profile and within horizontal distances. As the distances between the pits are great and the soils are complex, it is impossible to make any correlation. The pH paste ranges between values of 8.22 and 9.55 and in general the soils have alkalinity problems above the values of 8.5. The pH at dilution of 1:5 ranges between values of 8.1 and 10.9. In general the higher the difference on dilution the higher the alkalinity.

4.112 Sandy Soils (Psammustents)

Fixed and active dunes frequently occur in the basins between Shendi and Kitiab and along the Atbara river. These give rise to Psammustents. The material of which they are built is complex. They consist of waterborne and windblown sand. The texture is in general fine to medium sand, except in the north of the area, where it consists of very fine sand.

One pit, No.2106, was dug in the dunes near Tayiba. The colours are in general dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6 - 10YR 5/8). For the chemical data see appendix. Probably they are too sandy for any economic agricultural use.

4.12 Soils of the higher terraces

The older soils of the alluvial deposits vary in texture from coarse sand to clay. As in the Recent Floodplain the distribution of textures is complex. In general the second horizons show slight indications of clay migrations, but others may have a distinct argillic horizon.

The soils may be overlayed by wind-blown sand in thicknesses varying between 2 cm-100 cm. Mica occurs frequently. Gravel and stones are abundant throughout the area and they were mapped in phases. They also occur in the subsoil at various depth in an old gravel terrace locally dissected and undulating, (Shendi area). Kankars and hard Calcium Carbonate concretions occur frequently on the surface. The soils of the higher terraces belong to the order of the Entisols and Aridisols, in which Orthustent and Psammustent and weakly structured Natrargid occur.

The colours of the finer textured Orthustents are in general brown (10YR 4/3) to very dark grey (10YR 3/1). These darker coloured soils are mostly intergrading towards the Natrargids and are classified as Natrargidic Orthustent. The coarser textured Orthustents are lighter coloured and mostly dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6 - 5/8). The very sandy soils may have colours varying between reddish-brown (5YR 4/4 - 4/3) or strong brown (7YR 5/6) and dark yellowish brown (10YR 4/4). Sparse rusty stained mottles were noted.

The Orthustents are generally structureless or weakly structured, and the most common structures vary between structureless and weak, fine, subangular, blocky. The surface is in general cracked, but the cracks are mostly covered with a sandy layer and so not always visible. The cracks are often infilled with sand and somtimes with gravel. The consistency of the soils varies between loose and very hard. An extremely hard consistency was found at pit 2123, although the texture is sandy (66% sand). In general the soils are dry throughout the profile and they are rapidly moisture absorbent.

These high terrace soils are mostly very saline and alkaline. E.C.'s range between 0.2 and 49.5 mmhos. throughout the profile and the E.S.P.'s between 1 and 100 per cent. No correlation could be detected between E.S.P.'s and depth nor between E.C.'s and depth, because the thicknesses of the horizons range between 15 cm. and 180 cm. On the highest and eroded terraces the soils are non-saline and non-alkaline and are generally sandy loams or loams. However, pits No. 2130 and No. 2175 are loamy in texture but very saline/alkaline. High E.C.'s in the topsoil are associated with low rainfall, but where some leaching takes place due to higher rainfall, the E.C.'s in the second horizon will be higher.

The pH paste and pH at dilutions of 1:5 range respectively between 7:35 and 10:00 and 7:60 and 10:55.

Calcium carbonate was found in the profile in the form of :-

i) Soft white streaks down the profile;

ii) Semi-hard and hard, bright coloured, concretions, generally appearing between 50 cm. and 150 cm;

iii) Solid, massive beds of Calcium Carbonate occuring between 100 and 200 cm;

iv) Kankars (dark hard concretion), generally found at the surface, but occuring frequently down the profile. They decrease with depth.

Gypsum was found at approximately 20% of the total sites and occurs normally between 40 and 150 cm. Both lenticular and hexagonal forms of gypsum were recognised. In addition amorphous gypsum was found in small whitish aggregates.

The Natrargids in area 4 South, are weakly structured. They show a natric or an argillic horizon, but miss the prismatic structure common for developed Natrargids. The structure is moderate medium subangular blocky. In other respects they are similar to Orthustent.

Psammustents occur not only in dunes but also in thick layers of wind-blown sand. Three pits were dug in psammustents; two were classified as Orthustentic Psammustent and 1 as Oxic Psammustent. These soils were mostly eliminated by photo interpretation. The textures vary between sand and sandy loams. They are structureless.

The soils on the eroded areas (highest terrace) were mapped as Lithic Orthustents. Normally there are common to abundant stones on the surface. The textures vary in general from coarse loamy sand in the top 20 cm. to gravelly sandy loam in the second horizon. The second horizon may vary between 20 and 100 cm. In general the gravels and stones make up 90% of the 2nd horizon.

It was not always possible to map accurately the land forms on the higher terraces as they are very complex. One main association has been introduced in these cases the Association of S.G.L., Sandy and undulating terrain.

4.2 SOIL CLASSIFICATION SYSTEM

The soils have been classified according to the 7th approximation specifications of the U.S. Department of Agriculture (1960). The soil orders, suborders, great groups and subgroups are described as follows.

Entisols are soils either without natural genetic horizons or with only the beginning of horizons. The horizons present are so weekly expressed that they fail to meet the requirements of any of the diagnostic horizons, except the albic (white) horizon and those that are produced through cultivation by man. At one extreme in age an Entisol might consist of very recent alluvium; at the other extreme it may include quartz sands that have been in place for many thousands of years. These soils are found throughout a wide range of climates. The central concept includes soils in deep regolith or earth with no horizons except a plough layer. Colour is not of significance in defining the Entisols.

Ustents are Entisols that, unless irrigated, are dry soils. They include many of the soils of arid and semi-arid regions of the world that have been called Lithosols, Regosols and Alluvial soils. The Ustents have ochric epipedons (light coloured surface horizons). They lack other diagnostic horizons, although they may have discernible secondary carbonates or accumulations of salts. They may even show slight cementation in some horizons, enough to give few to many hard or very hard disconnected nodules. Unless the soil is irrigated, moisture is held at tensions of more than 15 atmospheres throughout the soil for more than half the year. If irrigated, the soil soon becomes dry when irrigation ceases.

Psammustents are dry, coarse-textured soils that are below the wilting point for most of the year. The coarse-textured horizons extend to 50 centimetres or more and include sands and loamy sands, but exclude very gravelly and stony soils. These soils are often found on at least partially stabilized dunes. Some of the sands have been deposited by water on fans or on flood plains. The vegetation is scattered and is zerophytic if perennial.

Oxic Psammustents (1.31-9)

This subgroup includes soils that have been highly weathered chemically during some previous period. The sand fraction is dominantly quartz, 95 per cent or more. The Clay fraction is mostly 1.1 lattice clay and free oxides, but the clay content is too low for the oxic horizon. These soils are not known to occur in the United States but are thought to occur in parts of Africa and Australia.

Orthustentic Psammustents have a layer with textures as fine or finer than very fine sand within 75 centimetres. Carbonates are normally present. As these soils are stratified they are usually found on fans or on flood plains throughout the arid zones of the world.

Lithic Psammustents. They have hard rock (usually ferruginous sandstones) at shallow depth in the profile. In this survey also gravelly and stony banks have been classified as lithic. The depth varies between 0 and 60 cm.

Orthustents include dry, loamy soils with textures finer than loamy fine sand extending to 50 centimetres or more. They have an ochric epipedon that may or may not be slightly darker than the underlying horizons or layers. Weak cementation that is not destroyed by soaking in acid is permitted in the lower horizons if only cemented nodules are present. Accumulations of secondary line, gypsum or salts may be seen as efflorescences or mycelia. Distinct CS and SA horizons may be present but not gypsic or salic horizons (accumulations of gypsum exceeding 5 per cent or soluble salts exceeding 2 per cent). Redistribution of carbonates sufficient to give a CA horizon underlying a horizon that has lost its carbonates is not permitted, for the leached horizon comes within the definition of a cambic horizon (a changed or altered horizon). These soils are found on flood plains, fans and uplands throughout the arid and semi-arid regions of the world. Vegetation, if undisturbed, consists of annuals and zerophytic perennials.

Orthic Orthustents are loamy soils extending to 30 centimetres or more, having less than 40 per cent expanding lattice clay and in lower horizons lacking cementation into small nodules that will not soften in acid. They have less than 15 per cent exchangeable sodium in some part of the upper 50 centimetres. Secondary accumulations of gypsum and salts that do not constitute gypsic or salic horizons are permitted but not required. Visible secondary lime is also permitted but leached surface horizons lying on CA horizons are excluded.

Vertic Orthustents. They have more than 40 per cent expanding lattice clay but lack cracks, slickensides, gilgai or structure diagnostic for vertisols. But in the basins of area 4 South, cracks have been found on those places where the drainage is poor. Nevertheless these soils are classified as Vertic Orthustents. These soils are in intergrade towards the order of Vertisols.

Psammustentic Orthustents have a layer of sand or loamy sand on the upper 50 centimetres of the profile. They are found on the higher terraces, and the basins, where a layer of sand overlies terrace silts. These soils are an intergrade towards the great group of Psammustents.

Calcorthidic Orthustents have a layer containing more than 15 per cent calcium carbonate within 50 centimetres of the surface. These soils are an intergrade towards the Calcorthid Great Group of the Order of Aridisols; there is no evidence, however, of the movement of calcium carbonate within the profile and the carbonate rich layer does not therefore, qualify as a calcic horizon, nor does the overlying layer qualify as a cambric horizon.

Natrargidic Orthustents have 15 per cent or more exchangeable sodium in some part of the upper 50 centimetres. These soils are an intergrade towards the Natrargid Great Group of the Order of Aridisols. They may show slight indication of clay migration. The clay content of the textural B horizon should not exceed that of the A horizon by more than 5%.

Natrargidic Vertic Orthustents have 15 per cent or more exchangeable sodium in some part of the upper 50 centimetres of the profile and more than 40 per cent expanding lattice clay but lack the cracks, slickensides, gilgai or structure diagnostic for Vertisols. They are intergrade towards the Order of Vertisols, and, as well, towards the Natrargid Great Group of the Order of Aridisols. They may have cracks due to poor drainage conditions.

Lithic Orthustents have hard rock (usually ferruginous sandstones) at shallow depths in the profile. They may have a gravelly or stony bank. The depth of Lithic Orthustents varies between 0 and 60 cm. Rock outcrops in each pedon are common but are not required in the subgroup. Textures are variable; they are sometimes gravelly or stony but they do not include clays that have 40 per cent or more expanding lattice clay. The soils in this subgroup have previously been called lithosols for the most part.

Aridisols are primarily soils of dry places. They have an ochric epipedon (light coloured surface horizon) and one or more additional diagnostic horizons. These are cambic, argillic, natric, calcic, gypsic and salic horizons and duripans. The Aridisols do not have a spodic or oxic horizon, nor do they have a mollic or umbric epipedon. Included in the order of Aridisols are most soils that previously were Desert Soils, Red Desert Soils, Sierozems, Reddish Brown Soils and Solonchaks. Some of the Regosols and Lithosols of dry climates and some Brown Soils and Solonetz are also included.

Argids are the Aridisols that have an ochric epipedon and a subsurface argillic or natric horizon. They are dry most of the time unless irrigated. They may also have a calcic, gypsic or salic horizon or duripan. In the arid regions of the world where these soils are found the associated vegetation commonly consists of scattered, zerophytic, woody or succulent plants, and annual grasses and herbs. Towards the margins of the desert, grasses become dominant but as a rule do not form a sod; rather they seem to have been scattered perennial or annual plants. Some of the Argids are on old land surfaces, perhaps early Pleistocene; others, particularly those with a natric horizon, are found on much younger surfaces. Bedrock may be deep or shallow; where shallow, ruptic intergrades with the Entisols or "Not-Soil" are common.

Natrargids are the Argids that have an ochric epipedon and a natric horizon (E.S.P. exceeds 15 in a subsurface argillic horizon). Unlike the Haplargids they may be usually moist but conductivity of the saturation extract must exceed one millimo at some depth. In the U.S. the Natrargids are often found on the lower slopes of fans of late Wisconsin age or possibly even more recent; in this topographic position they receive run-off from higher areas.

The following chart shows that section of the U.S.D.A. Seventh Approximation which is relevant to the present survey.

Table 4.21

Soil Classification Chart

U.S.D.A. 1960 system.

Order	Sub Order	Great Group	Sub Group
1. Entisol	1.3 Ustent	1.31 Psammustent	Oxic Psammustent Orthustentic Psammustent Lithic Psammustent
		1.32 Orthustent	Orthic Orthustent Natrargidic Orthustent Lithic Orthustent Calcorthidic Orthustent Psammustentic Orthustnet Vertic Orthustent Natr. Vertic Orthustent
4. Aridisol	4.2 Argid	4.23 Natrargid	

CHAPTER 5

ENGINEERING STUDIES

5.1 INTRODUCTION

The terms of reference for engineering studies to be included in the reconnaissance surveys are stated in the Contract for soil survey of irrigable lands in the Sudan as follows :-

"An engineering survey to establish the 20 metre isopotamon using data on river levels supplied by the Ministry of Irrigation, excluding lands where a major, topographical obstacle is encountered between the 20 metre level and the river. Adequate field survey shall be carried out to establish these levels and to define the irrigable areas".

The term isopotamon was first used by the Sudan Survey Department in their 1951-52 Survey of Irrigable Areas in Northern Province and was defined as :-

"A line formed by the intersection of the ground and a surface parallel to the surface of the river at mean low water level".

The reconnaissance engineer, appointed to carry out the studies for the remainder of Area 4, not covered by Report No. 3, started work in Khartoum on 26th October, 1963 and spent an initial period collecting and examining maps and survey data prepared for the 1951/52 Northern Province Survey of Irrigable Areas.

Fieldwork in the area commenced on 3rd November 1963 and continued until 17th May 1964. During this period, the engineering reconnaissance was completed on both banks of the Nile for a distance of 755 river kilometres from Khartoum to Kareima and on both banks of the river Atbara for a distance of 75 river kilometres from its mouth.

5.2 MAPS AND SURVEY DATA AVAILABLE

The maps available consisted of a set of 1:100,000 scale sheets entitled "Cross Sections of the Survey of Irrigable Areas Northern Province" and dated June 1951 and April 1952. These sheets are numbered from 1 to 10 inclusive, plus sheet number 8A which covers part of the River Atbara and from 12 to 14 inclusive. They are based on cadastral maps at 1:50,000 scale with additions from current 1:250,000 scale series and American air survey compilation. These sheets show the cross sections at approximately 4 kilometre intervals, established by the Sudan Survey Department in their 1951/52 survey, covering ground up to the 15 metre isopotamon.

Detailed contour plans were available for the following areas at 1:10,000 scale, showing contours at 0.25 metre intervals :-

i) El Hugna Basin. No drawing number.

ii) Wad Hamid Basin and part of Medisisa Basin. Drawing number SID/46 - 10,640.

iii) Basabir Basin. Drawing number SID/46 - 10,658.

iv) Guweir Basin. Drawing Number SID/53 - 11,652.

v) Zeidab West. Drawing obtained from Zeidab Plantation Company. No drawing Number.

Vertical air photography at 1:25,000 scale and mosaic at 1:50,000 scale were available for most of the area studied. Figure 9 shows the extent of the map and photographic cover.

5.3 REFERENCE DATUM

The zero of the river gauge at Khartoum is the reference datum used for the sections established in the 1951/52 Survey of Irrigable Areas. The recently established value for the gauge zero is 363.00 metres above mean sea level at Alexandria. This was the value used in the 1951/1952 Survey and has been used for our reconnaissance surveys throughout the project area north of Khartoum.

Bench marks on individual cross sections have been established by the Sudan Surveys Department by assuming a uniform river slope between adjacent river gauges.

5.4 ACCURACY OF SURVEY DATA

Differences of up to 1.20 metres occur in the normal minimum water level computed for corresponding points on opposite sides of the river but in most cases the normal minimum water level for cross sections is probably within 0.5 metre of the assumed slope.

5.5 HYDROLOGY

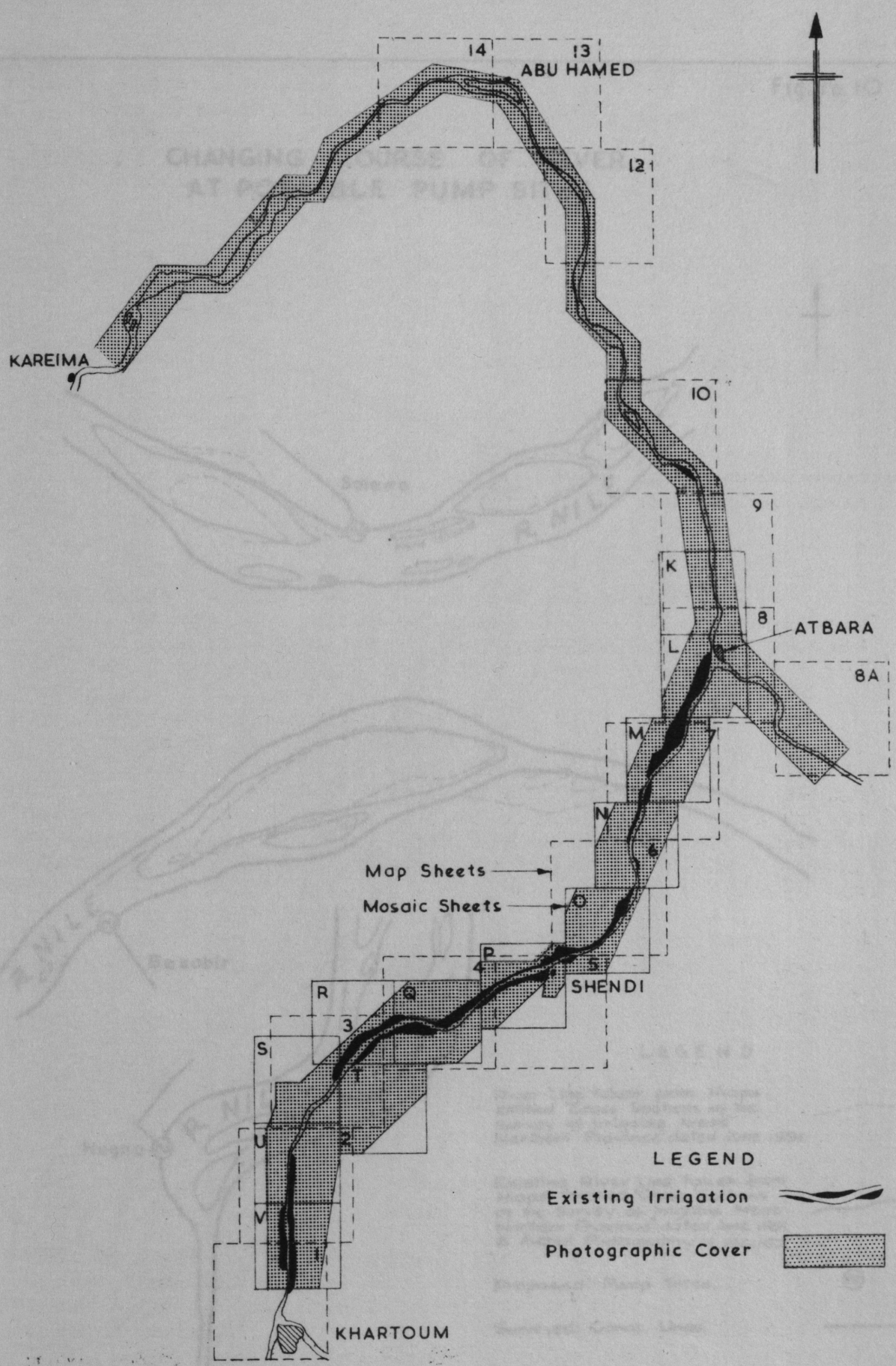
The Blue and the White Niles join at Khartoum to form the Main Nile. The only tributary to join the Main Nile between here and the sea, is the River Atbara which enters the Nile 320 kilometres downstream of Khartoum.

In the 1,840 river kilometres from Khartoum to Aswan, the most outstanding features in the river profile are the five cataracts, each of which consists of a series of rapids extending 20 to 30 kilometres along the river. The fourth and fifth cataracts occur in the area under investigation. The fourth is situated 50 kilometres upstream of Kareima and the fifth, 70 kilometres downstream of Atbara. The Sabaloka Gorge is sometimes referred to as a sixth cataract. This gorge is a deep cleft 20 kilometres long with a sharp bend in the middle and is 80 kilometres downstream of Khartoum. The bed is rocky and irregular but the depth of water at low river is usually about 20 metres and is some times as much as 40 metres.

The 755 kilometres of the Main Nile, covered in the 1963/64 reconnaissance survey, extend from Khartoum, 1,845 kilometres upstream of Aswan, to Kareima, 1,090 kilometres upstream of Aswan. Along this section of the river, the main river channel varies in width between 200 metres and 1,800 metres. A feature of this stretch of the river is the large number of islands which occur. At such places, the distance between banks of the river may be as much as 7 kilometres. At low river level the water section is reduced to one or more shallow channels, and large sandbanks, the position and extent of which may appreciably change during periods of high flood, become prominent. Figures 10 to 12 indicate such changes at possible pump sites.

Figure 9

EXISTING IRRIGATION MAP AND PHOTOGRAPHIC COVER



Scale. 1/2,000,000

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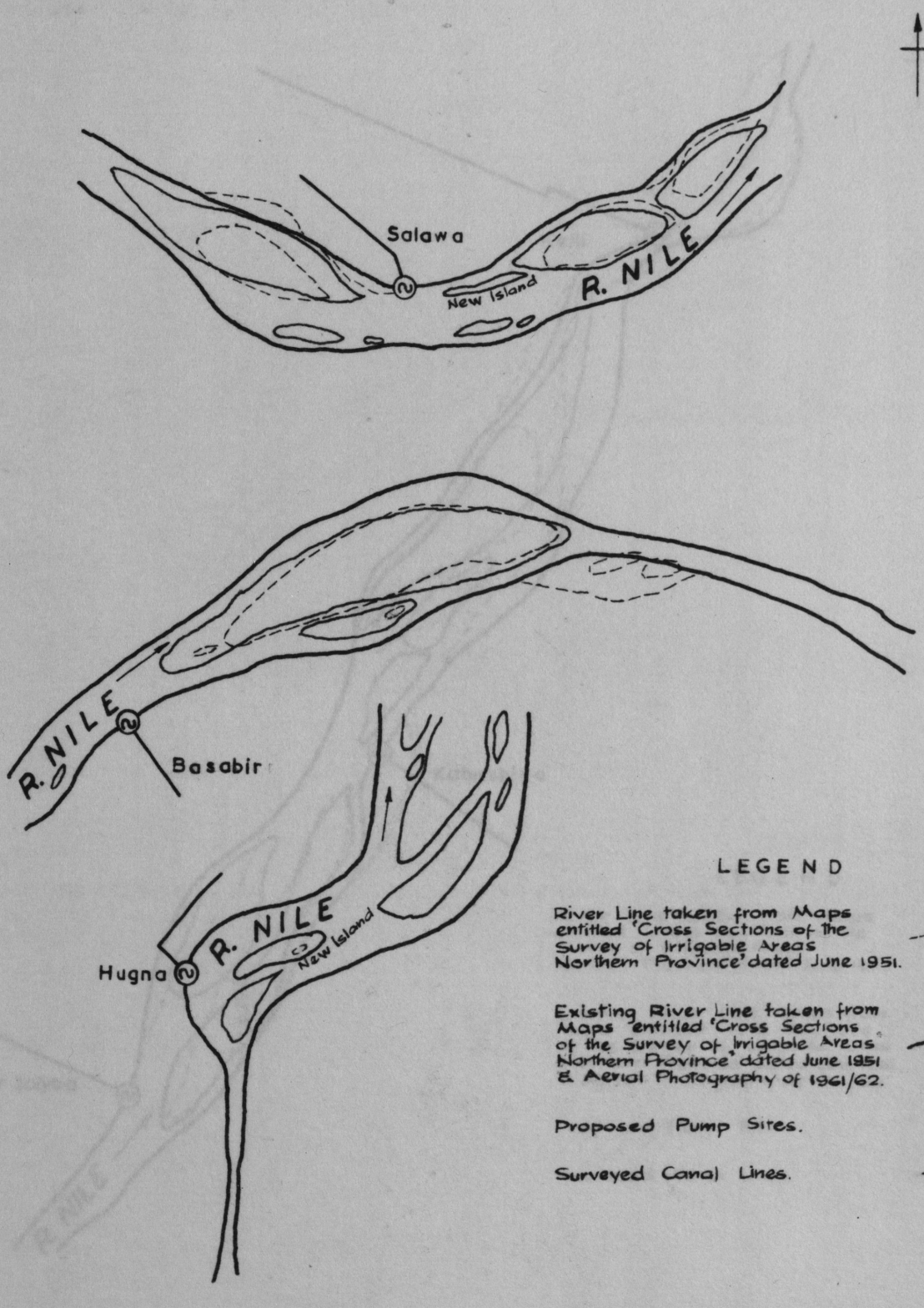
Figure 10

CHANGING COURSE OF RIVER AT POSSIBLE PUMP SITES



LEGEND

River Line taken from Maps entitled 'Cross Sections of the Survey of Irrigable Areas Northern Province' dated June 1951.

Existing River Line taken from Maps entitled 'Cross Sections of the Survey of Irrigable Areas Northern Province' dated June 1951 & Aerial Photography of 1961/62.

Proposed Pump Sites.

Surveyed Canal Lines.

Scale: 1 : 100,000.

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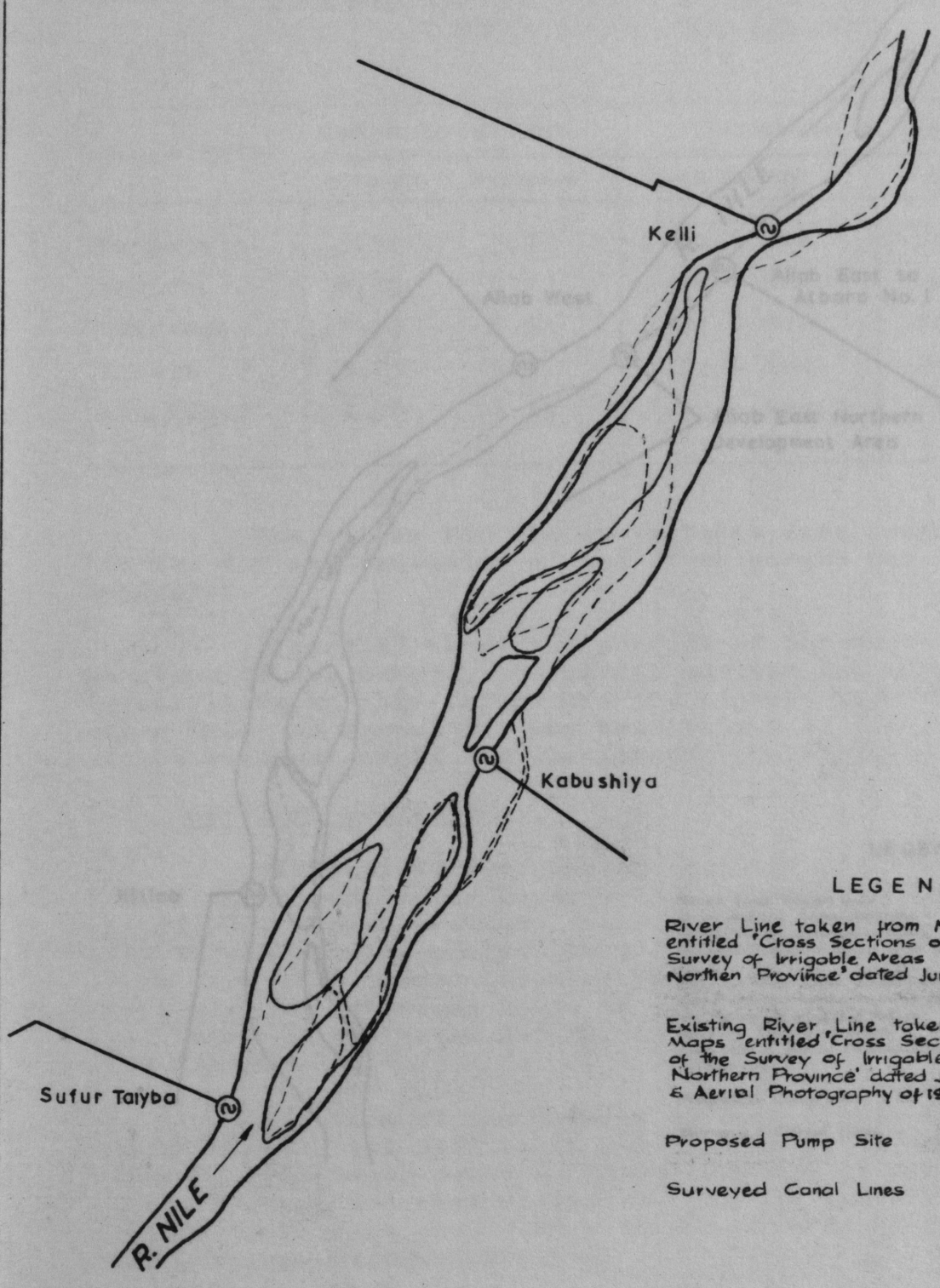
SEPTEMBER 1964.

Figure 11

CHANGING COURSE OF RIVER AT POSSIBLE PUMP SITES



LEGEND

River Line taken from Maps entitled 'Cross Sections of the Survey of Irrigable Areas Northern Province' dated June 1951.

Existing River Line taken from Maps entitled 'Cross Sections of the Survey of Irrigable Areas Northern Province' dated June 1951 & Aerial Photography of 1961/62

Proposed Pump Site

Surveyed Canal Lines

Scale: 1: 100,000

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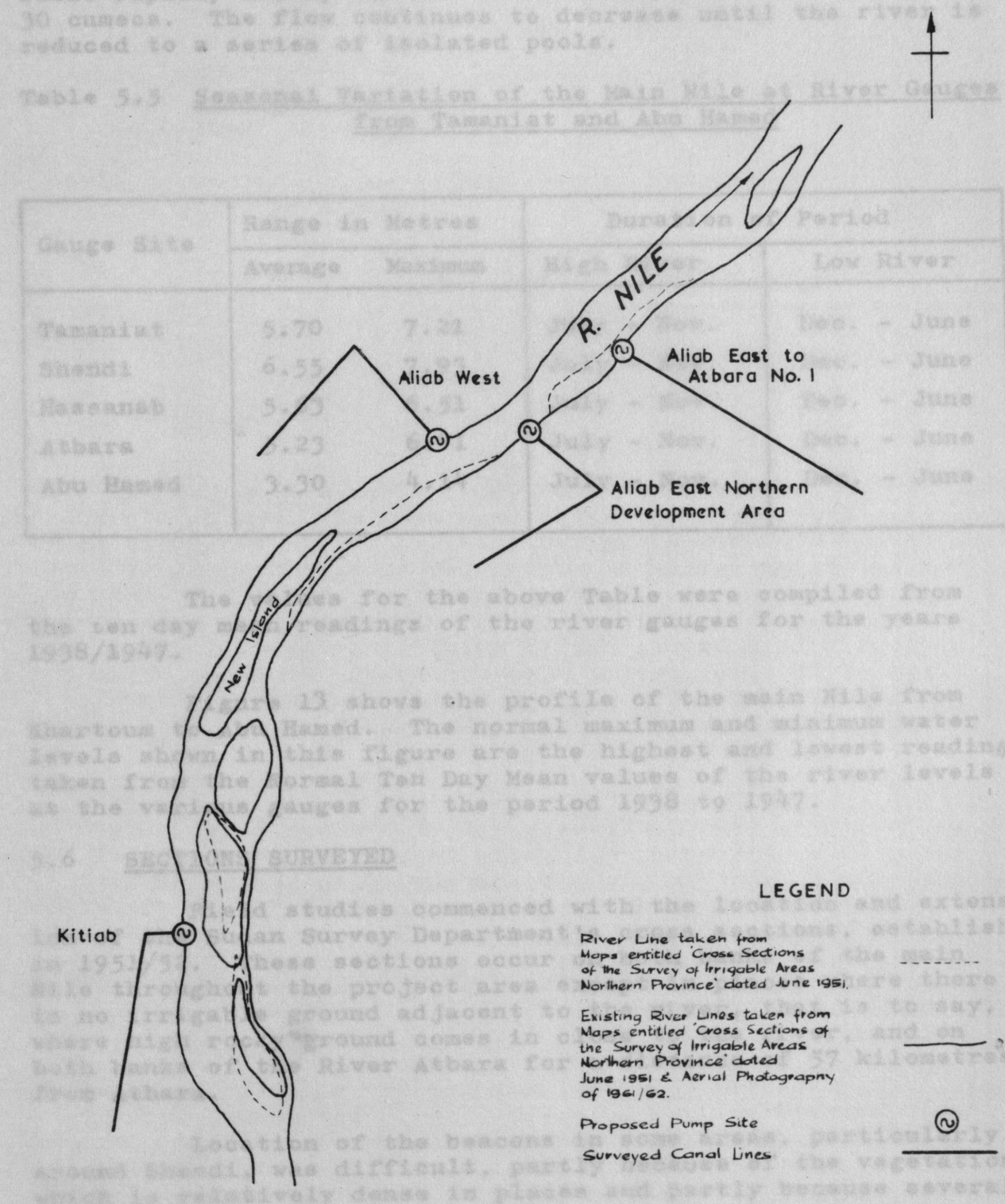
Figure 12

CHANGING COURSE OF RIVER AT POSSIBLE PUMP SITES



SCALE 1 : 1000000

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SEPTEMBER 1964

River gauges are maintained at Khartoum (Blue Nile), Tamaniat, Shendi, Hassanab, Atbara and Abu Hamed. Table 5.5 gives a summary of the seasonal variations of the river.

There are two seasons for the river, the flood from July to September and the low river from October to June. The flow in the main Nile at the peak of the flood, normally between late August and early September, is usually about sixteen times that of its lowest stage. The river Atbara, near its mouth, starts to rise in June, the flood reaching its peak about mid-August. After the end of August the river falls rapidly and by the end of December, the flow is about 30 cumecs. The flow continues to decrease until the river is reduced to a series of isolated pools.

Table 5.5 Seasonal Variation of the Main Nile at River Gauges from Tamaniat and Abu Hamed

Gauge Site	Range in Metres		Duration of Period	
	Average	Maximum	High River	Low River
Tamaniat	5.70	7.21	July - Nov.	Dec. - June
Shendi	6.55	7.93	July - Nov.	Dec. - June
Hassanab	5.63	6.51	July - Nov.	Dec. - June
Atbara	5.23	6.41	July - Nov.	Dec. - June
Abu Hamed	3.30	4.14	July - Nov.	Dec. - June

The values for the above Table were compiled from the ten day mean readings of the river gauges for the years 1938/1947.

Figure 13 shows the profile of the main Nile from Khartoum to Abu Hamed. The normal maximum and minimum water levels shown in this figure are the highest and lowest readings taken from the Normal Ten Day Mean values of the river levels at the various gauges for the period 1938 to 1947.

5.6 SECTIONS SURVEYED

Field studies commenced with the location and extension of the Sudan Survey Department's cross sections, established in 1951/52. These sections occur on both banks of the main Nile throughout the project area except in places where there is no irrigable ground adjacent to the river, that is to say, where high rocky ground comes in close to the river, and on both banks of the River Atbara for a distance of 57 kilometres from Atbara.

Location of the beacons in some areas, particularly around Shendi, was difficult, partly because of the vegetation which is relatively dense in places and partly because several of the beacons had been destroyed. Of the sections investigated, there were about 20% with one or more beacons either broken or completely destroyed.

Extensions to the Sudan Survey Departments sections were made according to the following categories:-

i) Where there appears to be a possibility of future irrigation development up to or above the 15 metre isopotamon: section extended from the 15 metre to the 20 metre isopotamon.

ii) Where the 15 metre isopotamon is definitely beyond the topographical limit of irrigable land: section extended from the 15 metre isopotamon for token length of 0.6 to 1.0 kilometre only.

iii) Where the section line is situated in high rocky desert or sand dune areas where no irrigation is possible: section not extended.

The number of sections of each category is given below :-

Sections extended to the 20 metre isopotamon	46
Sections token extension only	10
Sections not extended	20
Sections not located	7
Total	83

On the 14th March 1964, after a study of the soil survey field work which was then complete, and discussions with the Ministry of Agriculture, it was decided that there was no justification in continuing to extend sections from the 15 metre to the 20 metre isopotamon since the limit of suitable soils as defined by the reconnaissance soil survey did not extend beyong the 15 metre isopotamon. At this stage of the engineering reconnaissance, sections which had not been investigated were those (i) on the right bank of the Main Nile from Khor Es Saqqai downstream to Wadi Arus and (ii) on both banks downstream of J. Daiyiqa.

The 20 metre isopotamon was marked by a 2" x 2" x $\frac{1}{4}$" or 3" x 3" x $\frac{1}{4}$" mild steel angle, 1.0 metre long, driven into the ground with about 0.5 metre length showing for easy identification. The visible part of the angle was painted in alternate black and white stripes and marked with the cross section number and 20M.

The limit of a token extension was marked in a similar way, the height reached (e.g. 17.8 M) being used in place of 20 M.

As the fieldwork was carried out, the survey results were plotted on maps at scale 1:100,000 together with the relevant data obtained for the sections established in 1951/1952 Using this information, together with any additional topographical information obtained during fieldwork, reconnaissance contours were plotted at 1.0 metre intervals.

5.7 SELECTION OF PROJECT AREAS

Working with the aid of the air photography, and the plotted contours and in conjunction with the soil reconnaissance survey, it was possible to select the areas which were likely to be suitable for further development. Field inspections were then made to locate suitable pump station sites and lengths of proposed supplu canals were surveyed to indicate how each area might be irrigated. All surveyed canal lines were marked with concrete posts 0.7m x 0.2m x 0.2m, with an identification number stamped on the top, sunk in to the ground with about 0.05 metre visible and/or with steel angles as used for the 20M isopotamon with an identification number painted in black.

In all cases, except the El Qoz (Taragma) area, it is possible for the pumps to deliver directly in to a discharge basin at the head of the supply canal, though, in some instances, a second lift pump and a rising main is necessary to reach a part of the project area on higher ground. For the El Qoz (Taragma) area pumps may deliver directly into a discharge basin and the water led to the project area some distance away from the river, but second stage pumping and a length of rising main is necessary before the project land may be irrigated.

An important feature of the area is the Shendi Basins, all of which were studied with a view of conversion to perennial pump schemes.

Pump sites were located for twenty areas. A list of the sites is given in Table 5.7.

A short description of each of the project areas is given below :-

i) El Hugna Basin (Sheet 3)

This is a high basin with little topographically irrigable land outside the existing basin. According to local information there has been no "Tamam Rai", or good flooding, of the basin since 1946.

The mouth of the existing canal, which serves the basin during river flood, was investigated with a view to siting a pump station. This proved unsuitable on account of the numerous small islands and sand banks in the river.

The land rises towards the southern end of the basin, about one kilometre upstream of the existing canal, to the village of El Hugna. Here, a pump site was located near the mouth of an old canal which has silted up and fallen out of use. This site is on the inside of a wide bend in the river. In view of this and islands on the far side of the river, barge-mounted pumps would be advisable. Diversion banks would be required for Wadi Sibna, which joins the river in this area. From this site, 2,900 feddans could be commanded with a static lift of 9.00 metres. About 300 feddans of the total area is already privately developed.

It may also be possible to command Medisisa Basin and part of Wad Hamid Basin from this site but further detailed study is necessary to see it the high land to the north of Hugna basin can be passed by a canal line.

Table 5.7 Areas studied in the Engineering Reconnaissance.

Location	Commanded Area Gross Feddans	Irrigation Supply by Pumps	
		Sites surveyed (Number)	Static Lift from N.M.W.L. (Metres)
El Hugna Basin	2,900	1	9.00
Medisisa Basin	2,000	1	8.25
Wad Hamid Basin	14,500	2	8.50
Basabir Basin	10,800	1	8.50
Salawa Basin	9,500	1	8.00
Seyal Basin	3,800	2	8.25
El Qoz (Taragma)	-	1	-
Sufur Taiyba	27,600	1	10.00
Kabushiya	6,800	1	7.50
Kelli	25,500	1	9.50
Kitiab (West)	1,170	1	8.25
Aliab (West)	2,280	1	9.50
Aliab East Northern Development Area	1,100	1	8.75
Aliab East to Atbara	-	2	-
Zeidab West	3,000	2	-
Hassa	7,500	1	11.50
Bauga	9,000	1	14.75
Abu Hamed	-	1	-
Kineidra (Right Bank)	-	1	-
Kineidra (Left Bank)	-	1	-

ii) Medisisa Basin (Sheet 3)

This is a narrow, rather uneven basin, about 10 kilometres long, varying in width between 0.2 and 1.0 kilometres . The area is 600 feddans. It is surrounded by topographically unirrigable land except for about 100 feddans outside the present basin which might be included in a pump project. Only about one year in four is the river flood high enough to enter the canal serving the basin.

Numerous islands and sandbanks occur in the river adjacent to this basin. Higher ground comes in closer to the river at the southern end of the basin where the river is free from obstructions and appears to be stable. A pump site was located here and a length of supply canal surveyed. Land based pumps could be used to command an area of 2,000 feddans, the static lift being 8.50 metres.

iii) Wad Hamid Basin (Sheets 3 & 4)

This is the largest of the basins and is comprised of Hod Wad Hamid (2,000 feddans) and Hod Beriab (5,800 feddans) making a total basin area of 7,800 feddans. These are the figures given by the Sudan Irrigation Department. However, from the photographic mosaics, it would appear that a total of 11,000 feddans is used as basin land.

Several possible pump sites were inspected and two were selected as being the most suitable.

The total project area, excluding the Medisisa area, is 29,000 feddans, of which 16,000 feddans is Type 1 land. Of this, about 14,500 feddans could be commanded from the pump site, Wad Hamid No. 2 with a static lift of 8.50 metres. A second lift pump and a rising main 3.0 kilometres in length would be necessary to command a further 7,000 feddans of higher land, much of which is steeply sloping and undulating and is not very suitable for canal irrigation. The area could also be commanded from the proposed site Wad Hamid No. 1 with a lift of 9.0 metres. As the land in general falls from site No. 2 to Site No. 1, the former is recommended. If the basin is converted to a perennial pump scheme, about 20 kilometres of flood protection banking, varying in height between 1.0 and 2.0 metres will be required to stop the river from flooding the area.

iv) Basabir Basin (Sheet 4)

Much of the land in this even basin is already privately developed and all the land adjacent to the river is registered, leaving a 'Hod' area of about 3,000 feddans. Flooding of the basin is erratic and, according to local information 1963 was a good flood, in 1962 only half and in 1961 only one quarter, of the total area was flooded.

A pump site was located upstream of Nasri Island at a point where the river bank is steep and stable. Possibly, a better site could be located a little further upstream but dense palm trees made it impossible to survey a canal line from any site other than the one chosen. It seems likely that the large sandbank on the upstream end of Nasri Island will extend further upstream. Therefore barge- mounted pumps should be used at this site.

The area which could be commanded from this site with a static lift of 8.50 metres is 10,800 feddans though gilgai (cracking of heavy clays) occurs over about 1,000 feddans of this. Another 1,300 feddans at the eastern end of the basin could probably be used but detailed contours for this area are not avilable. To irrigate the area (4,200 feddans) of higher land around Wadi Arus a second lift pump and a length of rising main of about 2½ kilometres would be necessary.

Several wadis drain into this basin. Protection banks and drains will be necessary along the southern side if the area is developed as a perennial pump scheme.

v) Salawa Basin (Sheet 4)

The basin land is comprised of Hods Salawa (1,400 feddans), Tabuga (2,600 feddans) and Hobagi (1,000 feddans), all watered during flood by a canal starting in Salawa basin and terminating at Salawa saliba.

From a study of the maps and photography various possible pump sites were selected. Some were eliminated by site inspection and the most suitable one approved to be at the southern end of the basin, about 2½ kilometres downstream of the existing canal serving the basin, at a point where the river appears stable and free from obstructions. However, in view of the unstable nature of the river upstream and downstream of this site, barge-mounted pumps would be advisable.

From this site, 9,500 feddans can be commanded with a static lift of 8.00 metres.

vi) El Qoz (Taragma) (Sheet 5)

Originally a pump site was located at Taragma (north east corner of Sheet 5) and a canal line surveyed with the undeveloped land inside the railway line and immediately outside the railway line, only, as a project area. This land was subsequently rejected by the soils survey, leaving only higher terrace, Type II, land which is rather difficult to command. Much of this new area is uneven and steep with prominent gravel areas.

After studying the maps and mosaics, two pump sites were located, El Qoz 1 & 2, 7,700 and 8,500 feddans respectively may be commanded from these with static lifts of 10.25 metres and 8.75 metres but, in each case, a main canal, second lift pump and rising main 2½ and 2 kilometres respectively are required.

Possibly, from site No. 2 the area of 9,000 feddans south of Kabushiya could be commanded. Alternatively, this could be irrigated from the Taragma site, with a static lift of 10.50 metres.

vii) Sayal Basin (Sheet 5)

Apart from a small area at the upstream end, this basin is level and even. Two pump sites were located and lengths of supply canal surveyed for each one.

The area which can be commanded is 3,900 feddans with a lift of 8.25 metres.

The river bank along this reach gradually shelves over 300 metres to water level at low river levels. This shelving is a general feature in this area though at site No. 2, for a very short length, the bank is steeper. For this reason, this site is the better of the two. At either site, barge-mounted pumps should be used.

viii) Sufur Taiyba Basin (Sheet 6)

Outside the boundary of the basin land lie large areas of soil suitable for development though, in many instances these areas are isolated and almost surrounded by fixed and active sand dunes.

Along the length of this and Guweir Basin, which lies upstream, there are many islands and sandbanks in the river, making the selection of a suitable pump site extremely difficult. A site was located about 6 kilometres downstream of the existing canal serving Sufur Taiyba Basin, at a point where, for a short reach, the river channel is free from obstructions and the bank appears stable. A canal line, 7.4 kilometres long, was surveyed, avoiding the major sandy areas outside the basin land.

With a static lift of 10.00 metres it would be possible to command the Guweir and Sufur Taiyba areas. Barge-mounted pumps should be used.

A preliminary canalisation layout has been made but large areas may be eliminated because they are uneven or sandy; this can only be confirmed by further investigation after a detailed contour survey has been made.

ix) Kabushiya Basin (Sheet 6)

The total project area is 11,900 feddans of which 2,000 feddans lie in the Wadi El Hawad. Gilgai occurs over a further 2,900 feddans, making a total 4,900 feddans unsuitable for irrigation.

The area commanded is 6,800 feddans with a static lift of 7.50 metres. This area includes 2,400 feddans already developed as a private pump scheme. Barge-mounted pumps would be advisable.

x) Kelli Basin (Sheets 6 and 7)

The basin land is comprised of three Hods, Malaga, Abeidab and Kimir, with the higher land lying towards the upstream (Malaga) end. This end, however, is unsuitable for a pump site owing to the large island close to the river bank. The channel between the island and the mainland dries out completely at low river levels.

A pump site was located near the head of the existing canal serving the basin. In view of the unstable nature of the river, barge-mounted pumps should be used. With a static lift of 9.50 metres 25,500 feddans could be commanded though large areas of uneven land, sand dunes and gravel ridges would be eliminated.

xi) Kitiab West (Sheet 7)

This is a very uneven area of 1,300 feddans. At the pump site located, barge-mounted pumps would be advisable because of the unstable nature of the river. 1,200 feddans could be commanded from this site with a static lift of 8.25 metres.

Probably, the reason this area has not already been developed as an extension to Kitiab scheme, is the uneven terrain, the whole area being crossed by numerous drainage lines and small khors which would have to be levelled before development could proceed. A certain amount of flood protection banking would be necessary but without detailed contours it is not possible to give an estimate of the height and lengths involved.

Gilgai occurs over about 360 feddans of the demarcated area and a further 250 feddans have already been incorporated as an extension to Kitiab Pump Scheme.

xii) Aliab West (Sheet 7)

The terrain at the north-eastern end of this area is uneven and levelling would be necessary before any further development could take place.

The unstable nature of the river along this reach makes the location of a suitable pump site difficult. A site was located at the northern end, but this would only be suitable for barge-mounted pumps. 2,300 feddans could be commanded, using a static lift of 9.50 metres.

xiii) Mutmir (Sheets 6 and 7)

The two narrow strips between Mutmir and Aliab are referred to as Mutmir on Sheets 5 and 6. After the completion of fieldwork, these areas were added by the soils survey. No engineering survey was made. From the aerial photography, it would appear that the areas are low lying basin land. Flood protection and wadi diversion banks would probably be required. Although these small areas are probably best left for private development, preliminary pump sites and canals have been indicated. At Mutmir North an area of 1,600 feddans can be commanded with a static lift of 7.50 metres. A lift of 8.25 metres will command a further area of 1,600 feddans at Mutmir South.

xiv) Aliab East. Northern Development Area (Sheet 7)

This land is very irregular with many drainage lines, small khors and gilgai and could hardly be recommended for development as a separate pump scheme. Many of the slightly more even parts of the area are gradually being incorporated into the existing Aliab pump scheme, 160 feddans having been taken in 1963/64.

It would seem that this is the best method of development for the area. However, a pump site was located, from which an area of 1,100 feddans could be commanded with a static lift of 8.75 metres.

During high river levels much of the area is flooded to a depth of about one metre. Detailed contours would be required to discover the amount of flood protection banking which would be necessary.

xv) Aliab East to Atbara (sheets 7 and 8)

A large area running from Aliab East up to Atbara, has subsequently been rejected by the soils survey. Two pump sites were located and lengths of supply canals surveyed.

xvi) Zeidab West (Sheet 7)

The area of about 3,000 feddans is well away from the river to the west of Zeidab main pump station. To develop this area as a separate scheme, a supply canal 7 kilometres long in high embankment will be necessary from the river to the area. It would be preferable to develop this as an extension to Zeidab scheme and with this in mind, two canal lines were surveyed to indicate how it might be done. These lines are shown on the engineering plans and in section in Plate 3. The area was subsequently rejected by the soils survey.

xvii) Zeidab N.W. (Sheet 8)

A further area of 4,300 feddans was added by the soils reconnaissance after completion of the field work. Consequently, this was not studied in the engineering reconnaissance. This is a long narrow strip of land adjacent to Zeidab Pump Scheme and 3 to 5 kilometres from the river. It could best be developed as an extension to Zeidab Scheme.

xviii) Atbara South (Sheet 8)

This area was not studied in the engineering reconnaissance as it was only later included by the soils reconnaissance. From a study of the photographic cover available, a pump site has been located. A preliminary canal layout has been made. With a static lift of 10.75 metres it may be possible to command 4,900 feddans.

xix) Adabia (Sheets 8 and 9)

This is a long narrow strip between Atbara and Berber and again was only included after field work had been completed. From the pump site shown and with a static lift of about 10.25 metres it should be possible to command approximately 5,800 feddans.

xx) Hassa Plain (Sheet 9)

The river is very unstable along this reach. This has probably been the reason for the closing down of a private pump irrigating much of the area. A pump site was located at the only suitable site, though this is a low lying 'island'. Elsewhere the river and bank are more unstable with islands and khors. Barge-mounted pumps would be advisable here and a short length of canal (600 metres) in high embankment (5 metres) or a length of rising main would be necessary. With a static lift of 11.50 metres an area of 9,000 feddans could be commanded.

xxi) Bauga (Sheets 9 and 10)

A pump site was located at the northern end of the area where the high land approaches the river. The project area is even and with a static lift of 14.75 metres 9,000 feddans could be readily commanded.

xxii) Abu Hamed (Sheet 13)

The land on the left bank of the river, opposite Abu Hamed and Mograt Island was studied in the engineering reconnaissance. This area was subsequently rejected by the soils reconnaissance. The land adjacent to the river has been developed by private pump schemes, leaving only a narrow strip up to 200 metres in width between the existing schemes and the high, rocky ground. A pump site was located from which the area could be commanded but as this would mean running a supply canal, either across land already developed and/or across the small area of land to be used it would be better to leave this to be incorporated in the private schemes.

xxiii) Kineidra (Sheet 8A)

The right and left banks of the river Atbara, at Kineidra, were originally studied with smaller areas in mind. The project areas were later increased after the completion of field work. No Sudan Survey Department's sections or bench marks exist in this area consequently no contour cover is available. A pump site was located on each bank.

The terrain on both banks is even, though sand dunes occur along the river banks.

The river in this reach is dry from about mid March until June. Unless sufficient compensation water is released from Khashm El Girba dam, which is unlikely, year round pumping will not be possible.

5.8 THE SELECTED PROJECT AREAS

The areas which have been selected for further study are indicated by shading on the engineering plans. For each area, a preliminary canalisation layout has been shown. These have been based on reconnaissance contours when available. In areas where there is insufficient contour cover idealised layouts have been shown. In either case, these layouts would require substantial revision when more detailed topographical surveys, necessary for designing the canalisation systems, are carried out. They are of value, at this stage, in evaluating the relative merits of the various areas and their use should be restricted to this.

For all the low lying basin land, flood protection banks would probably be required though this has not specifically been mentioned in each individual case as sufficient contour detail is not available.

In some cases the canalisation shown does not cover the whole of the area recommended for semi-detailed soil survey. This is because of the difficulty of commanding higher ground near the scheme boundary from a single pumping station designed to serve the area as a whole. The use of a secondary pump to serve the additional area could be considered if sufficient good quality land is found to exist.

Table 5.8 The Selected Project Areas.

Area	Map Sheet No.	Gross Area in Feddans			Pumps, Static Lift from Normal Min. Water Level Metres
		New Land	Registered Land	Total	
El Hugna Basin	3	1,000	1,800	2,800	9.00
Medisisa Basin	3	200	1,600	1,800	8.25
Wad Hamid Basin	3 & 4	26,400	3,300	29,700	8.75
Basabir Basin	4	5,400	10,600	16,000	8.50
Salawa Basin	4	1,500	9,000	10,500	8.00
Sayal Basin	5	1,300	2,500	3,800	8.50
El Qoz (Taragma)	4, 5, & 6	49.200	1,000	50,200	8.75/10.25
Sufur Taiyba Basin	5 & 6	23,000	7,000	30,000	10.00
Kabushiya	6	9,700	1,700	11,400	7.50
Kelli Basin	6 & 7	14,600	12,700	27,300	9.50
Mutmir (South)	6	-	1,600	1,600	8.25
Mutmir (North)	7	1,400	200	1,600	7.50
Kiteab West	7	800	200	1,000	8.25
Aliab West	7	1,700	1,200	2,900	9.50
Aliab East) Northern) Development) Area)	7	1,000	200	1,200	8.75
Zeidab N.W.	8	4,300	-	4,300	-
Atbara South	8	5,500	500	6,000	10.75
Adabia	8 & 9	6,800	-	6,800	10.25
Hassa Plain	9	1,700	6,800	8,500	11.50
Bauga	9 & 10	600	9,400	10,000	14.75
		RIVER ATBARA			
Kineidra (Right Bank)	8A	18,100	-	18,100	-
Kineidra (Left Bank)	8A	22,000	-	22,000	-
Right Bank Between Cross) Sections 7 & 9)	8A	1,500	2,000	3,500	-
TOTAL AREAS	-	198,300	73,300	271,000	-

CHAPTER 6

LAND SUITABILITY CLASSIFICATION

6.1 LIMITING PHYSICAL FACTORS TO LAND DEVELOPMENT

The general specifications for topographic limitations and soil limitations follow the lines of the U.S.B.R. System, adapted to local conditions as explained.

6.11 Topographic limitations

Sloping eroded land was generally found where the higher terraces are bounded by an escarpment of the Nubian Series, or where these lands are associated with the break of slope from the sandstone plateau to the highest terrace of the old flood plain. In spite of the low annual rainfall there is a considerable run-off after heavy rains. Large wadis originating on the higher ground often occur. The high sloping areas suffer mostly from sheet erosion. Their surface is covered predominantly with sandstone detritus and/or gravels. Lithic and Orthic Orthustents are the most common soil classes in these areas.

Sloping gullied land was mapped as S.G.L. It is effectively Class 6 on topographic grounds, but for mapping purposes has been included in : "Miscellaneous Land Classes", all of which are non-arable.

Sand movement is particularly common in the winter season due to the prevailing northerly wind. Barchans were found north of Kurgos. Crops are frequently covered by sand throughout the area north of El Bauga. Both fixed and active dunes occur frequently in the basins between El Guweir and Kitiab. These basins are suitable for agriculture, but it must be recognised that the areas suitable for cropping alternate with sand dunes. Sand movement is a potential danger and active dunes must be stabilised to avert it.

6.12 Soil Limitations

Alkalinity

The E.S.P. limit of 30, established for this reconnaissance study, is high by normal standards. The soil pattern, especially in the basins, is however a complex one and sampling sites were very far apart. We have therefore used additional evidence, including quality of crops already being grown, in recommending these areas for further study.

As the basins in particular clearly constitute one of the major land resources in this general area, we have recommended all of these for semi-detailed survey. The possibility of a local alkalinity hazard must however be recognised.

Salinity

The soils in the basins and on the eroded terraces are in general non-saline to slightly saline. The salinity in most of the terrace soils is moderate to severe. Overall salinities range from non-saline up to E.C. of 49 millimhos. As the soils are generally rather sandy and therefore more permeable, it should be possible to leach some of the salts.

The top limitations of E.C. for the higher terraces was taken at E.C.'s much less than 18 mmhos, for reasons similar to those described for E.S.P. All the basins are recommended for semi-detailed survey, even if their E.C.'s are greater than 18 mmhos.

Gravels and Stones

The higher sloping grounds are mostly covered with stones and gravels derived from the Nubian series. It is probable that these areas could be developed at high costs, but careful planning would be necessary. Sprinkler irrigation should be taken into consideration.

Excessive Sandiness

Excessive sandiness not only occurs in dunes but also in flat areas e.g. South West of Shendi. The silt and clay content in the top horizons of these soils is low and this results in a very high permeability and low water retaining capacity. We do not consider that they are suitable for general agriculture.

6.2 LOCATION AND EXTENT OF LANDS RECOMMENDED FOR SEMI-DETAILED SURVEYS

The reconnaissance soil survey was concerned only with undeveloped land, most of which was government land. The survey included Basin lands, but the terms of reference excluded developed registered lands, Government and private pump schemes. Nevertheless a few sites (pits and bores) were made in the cultivated areas.

The areas recommended for further study shown in Table 6.2, are large enough to warrant the expense of a pump scheme. They are described as follows :-

Class I — Favourable Lands

West Bank

a 1 Hugna Basin — 2,800 feddans

Although no chemical data were available for this area, it was classified as Orthic Orthustents. Some salt crystals were found at 140 cm. Unfortunately Wadi Tibna carried a lot of sand down and due to this a part of the existing scheme was abandoned. A protection dyke would be necessary prerequisite for further development.

a 2 Medisisa-Wad Hamid Basin — 18,000 feddans

This uneven basin has excellent soils, classified as Orthic Orthustents. The development of this basin has been considered in conjunction with the area as a whole. Wad Hamid is situated on the West Bank half way between the main markets Khartoum and Shendi and the communications are very bad.

a 3 Salawa-Habashi Basin 10,500 feddans

The soils were classified as a complex of Natrargidic and Orthic Orthustents, although the chemical data of pit No.2062 indicates only Natrargidic Orthustents. But as the area is very complex according to bore observations it is decided to classify the soils accordingly. Pit 2062 shows an extremely high alkalinity and salinity. The texture is mostly silty clay loam.

a 4 Sayal Basin 5,600 feddans

This basin is probably the most level and even basin in the Shendi reach. A pit was dug near the edge of the basin because most of the basin was still inundated. Pit 2030 shows a non-saline/alkaline soil, but with a light texture. The classification is Natrargidic Orthustent.

a 5/ Guweir-Kelli-South end of Kitiab 59,000 feddans
a.6

After Wad Hamid this extensive basin merits prioity for further development. In fact the area between Guweir and Kitiab is one large discontinuous basin. The obstacle to further development appears to be the lack of population. The local people have moved out of the area during the last 10 years and they now work in the Three Towns. The soils were classified as Complexes: Complex of Psammustents and Orthustents and complex of Natrargidic and Orthic Orthustents. They are slightly saline/alkaline soils. Sand dunes frequently occur throughout the area.

a 7 Kitiab West 1,000 feddans

No chemical data were available, but in conformity with the soil descriptions the soils are classified as Vertic Orthustents. Probably they are intergrading towards the Natrargidic and thus alkaline. West of Kitiab is a small strip of land which could be developed. Gravels and stones washed down from the jebels occur on the surface.

a 8 Aliab West 2,900 feddans

No chemical data were available, but the soil was classified as Complex of Natrargidic and Vertic Orthustents. The area has been cultivated, but the pump scheme has failed due to river flood. Before any development could take place, a protection dyke would have to be constructed.

a 9 Zeidab-N.W. Extension 4,300 feddans

This agricultural land lies between the edge of the Zeidab syndicate and an uneven gravelly terrace. It consists of a narrow strip of land along the boundary of the scheme, becoming wider at the northern end. This latter area covers about 2,500 feddans and could easily be developed as an extension to the existing scheme. The narrow strip (about 1,800 feddans) is probably not worth developing. The soil was classified as Natrargid and is heavy textured.

b 10 El Bauga extension 10,000 feddans

The soils were classified as Complex of Vertic (Pit 2231) and Natrargidic (pit 2229) Orthustents. They occur between the pump scheme and the Nubian sandstone in the South-West and South of El Bauga. Pit 2231 shows in the top 50 cm. no salinity and alkalinity, while pit 2229 is extremely saline/alkaline. Both are heavy textured.

East Bank

a 11 Basabir/Wad Ban Naga Basin 16,000 feddans

The area consists not only of these two mentioned basins (pit No.2045), but also of a part of the higher terrace, (pit No.2077). The chemical data shows respectively a saline/alkaline and a non-saline/non-alkaline soil. The basin is heavier textured (clay content: 41) than the terrace soils (clay content: 21). Orchards would probably do well on these gravelly loamy soils.

a 12 Kabushiya Area 11,400 feddans

Approximately 2,000 feddans of the Wadi el Hawad (pit No.2018) is included in the total area. A protection dyke should be considered in any development plan. The soils were classified as Orthic Orthustents, although patches of Vertic Orthustents occur. They are heavy textured and are non-saline/non-alkaline.

a 13 Small strip between Mutmir and Aliab 3,200 feddans

The soils were mapped as Orthic Orthustents, although no chemical data were available.

a 14 Aliab East, Northern Development Area 1,200 feddans

The soil, classified as Natrargidic Vertic Orthustents is slightly saline/alkaline and heavy textured. The E.S.P. is 30.8, and probably will be reclaimable by leaching.

b 15 Atbara South 6,000 feddans

Parts of this area have been under cultivation. The soil is slightly saline/alkaline, but this would probably leach. Between Atbara and Ed Damer and along the river Atbara Calciorthidic Orthustents probably occur. There were no chemical data available for the latter area; the soils were classified according to bore observations.

b 16 Adabia between Atbara and Berber 6,800 feddans

Parts of the area were cultivated and others were abandoned. The soil is medium textured and is non-saline/non alkaline in the top horizon. There is some sand movement from higher parts. The soils were classified as Orthic Orthustents.

b 17 Hassa (north of Berber) 8,500 feddans

Two pits were dug in this area: pit No.2237 in the abandoned Hassa pump scheme and pit No. 2247 approximately 6 kilometres south of it. Pit 2237 shows a heavy textured, non saline/non alkaline soil while pit 2247 shows a medium textured, extremely saline/extremely alkaline soil. The soils were mapped as a complex of Vertic Orthustents and Natrargid. It was not possible to delineate the unsuitable area in the reconnaissance survey.

Left bank-river Atbara 22,000 feddans

b 18 (opposite Kineidra)

This area is very complex and it was not possible to delineate unsuitable areas. Thus a great complex of Orthustents and Natrargids occur, but sand dunes are also frequent along the river side. Pit 2190 and pit 2194 show no salinity, but alkalinity, especially pit 2194. The soil is light textured and should leach readily.

Right Bank-river Atbara 18,100 feddans

b 19 Kineidra

The area is quite even and classified as Vertic Orthustents, although Orthic and Natrargidic Orthustents may occur. Pit 2197 showed no salinity and no alkalinity and a heavy textured top soil decreasing with depth.

Class II Difficult Lands

Left Bank

a 20 Area West of Wad Hamid 13,500 feddans

The area is very complex and it is difficult to delineate soil boundaries accurately. Complexes of Psammustents and Orthustents and Natrargidic and Orthic Orthustents occur. Pit No. 2056 shows very high salinity and alkalinity. Due to this plus the complexity, uneven terrain, gravel and rock outcrops it is not possible to make a strong recommendation for semi-detailed survey as development would be doubtful.

Right Bank

a 21 Higher Terrace El Qoz (Taragma) (Shendi area) 37,500 feddans

This complex of Orthic and Lithic Orthustents may be suitable for agriculture, although they require careful study before development. They are non saline/non alkaline and in general coarse textured. Alternating patches of gravel and sand occur and the area is uneven. Where mapped as Lithic abundant gravel and stones occur at a depth of approximately 40 cm.

b 22 Sandy area S.W. of Shendi 6,600 feddans

Pit descriptions and photo-interpretation excluded this area from Class I because of the excess of sand. However it may be suitable for certain crops, such as groundnuts.

b.23 Taragma 6,100 feddans

The area is a complex of Psammustents and Orthustents, although small alternating patches of pure Orthustents and Psammustents were distinguished by photo-interpretion. There were no chemical data available. The area may be suitable for specialised agriculture, but this requires more study before deciding on development.

Right Bank Atbara River

c.24. Area between Cross Sections 7 and 9 3,500 feddans

There were no chemical data available although the area may be suitable for agriculture. Former cultivation was noted and an old canal was seen in the area. Of these difficult areas this is the most suitable for semi-detailed survey. It is however small in area.

Table 6.2 Areas Recommended for semi-detailed Survey

Class I

Favourable Lands

	RIVER NILE	
	West Bank	
a 1	Hugna Basin	2,800 Feddans
a 2	Medissa-Wad Hamid Basin	18,000
a 3	Salawa-Habashi Basin	10,500
a 4	Sayal Basin	3,800
a 5	Guweir-Kelli Basin	30,000
a 6	Kelli-Kitiab	27,300
a 7	Kitiab (West)	1,000
a 8	Aliab (West)	2,900
a 9	Zeidab N.W.	4,300
b 10	El Bauga (extension)	10,000
		110,600 Feddans
	East Bank	
a 11	Basabir/Wad Ban Naga Basin	16,000 Feddans
a 12	Kabushiya Area	11,400
a 13	Area between Aliab and Mutmir	3,200
a 14	Aliab (N-extension)	1,200
b 15	South of Atbara town	6,000
b 16	Between Atbara and Berber (Adabia)	6,800
b 17	Hassa (north of Berber)	8,500
		53,100 Feddans
	RIVER ATBARA	
b 18	Left Bank (opposite site of Kineidra)	22,000 Feddans
b 19	Right Bank (Kineidra)	18,100
	Cumulative Total :-	203,800 Feddans

Class II

Difficult Lands

	West Bank (Nile)	
a 20	West of Wad Hamid	13,500 Feddans
	East Bank (Nile)	
a 21	Higher terrace (Shendi Area)	37,500
b 22	Sandy area S.W. of Shendi	6,600
b 23	Taragma	6,100
c 24	River Atbara on the right bank between cross sections 7 & 9	3,500
	Total :-	67,200 Feddans

APPENDIX 1

Profile Description at 45 pit sites

Soil Classification

ORTHUSTENTS

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ROSEIRES SOIL SURVEY

REPORT NO. 5

ADDENDA TO APPENDIX I

LOCATION OF 45 PIT SITES

Site No.	Sheet No. SU	Description of the Locality
2001	105	10 km. S.W. of Shendi along railway line & S.W. of El Gabeah village.
2005	105	30 km. S.W. of Shendi & 3 km. north direction Gandetto.
2014	105	5 km. east of Shendi.
2018	106	In Wadi el Hawad near Kabushiya.
2030	105	In Sayal Basin near El Sayal village.
2031	106	Northern end of Sufur Taiyiba Basin near Gabalab village.
2037	106	In Kelli Basin near Kelli village.
2040	106	Beside railway line, 8 km. N.E. of Taragma railway station.
2045	104	In the Basabir Basin near the Wadi Abu Meiga and Deem village
2056	104	Wad Hamid Basin, northern edge, near Beryab village.
2061	103	Wad Hamid Basin, western edge, near Wad Hamid village.
2062	104	Salawa Basin, southern end.
2077	104	Basabir Basin, beside railway line, 10 km. S.W. of Wad Ben Naga station.
2081	105	High ground south of El Goz railway station.
2087	105	High ground about 6 km. south of Shendi.
2092	105	High ground 8 km. south of Taragma station.
2100	106	Beside railway line, 10 km. S.W. of Kabushiya.
2106	106	In sand dunes west of Sufur Taiyiba Basin.
2112	107	On terrace west of Zeidab scheme.
2117	107	On terrace west of Zeidab scheme.
2123	107	On terrace west of Zeidab scheme.

Site No.	Sheet No. SU	Description of the Locality
2130	106	On terrace west of Kelli Basin.
2137	106	Kelli Basin near Maknia village.
2143	106	Kelli Basin near Shebetiya Island.
2145	108	On terrace west of Zeidab-Fadlab Schemes.
2154	108	Nile right bank, 3 km. south of Nile-Atbara Confluence.
2160	108	Nile right bank, 5 km. south of Hudeiba.
2164	107	Nile right bank, 4 km. S.W. of Zeidab railway station.
2169	107	Nile right bank between Aliab railway station and the river.
2175	108	Southern outskirts of Ed Damer town.
2178	107	Nile right bank, 10 km. N.E. of Zeidab railway station.
2185	108	Atbara River left bank about 24 km. from Atbara town.
2190	109	Atbara River left bank.
2194	109	Atbara River left bank, Kineidra area.
2197	109	Atbara River, right bank, Kineidra area.
2204	108	Atbara River, right bank about 16 km. from Atbara town.
2211	110	Nile right bank, Adabia area, 16 km. south of Berber town.
2216	112	Nile left bank.
2221	113	Nile left bank opposite Mograt Island and Abu Hamed.
2229	110	Nile left bank, El Bauga area.
2231	111	Nile left bank, east of El Bauga Pump Scheme.
2237	110	Nile right bank, Hassa area, 12 km. north of Berber town.
2243	110	Nile left bank, about 10 km. south of Berber town (opposite bank).
2244	108	Nile left bank near Wadi el Shabashia.
2247	110	Nile right bank, Hassa area, about 4 km. north of Berber.

Pit	2018
Location:	Wadi El Hawad; near Kabushiya.
Topography:	Pit site level and flat.
Surrounding:	Uneven, very gently sloping
Cultivation and Land Use:	Common grazing; beside dura fields and some dura between the grass.
Vegetation:	Abundant Aristida Sp; common Indigofera suaveolens.
Surface:	Very thin discontinuous crust. Few vertical cracks visible.

Profile description:-

0 - 28 cm.	Moist 10YR 4/3 Silty Clay Loam. Moist friable structureless (single grain) with common wide vertical cracks infilled with coarse sand. Moderately rapidly moisture absorbent. Some gravel. Abundant pores. Abundant roots.
28 - 76 cm.	Moist 10YR 4/3. Light Silty Clay Loam. Moist very firm, moderate medium subangular blocky with common wide vertical cracks, infilled with coarse sand. Moderately moisture absorbent. Common gravel. Very few soft Calcium Carbonate concretions. Very few Manganese concretions? Abundant pores. Few roots.
76 - 120 cm.	Moist 10YR 4/4. Sandy loam and some clay lenses. Moist friable structureless single grain. No cracks. Moderately moisture absorbent. Common gravel. Abundant Calcium Carbonate streaks decreasing after 95 cm. No pores. No roots.
120 - 160 cm.	Moist 10YR 4/4. Sandy loam and some clay lenses. Moist friable, structureless single grain. No cracks. Moderately moisture absorbent. Abundant medium hard and hard Calcium Carbonate concretions.
160 - 200 cm.	Moist 10YR 5/4. Sandy loam and some clay lenses. Moist very friable structureless single grain. No Cracks Moderately moisture absorbent. Some Calcium Carbonate streaks.

Orthic Orthustent

Non Saline/Non Alkaline

Pit 2031

Location:

Topography: Flat and level at pit site. At distance relic sand dunes.

Cultivation and Land Use: Grazing.

Vegetation: Common Aristida sp. Common Acacia ehrenbergiana. Common tephrosia appolinea.

Surface: Common kankars. Few big gravels. Common cracks. Firm crust.

Profile description:-

0 - 45 cm. Moist 10YR 4/3. Loamy sand. Dry loose, structureless single grain. Rapidly moisture absorbent. Common kankars. Common gravel. Few mica. Common roots.

45 - 160 cm. Moist 10YR 3/3. Light silty clay loam. Moist loose, structureless single grain, laminations. Moderately moisture absorbent. Common gravel. Common mica. Few kankars. Few manganese mottles? Few roots up to 80 cm.

160 - 200 cm. Moist 10YR 4/3. Sandy loam. Moist loose, structureless single grain. Moderately moisture absorbent. Common gravel.

Orthic Orthustent
Non Saline/Non Alkaline

Pit:	2077
Location:	
Topography:	Flat and gently sloping.
Cultivation and Land Use:	None.
Vegetation:	Common Aristida sp. and few Acacia ehrenbergiana in patches.
Surface:	Quartz gravel and Loose coarse sand on hard thin crust. Few stones.

Profile description:-

0 - 1 cm.	Quartz gravel and loose course sand.
1 - 30 cm.	Moist 10YR 4/4. Gravelly loam and few clay lenses. Dry loose, structureless with common fine cracks. Moderately moisture absorbent. Common pores, Few roots. Few gravel and stones. Common mica.
30 - 113 cm.	Moist 10YR 4/3. Gravelly loam and clay lenses. Dry hard weak fine subangular blocky (cemented) with common pores. Rapidly moisture absorbent. Few roots up to 70. Common gravel and stones. Common mica.
113 - 180 cm.	Moist 10YR 5/4 - 4/4. Gravelly loam and common clay lenses (gravelly clay loam). Slightly moist, structureless (cemented) with common pores. Rapidly moisture absorbent. Common gravel and stones. Abundant soft and semi-hard Calcium Carbonate concretions. Common mica.

Orthic Orthustent
Non Saline/Non Alkaline

Pit: 2092

Location:

Topography: Flat and level - gently sloping.

Cultivation and Land Use: Nil.

Vegetation: Common Panicum turgidum and few Acacia ehrenbergiana.

Surface: At pit site few iron conglomerates, loose and dry. Common fine gravel. At 100 m abundant gravel and stones.

Profile description:-

0 - 10 cm. Moist 5.5YR 5/6. Medium sand. Dry loose structureless with common pores. Rapidly moisture absorbent. Few fine gravels. Few roots.

10 - 30 cm. Moist 10YR 4/4. Sandy loam. Dry loose structureless with common pores and few common cracks. Rapidly moisture absorbent. Few fine gravels. Few roots.

30 - 80 cm. Moist 10YR 4/3. Sandy loam and few clay lenses. Dry hard moderate medium subangular blocky with common pores and cracks. Moderately to rapidly moisture absorbent. Few calcium carbonate streaks. Sand accumulations in the cracks. Few mica. Few hard Calcium Carbonate concretions. Few roots.

80 - 110 cm. Moist 10YR 4/3. Sandy clay loam. Dry very hard, moderate medium subangular blocky with common cracks infilled with sand. Moderately moisture absorbent. Few common soft and hard Calcium Carbonate concretions. Few fine gravels.

110 - 170 cm. Moist 10YR 5/4 - 6/4. Loam. Dry hard.

Ca-horizon. Moderate medium subangular blocky to abundant Calcium Carbonate concretions. Common gravels. Mottles around the iron-pan at 8 mm at 130 cm. 10YR 5/8.

Orthic Orthustent
Non Saline/Non Alkaline

Pit:	2178
Location:	
Topography:	Slightly undulating.
Cultivation and Land Use:	Nil.
Vegetation:	Nil.
Surface:	Soft broken crust. Abundant gravels and stones. Common kankars. Few big hard and dark Calcium Carbonate concretions.

Profile description:-

0 - 8 cm.	Moist 10YR 4/4. Sand. Dry loose, structureless. Rapidly moisture absorbent. Common kankars. Abundant gravels.
8 - 135 cm.	Moist 10YR 3/2. Loam. Dry hard to very hard. First 10 cm. crumble and common pores, then cemented. No pores. Common large cracks, infilled with sand, and gravel. Rapidly moisture absorbent. Common fine roots decreasing with depth. Common fine Calcium Carbonate concretions. Gypsum? Common mica. Salt?
Pit ends at 135	Abundant gravel.

Orthic Orthustent
Slightly Saline/Non Alkaline

Pit: 2190

Location:

Topography: Uneven.

Cultivation and Land Use: Nil.

Vegetation: Common Dcm Palms on relic mounds. Few Calotropis procera.

Surface: Common hard Calcium Carbonate concretions. Loose dust.

Profile description:-

0 - 50 cm. Moist 10YR 4/4. Silt loam. Dry soft, structureless with some laminations, with common large cracks, infilled with fine sand. Common pores. Rapidly moisture absorbent. Common fine roots. Sparse hard Calcium Carbonate concretions. Common mica. Sparse kankars. Old roots channels.

50 - 140 cm. Moist 10YR 4/3 - 3/3. Silty clay loam. Dry very hard, massive with common large cracks infilled with sand. Common pores. Rapidly moisture absorbent. Common very small Calcium Carbonate concretions. Common mica.

140 - 180 cm. Moist 10YR 4/3 - 3/3. Silty clay loam. Dry hard, structureless with common pores. Moderately moisture absorbent. No roots. Few shell fragments. Common mica.

Orthic Orthustent
Non Saline/Non Alkaline

Pit: 2211

Location:

Topography: Uneven. In the surroundings, relic sand dunes.

Cultivation and Land Use: Nil.

Vegetation: Few Acacia ehrenbergiana on relic sand dunes. Few Capparis decidua on relic mounds.

Surface: Very hard crust. Common kankars. Few gravel.

Profile description:-

0 - 55 cm. Moist 10 YR 4/4. Sandy Clay loam. Dry loose, structureless (laminations) with common cracks infilled with sand. Rapidly moisture absorbent, Abundant roots. Abundant mica.

55 - 145 cm. Moist 10 YR 3/2. Sandy clay. Dry very hard. Massive with common large cracks infilled with fine gravel and sand. Few pores. Rapidly moisture absorbent. Common fine gravel. Few Calcium Carbonate concretions and streaks. Common mica. Salt crystals? No roots.

145 - 190 cm. Moist 10 YR 4/3. Sandy Clay. Dry hard, structureless with common pores. Rapidly moisture absorbent. No roots. Common Calcium Carbonate concretions. Common mica. Common black stains (10 YR 3/2) Manganese? Few salt crystals.

Orthic Orthustent

Non Saline/Non Alkaline

Pit: 2216

Location:

Topography: Moderately sloping on edge of pump scheme.

Cultivation and Land Use: Nil.

Vegetation: Nil at pit site, very sparse Capparis decidua at distance.

Surface: Abundant mica. Few stones. Abundant fine gravel. Loose dust.

Profile description:-

0 - 170 cm. Moist 10YR 4/3. Loamy fine sand. Dry slightly hard, structureless. Sparse fine cracks and abundant pores. Rapidly moisture absorbent. Common roots decreasing to sparse at 150 cm. Abundant mica.

170 - 190 cm. Abundant gravel.

Orthic Orthustent
Non Saline/Non Alkaline

Pit: 2005

Location: 15 Km SW of Shendi and 1.5 Km north direction Gandetto.

Topography: Flat and level, surrounded on various distances with sand dunes; relic sand dunes around bushes.

Cultivation and Land Use: Not cultivated. Roughly (sparse) grazing.

Vegetation: Few Aristida sp; common Acacia Nubica and Capparis decidua.

Surface: Dry, very thin discontinuous crust; 0-5 cm. dust mulch; very few dark calcium carbonate concretions.

Profile description:-

0 - 30 cm. Moist 10YR 4/3. Silty loam. Dry, slightly hard, weak fine subangular blocky with common cracks and few fine pores. Moderately moisture absorbent. Few roots. Few medium hard and dark Calcium Carbonate concretions. Few Calcium Carbonate streaks.

30 - 110 cm. Moist 10YR 3/4. Silty Clay Loam. Dry hard, moderate medium subangular blocky with wide cracks, infilled with loose sand. Rapidly moisture absorbent Common soft Calcium Carbonate concretions. Very few gypsum. Rapidly moisture absorbent.

110 - 200 cm. Moist 10YR 4/3. Silty Clay Loam. Dry hard, moderate medium subangular blocky with few small cracks. Rapidly moisture absorbent. Few medium hard Calcium Carbonate concretions, decreasing with depth.

Natrargidic Orthustent

Saline/Alkaline

Pit 2014

Location:

Topography: Flat and level at pit site. Undulating dissected levels.

Cultivation and Land Use. None.

Vegetation: Bare at pit site.
Sparse Acacia Nubica and sparse Acacia ehrenbergiana in the surroundings.

Surface: Loose, soft coarse sand and gravel.

Profile description:-

0 - 2 cm. Moist 10YR 4/4. Coarse sand. Dry loose structureless single grain. Common gravel. Rapidly moisture absorbent. Abundant roots.

2 - 17 cm. Moist 10YR 4/4. Silty loam with sand. Dry slightly hard, weak fine to medium subangular blocky, with fine cracks, infilled with sand. Frequent gravel. Rapidly moisture absorbent. Traces of Calcium Carbonate. Abundant Roots. Common pores.

17 - 40 cm. Moist 10YR 3/2 - 3/1. Light silty clay loam. Dry loose, structureless single grain. Rapidly moisture absorbent. Abundant Calcium Carbonates soft aggregates and semi-hard concretions. Abundant gravel. Few amorphous gypsum? Common pores.

40 - 88 cm. Moist 10YR 3/2 - 3/1. Light silty clay loam. Dry hard, moderate, medium subangular blocky. Rapidly moisture absorbent. Common pores. Rare Calcium Carbonate streaks. Common quartz. Fine cracks.

88 - 170 cm. Moist 10YR 4/3. Sandy loam. Dry hard, structureless single grain, with fine cracks infilled with coarse sand. Rapidly moisture absorbent. Abundant soft Calcium Carbonate and semi-hard concretions. Occasional subangular aggregates. Stones.

170 - 200 cm. Moist 10YR 4/3. Loamy sand. Dry loose structureless single grain. Rapidly moisture absorbent. Abundant Calcium Carbonate concretions.

Natrargidic Orthustent
Saline/Alkaline

Pit: 2030

Location:

Topography: Flat and level.

Cultivation and Land Use: Flood dura; sparse grazing.

Vegetation: Few *Acacia tortilis*, at 400 m abundant flood dura at 1.00 m + 40 cm. high.

Surface: Mulching crust; many cracks. Few kankars and few hard Calcium Carbonate concretions. Few gravel.

Profile description:-

0 - 17 cm. Moist 10YR 4/4. Sandy loam. Dry slightly hard, weak fine subangular blocky. Lamination with common cracks. Rapidly moisture absorbent. Common mica. Abundant roots.

15 - 35 cm. Moist 10YR 4/4. Sandy loam. Dry very hard, weak moderate subangular blocky lamination, with common cracks. Moderately moisture absorbent. Abundant Calcium Carbonate streaks. Abundant roots.

35 - 85 cm. Moist 7.5YR 4/4. Sandy loam. Moist friable structureless, single grain. Moderately moisture absorbent. Some clay lenses. Common semi-hard and hard Calcium Carbonate concretions. Abundant kankars. Few mica. Manganese mottles? At 60 cm. abundant gravel.

85 - 160 cm. Moist 10YR 3/3. Light silty clay loam. Moist firm, moderate fine to medium subangular blocky. Moderately moisture absorbent. Laminations. Few kankars and few hard Calcium Carbonate concretions. Some sand lenses.

160 - 200 cm. Moist 10YR 3/3. Light silty clay loam. Moist firm, weak fine subangular blocky. Laminations. Moderately moisture absorbent. Common kankars and hard Calcium Carbonate concretions. Manganese mottles? Some brickrests. Some sand lenses.

Natrargidic Orthustent
Slightly Saline/Alkaline

Pit: 2037

Location:

Topography: Flat and level at pit site. In the surrounding, sand dunes.

Cultivation and Land Use: Beside the pit at 20 m. Floodcrop: Dura, sparse grazing.

Vegetation: Many Aristida sp. Scattered spots with common Capparis decidua; few Acacia ehrenbergiana.

Surface: Common wide cracks; broken crust. Common kankars.

Profile descriptions:-

0 - 25 cm. Moist 10YR 3/3. Silty clay loam. Dry very hard, moderate medium subangular blocky with common wide cracks infilled with coarse sand, and pores. Moderately moisture absorbent. Common pores. Common kankars. Common roots.

25 - 55 cm. Moist 10YR 3/3. Silty clay loam. Dry very hard, moderate medium subangular blocky with common wide cracks infilled with sand. Rapidly moisture absorbent. Common roots. Few Calcium Carbonate streaks.

55 - 90 cm. Moist 10YR 3/3. Silty loam. Dry hard, moderate medium subangular blocky with common cracks. Rapidly moisture absorbent. Few roots. Common semi-hard Calcium Carbonate concretions. Few Calcium Carbonate streaks. Common mica. Few amorphous gypsum?

90 - 180 cm. Moist 10YR 4/3. Loam. Dry very hard moderate medium subangular blocky. Moderately moisture absorbent. Common pores. Few hard Calcium Carbonate concretions. Some salt crystals? Common mica. Gypsum?

Natrargidic Orthustent
Non Saline/Alkaline

Pit: 2056

Location:

Topography: Flat and level at pit site. Outcrops in surroundings. At 100 m uneven.

Cultivation and Land Use: None.

Vegetation: None.

Surface: Common kankars, common gravels. Dust.

Profile description:-

0 - 40 cm. Moist 10YR 3/4. Light silty clay loam. Dry slightly hard, moderate fine to medium subangular blocky with common small cracks. Common pores. Rapidly moisture absorbent. Common kankars. Few hard Calcium Carbonate concretions. Common mica. Few gravel. Salt crystals at 40 cm. common gypsum? Common roots up to 30 cm.

40 - 55 cm. Moist 10YR 3/4. Light silty clay loam. Dry slightly hard, moderate medium subangular blocky with common small cracks infilled with sand. Common pores. Rapidly moisture absorbent. Common kankars; few salt crystals. Few gypsum? Common gravel. Few hard Calcium Carbonate concretions. Common mica.

55 - 75 cm. Caliche horizon. Moist 10YR 3/4. Silty clay loam. Dry hard, moderate medium subangular blocky with common small cracks, infilled with sand. Common pores. Rapidly moisture absorbent. Common hard Calcium Carbonate concretions. Common kankars. Common mica. Few salt crystals.

75 - 125 cm. Moist 10YR 5/6. Loam. Dry extremely hard moderate medium subangular blocky with common pores. Rapidly moisture absorbent. Common gravel. Abundant hard Calcium Carbonate concretions. Common mica.

125 - 200 cm. Moist 10YR 5/6. Loam. Dry hard, moderate medium subangular blocky. Common pores. Rapidly moisture absorbent. Few Salt crystals. Abundant hard and soft Calcium Carbonate concretions. Common mica.

Orthic Orthustent
Saline/Non Alkaline

Pit: 2062

Location:

Topography: At pit site uneven and level. At 100 m flat and level. Ploughed.

Cultivation and Land Use:

Vegetation: At pit site abundant Desmostachya bipinnata. At 100 m none.

Surface: Few cracks. Dry hard.

Profile description:-

0 - 40 cm. Moist 10YR 3/3 Silty loam. Dry slightly hard, structureless within the first 30 cm few fine cracks and common pores. Moderately moisture absorbent. Common mica. Common fine and thick roots. Few big shell fragments.

40 - 100 cm. Moist 10YR 3/3. Silt loam. Moist friable structureless. As above. Few mottles 10YR 5/8 and few Manganese mottles?

100 - 200 cm. Moist 10YR 3/3. Silty Clay loam. Moist firm structureless with common pores. Moderately moisture absorbent. Few big shell fragments. Common to abundant mica. Few sand lenses. Few fine roots up to 130 cm.

Natrargidic Orthustent
Saline/Extremely Alkaline

Pit:	2100
Location:	
Topography:	Flat and level.
Cultivation and Land Use:	Nil.
Vegetation:	Few *Acacia ehrenbergiana* and *Panicum turgidum* at patches.
Surface:	Few kankars. Common small Nubian sandstones and gravels. Few stones.

Profile description:-

0 - 8 cm.	Moist 7.5YR 5/6. Sand. Dry loose, structureless. Rapidly moisture absorbent. Few kankars. Few roots.
8 - 40 cm.	Moist 10YR 5/5. Sandy loam. Dry soft structureless with few cracks and common pores. Rapidly moisture absorbent. Common Calcium Carbonate streaks. Few mica. Few roots.
40 - 90 cm.	Moist 10YR 5/4. Fine sandy loam. Dry, slightly hard, cemented, weak fine subangular blocky with few old cracks infilled with sand (7.5YR 4/4) and common pores. Common soft and hard Calcium Carbonate concretions. Few gravels. Few mica.
90 - 115 cm. 1st Ca horizon	Moist 10YR 5/4. Fine sandy loam. Dry hard, weak fine subangular blocky with few pores. Rapidly moisture absorbent. Abundant hard and semi-hard Calcium Carbonate concretions.
155 - 160 cm.	Moist 10YR 5/4. Loamy sand. Dry soft, structureless with few pores. Rapidly moisture absorbent. Common abundant fine gravel. Few stones. Few soft and hard Calcium Carbonate concretions.
160 - 200 cm. 2nd Ca horizon	Moist 10YR 5/4. Loamy sand. Dry hard structureless, cemented with few pores. Rapidly moisture absorbent. Common abundant hard Calcium Carbonate concretions and common streaks. Few gravel and stones.

Natrargidic Orthustent
Saline/Alkaline

Pit: 2123

Location:

Topography: Gently undulating.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Abundant Nubian sandstones and gravel.

Profile description:-

0 - 75 cm.	Moist 7.5YR 4/4. Fine sandy loam. Dry hard structureless with common cracks up to 60 cm. and common pores. Rapidly moisture absorbent. Common fine roots. Few Calcium Carbonate streaks. Common kankars. Few mica. Few fine gravel.
75 - 100 cm.	Moist 10YR 5/4. Fine sandy loam. Dry extremely hard, structureless with common pores. No cracks. Rapidly moisture absorbent. No roots. Common hard and semi-hard Calcium Carbonate concretions. Few kankars. Few mica.
100 - 125 cm.	Moist 10YR 5/4. Fine sandy loam. Dry extremely hard, structureless with common pores. No cracks. Rapidly moisture absorbent. No roots. Few to common hard and semi-hard Calcium Carbonate concretions. Common iron concretions, 5YR 5/8. Manganese? Few mica.
125 - 175 cm.	Moist 10YR 5/4. Fine loamy sand. Dry very hard, structureless with common pores. No cracks. Rapidly moisture absorbent. No roots. Abundant hard and semi-hard Calcium Carbonate concretions. Common iron concretions, 5YR 5/8?

Natrargidic Orthustent
Saline/Alkaline

Pit:	2137
Location:	
Topography:	Uneven; in surrounding sand dunes.
Cultivation and Land Use:	Nil.
Vegetation:	Common Capparis decidua.
Surface:	Common shell fragments. Few gravel. Few kankars. Dry loose dust.

Profile description:-

0 - 20 cm.	Moist 10YR 4/3. Loamy sand. Dry loose, structureless with common cracks and few pores. Rapidly moisture absorbent. Few roots. Common gravel. Common shell fragments. Sparse kankars.
20 - 140 cm.	Moist 10YR 3/1. Sandy Clay. Slightly moist very firm, moderate medium subangular blocky with common old cracks infilled with sand and few pores. Moderately moisture absorbent. Few roots. Common Calcium Carbonate streaks. Few gravel and few mica.
140 - 185 cm.	Moist 10YR 3/1. Sandy clay. Slightly moist very firm, moderate medium subangular blocky with few old cracks infilled with sand and few pores. Moderately moisture absorbent. No roots. Sparse Calcium Carbonate streaks. At 160 cm common gravel. Few brick rests.

Natrargidic Orthustent
Slightly Saline/Alkaline

Pit: 2143

Location:

Topography: Uneven.

Cultivation and Land Use: Arable land.

Vegetation: Common *Aristida* sp.

Surface: Common mica.

Profile description:-

0 - 40 cm. Moist 10YR 3/3. Heavy silty clay loam. Dry very hard, moderate medium subangular blocky with common large cracks, infilled with sand. Slowly moisture absorbent. Common roots. Common kankars. Few fine gravel. Few mica.

40 - 90 cm. Moist 10YR 4/2. Silty clay loam. Slightly moist friable, structureless. No cracks. Rapidly moisture absorbent. Sand lenses. No roots. Sparse salt crystals at 80 cm. Sparse Calcium Carbonate streaks. Few kankars. Few mica.

90 - 170 cm. Moist 10YR 4/2. Light silty clay loam. Slightly moist friable, structureless. No cracks. Rapidly moisture absorbent. No roots. Common salt crystals, after 110 cm. Few calcium carbonate streaks. Few mica.

170 - 200 cm. Moist 10YR 4/2. Silty loam. Slightly moist friable, structureless. No cracks. Rapidly moisture absorbent No roots. No salt crystals.

Natrargidic Orthustent
Saline/Alkaline

Pit: 2160

Location:

Topography: Uneven with sand dunes in the surroundings.

Cultivation and Land Use: Nil.

Vegetation: Nil at pit site.
Common Acacia ehrenbergiana on relic sand mounds.

Surface: Few kankars and few hard Calcium Carbonate concretions. Few gravel. Thin soft crust.

Profile description:-

0 - 10 cm. Moist 10YR 4/4. Sand. Dry loose, structureless with common cracks and common pores. Rapidly moisture absorbent. Common roots. Common kankars. Sparse gravel.

10 - 60 cm. Moist 10YR 3/3. Light silty clay loam. Dry soft weak fine subangular blocky. No cracks. Common pores. Rapidly moisture absorbent. No roots. Abundant gypsum crystals. Common salt crystals. Few Calcium Carbonate streaks. Few kankars. Common mica.

60 - 140 cm. Moist 10YR 4/4. Silty loam. Slightly moist friable, structureless. No cracks. Common pores. Rapidly moisture absorbent. No roots. Abundant gypsum on patches. Few to common salt crystals. Few black dots (Manganese?) Sparse hard Calcium Carbonate concretions and streaks.

140 - 185 cm. Moist 10YR 4/4 - 5/4. Slightly loamy fine sand. Slightly moist friable, structureless. No cracks. No pores. Rapidly moisture absorbent. No roots. Manganese? Few semi-hard Calcium Carbonate concretions. Sparse salt crystals.

Natrargidic Orthustent
extremely Saline/extremely Alkaline

Pit: 2175

Location:

Topography: Flat and sloping.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Common gravel. Common kankars and hard Calcium Carbonate concretions. Thin soft crust.

Profile description:-

0 - 8 cm.	Moist 10YR 4/4. Sandy loam. Dry very hard, structureless with common cracks and common pores. Rapidly moisture absorbent. Sparse roots. Common mica. Common kankars.
8 - 45 cm.	Moist 10YR 3/2. Sandy loam. Dry soft crumble. No cracks and no pores. Rapidly moisture absorbent. Sparse roots. Common small hard Calcium Carbonate concretions. Few fine gravel. Common kankars. Common mica. Common gypsum? Common salt crystals.
45 - 85 cm.	Moist 10YR 3/2. Sandy loam. Dry very hard compacted with few fine cracks infilled with sand. Rapidly moisture absorbent. No roots. Common kankars. Common hard Calcium Carbonate concretions. Common mica. Few fine gravel. Gypsum?
85 - 125 cm.	Moist 10YR 4/4. Loamy sand. Dry soft, crumble. No cracks and no pores. Rapidly moisture absorbent. Common mica. Common to abundant Calcium Carbonate streaks and common semi-hard Calcium Carbonate concretions. Manganese?
125 - 200 cm.	Moist 10YR 5/4. Loamy sand. Dry loose, structureless. No cracks and common pores. Rapidly moisture absorbent. Common mica. Common small Calcium Carbonate concretions. Gypsum?

Natrargidic Orthustent
Saline/extremely Alkaline

Pit: 2185

Location:

Topography: Uneven (relic mounds).

Cultivation and Land Use: Nil.

Vegetation: Few Acacia ehrenbergiana on relic mounds. At 100 m Common Dom palms.

Surface: Dry loose sand. Common to abundant kankars. Common hard Calcium Carbonate concretions. Few gravel.

Profile description:-

0 - 3 cm. Moist 10YR 4/4. Loamy fine sand. Dry loose, structureless. Common kankars.

3 - 75 cm. Moist 10YR 4/4 - 3/4. Light silty clay loam. Dry slightly hard crumble with common fine cracks and common pores. Rapidly moisture absorbent. Few roots. Common gypsum crystals increasing after 30 cm. Common kankars. Few Calcium Carbonate concretions. Common mica. Salt crystals?

75 - 140 cm. Moist 10YR 4/4. Silty clay loam. Dry hard, structureless with common fine cracks infilled with fine sand. No pores. Slowly moisture absorbent. No roots. Few kankars. Few black stains, Manganese? Common mica.

140 - 200 cm. Moist 10YR 4/4. Silty clay loam. Slightly moist firm structureless with no cracks and no pores. Slowly moisture absorbent. No roots. Few hard Calcium Carbonate concretions. Common black stains, Manganese? Common mica.

Natrargidic Orthustent
Saline/Alkaline

Pit: 2221

Location:

Topography: Slightly uneven.

Cultivation and Land Use: Nil.

Vegetation: Common Acacia ehrenbergiana.

Surface: Loose dust. Common fine gravel. Few kankars. Common hard Calcium Carbonate concretions.

Profile description:-

0 - 25 cm. Moist 10YR 4/3. Loamy sand. Dry loose structureless with no pores. Rapidly moisture absorbent. Common fine gravel. Few kankars. Common mica.

25 - 70 cm. Moist 10YR 3/4. Fine sandy loam. Dry soft, structureless with abundant pores. Common to abundant mica. White dendritic pattern (Calcium Carbonate?) Common Calcium Carbonate streaks in first 30 cm. Few fine gravel. Few kankars.

70 - 175 cm. Moist 10YR 4/3 - 3/3. Loamy fine sand. Dry loose, structureless with abundant pores. Rapidly moisture absorbent. Abundant mica. Effervesces moderately with acid.

Natrargidic Orthustent
Slightly Saline/Alkaline

Pit: 2229

Location:

Topography: Even and gently sloping.

Cultivation and Land Use: Nil.

Vegetation: At 100 m few Acacia ehrenbergiana.

Surface: Dust. Abundant kankars and Calcium Carbonate concretions. Common fine gravel.

Profile description:-

0 - 27 cm. Moist 10YR 4/3. Silty Clay. Dry soft, structureless with common cracks and no pores. Rapidly moisture absorbent. Abundant gypsum. Common kankars. Few mica. Salt crystals?

27 - 80 cm. Moist 10YR 4/4 - 4/3. Silty Clay. Dry very hard, moderate, medium subangular blocky with common cracks and no pores. Rapidly moisture absorbent. Common shells and shell fragments. Few mica. Few kankars. Common to abundant gypsum, decreasing with depth.

80 - 185 cm. Moist 10YR 4/4 - 4/3. Clay. Dry hard, moderate, medium subangular blocky with few cracks. Rapidly moisture absorbent. Common hard Calcium Carbonate concretions. Common kankars. Few fine gravel. Common shell fragments.

Natrargidic Orthustent
extremely Saline/extremely Alkaline

Pit: 2243

Location:

Topography: Flat and level.

Cultivation and Land Use: Old arable land.

Vegetation: Abundant pump schemes. Few Calotropis procera. Few Acacia ehrenbergiana. Few Panicum turgidum.

Surface: Soft broken crust. Few gravel. Few small semi-hard Calcium Carbonate concretions. Common mica. Few kankars.

Profile description:-

0 - 10 cm. Moist 10YR 4/4. Silt loam. Dry loose, structureless with no cracks and no pores. Rapidly moisture absorbent. Common kankars. Common mica. Few small semi-hard Calcium Carbonate concretions.

10 - 75 cm. Moist 10YR 4/3 - 3/3. Loam. Dry very hard, massive with common old cracks infilled with sand. Common pores. Rapidly moisture absorbent. Few fine gravel. Common Calcium Carbonate streaks. Abundant gypsum crystals at 50 - 65 cm. Salt crystals? Common kankars Common mica.

75 - 150 cm. Moist 10YR 4/3. Sandy clay. Slightly moist firm structureless, with common old cracks infilled with sand. Few pores. Slowly moisture absorbent. Few gypsum? Common black stains (Manganese?) Few to common hard Calcium Carbonate concretions. Few kankars. Few fine gravels.

150 - 190 cm. Moist 10YR 5/4. Sandy clay loam. Moist friable, structureless. No cracks. Few pores. Slowly to moderately moisture absorbent. Few dark Calcium Carbonate concretions and few Calcium Carbonate streaks. Common black stains (Manganese?)

Natrargidic Orthustent
Saline/Alkaline

Pit: 2197

Location:

Topography: Slightly uneven.

Cultivation and Land Use: Nil.

Vegetation: Abundant Dom. Palms. Few Capparis decidua. Few Acacia seyal, few Acacia tortilis, few Ziziphus sp.

Surface: Loose dust, common kankars.

Profile description:-

0 - 60 cm. Moist 10YR 3/3. Clay. Dry slightly hard, structureless with common fine cracks. Common abundant pores. Rapidly moisture absorbent. Common fine and big roots. Abundant mica. Common old root channels.

60 - 145 cm. Moist 10YR 4/3. Silt Clay loam. Dry soft, structureless. Abundant pores. Rapidly moisture absorbent. Few fine and big roots. Whitish streaks which effervesce highly with acid. Abundant mica.

145 - 200 cm. Moist 10YR 4/4 - 4/3. Very fine sandy loam. Dry soft, structureless with common pores. Rapidly moisture absorbent. Sparse roots. Common old root channels. Efervesces highly with acid.

Vertic Orthustent
Non Saline/Non Alkaline

Pit: 2231

Location:

Topography: Flat gently sloping.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Sand on the soft broken crust. Common kankars. Common gravels. Abundant hard grey Calcium Carbonate concretions.

Profile description:-

0 - 50 cm. Moist 10YR 4/4. Sandy Clay. Dry hard, structureless with common cracks, infilled with sand. Rapidly moisture absorbent. Few salt crystals. Few kankars. Common mica. Few Calcium Carbonate streaks. Shell fragments.

50 - 130 cm. Moist 10YR 3/2. Clay loam. Dry very hard moderate medium subangular blocky with common cracks, infilled with sand. Rapidly moisture absorbent. Common salt crystals. Common hard Calcium Carbonate concretions. Common mica. Common gypsum crystals.

130 - 180 cm. Moist 10YR 3/2. Clay. Dry hard compacted. Rapidly moisture absorbent. Common salt crystals and gypsum crystals, decreasing with depth. Few to common hard Calcium Carbonate concretions.

Vertic Orthustent
Slightly Saline/Non Alkaline

Pit: 2237

Location:

Topography: Flat and level.

Cultivation and Land Use: Nil.

Vegetation: Abundant pump scheme (Hassa scheme). Few Acacia ehrenbergiana.

Surface: Dust mulch. Common shells and shell fragments. Common kankars. Few gravels. Common large cracks.

Profile description:

0 - 15 cm. Moist 10YR 5/4. Clay loam. Dry slightly hard, structureless with common large cracks infilled with sand. Rapidly moisture absorbent. Few roots. Common kankars. Few fine gravels. Common shell fragments. Common mica.

15 - 85 cm. Moist 10YR 3/3. Clay. Dry very hard massive with common large cracks infilled with sand. Moderately moisture absorbent. Sparse roots. Common to abundant kankars. Few Calcium Carbonate streaks. Common shell fragments. Common mica. Salt crystals?

85 - 190 cm. Moist 10YR 4/4 - 3/3. Clay. Dry hard, structureless with old cracks infilled with sand. Rapidly moisture absorbent. No roots. Common semi-hard Calcium Carbonate concretions and streaks. Common kankars. Common salt crystals. Gypsum?

Vertic Orthustent
Non Saline/Non Alkaline

Pit: 2045

Location: Near Wadi Abu Meiga in the basin near the village Deem.

Topography: Uneven, very gently sloping to gently sloping Gullies at 25 m, 2.5 m wide and ± 50 cm deep.

Cultivation and Land Use: None?

Vegetation: Few Capparis decidua on relic mounds. Few Cassia senna.

Surface: Dust. Common kankars. Common large cracks.

Profile description:-

0 - 10 cm. Moist 10YR 3/4. Silty clay loam. Dry hard, moderate medium subangular blocky with common wide cracks and few pores. Rapidly moisture absorbent. Common roots. Common gravels. Few kankars. Common mica.

10 - 76 cm. Moist 10YR 3/3. Silty clay loam. Moist firm, moderate medium subangular blocky with common cracks and common pores. Moderately moisture absorbent. Few roots. Few soft Calcium Carbonate concretions. Common mica. Few kankars. Few manganese mottles.

76 - 111 cm. Moist 10YR 3/3. Silty Clay loam. Moist friable weak fine subangular blocky with common cracks. Moderately moisture absorbent. Few gravels. Common mica. Few semi-hard Calcium Carbonate concretions.

111 - 126 cm. Moist 10YR 3/3. Silty clay loam. Moist friable, structureless single grain. Moderately moisture absorbent. Common semi-hard Calcium Carbonate concretions and Calcium Carbonate streaks. Few mica. At 120 cm few (iron) mottles 10YR 5/8.

126 - 200 cm. Moist 10YR 5/6. Slightly loamy coarse sand. Moist loose. Moderately moisture absorbent. Few hard and semi-hard Calcium Carbonate concretions. Few gravel.

Natrargidic Vertic Orthustent
Saline/Alkaline

Pit: 2154

Location:

Topography: Uneven.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Broken crust, common gravel. Common kankars.

Profile description:-

0 - 15 cm.	Moist 10YR 5/8. Sand. Dry loose, structureless. No cracks and pores. Rapidly moisture absorbent. Common roots. Common kankars. Common gravel.
15 - 100 cm.	Moist 10YR 3/2. Sandy clay loam. Dry hard, medium moderate subangular blocky with common cracks, infilled with sand. Few pores. Rapidly moisture absorbent. Few roots. Few Calcium Carbonate streaks. Few mica, sparse stones.
100 - 135 cm.	Moist 10YR 5/4. Fine sandy loam and few clay lenses. Dry soft, structureless. No cracks. Common pores. Rapidly moisture absorbent. No roots. Common Calcium Carbonate streaks. Sparse hard Calcium Carbonate concretions. Few mica.
135 - 185 cm.	Moist 10YR 5/6. Fine sandy loam. Dry soft, structureless. No cracks and no pores. Rapidly moisture absorbent. No roots. Abundant hard Calcium Carbonate concretions. Few mica.

Natrargidic Vertic Orthustent
Saline/Alkaline

Pit: 2164

Location:

Topography: Flat and level.

Cultivation and Land Use: Nil.

Vegetation: Few Acacia ehrenbergiana. Few Capparis decidua.

Surface: 2 cm gravelly sand. Common kankars. Common fine gravel.

Profile description:-

2 - 110 cm. Moist 10YR 4/3 Sandy Clay Loam. Dry very hard, massive up to 80 cm with common cracks, infilled with sand. No pores. Rapidly moisture absorbent. Few roots, to 10 cm. Common mica. Common salt crystals increasing with depth. Few kankars. Common Calcium Carbonate streaks. Few shell fragments.

110 - 150 cm. Completely compacted Calcium Carbonate .

Calcorthidic Orthustent
Saline/Alkaline

Pit: 2169

Location:

Topography: Slightly uneven.

Cultivation and Land Use: Flood dura.

Vegetation: Common Capparis decidua. Few Acacia ehrenbergiana.

Surface: Commor very large cracks. Few gravel. Few kankars. Loose dust. Common shell fragments.

Profile description:-

0 - 180 cm. Moist 10YR 3/3. Clay. Dry very hard massive with common wide cracks up to 65 cm. infilled with sand. Few to common pores decreasing with depth. Sparse to few cracks infilled with fine sand. Rapidly moisture absorbent. Common roots up to 65 cm. Few salt crystals increasing after 100 cm. Few gypsum after 110 cm. Few Calcium Carbonate streaks after 110 cm. Few shell fragments. Few gravel infilled the cracks. Few to common mica. Few brick rests.

Natrargidic Vertic Orthustent
Saline/Alkaline

Pit: 2130

Location:

Topography: Flat.

Cultivation and Land Use: Nil.

Vegetation: Few Acacia ehrenbergiana and Panicum turgidum on relic sand mounds.

Surface: Loose. Common kankars and hard Calcium Carbonate concretions. Few stones and few fine gravel.

Profile description:-

0 - 5 cm. Moist 10YR 4/4. Slightly loamy sand. Dry loose, structureless with common cracks and common pores. Rapidly moisture absorbent. Common roots. Few fine gravel. Few kankars.

5 - 65 cm. Moist 10YR 5/4. Loam. Dry hard, structureless with common cracks and common pores. Rapidly moisture absorbent. No roots. Common hard Calcium Carbonate concretions. Common mica at 65 - 70 cm. Calcium Carbonate pan with gypsum?

70 - 95 cm. Moist 10YR 5/4. Sandy loam. Dry slightly hard structureless with common pores. No cracks. Rapidly moisture absorbent. No roots. Few Calcium Carbonate concretions. Common mica.

95 - 125 cm. Calcium pan. Dry extremely hard. No roots. Abundant Calcium Carbonate concretions.

125 - 195 cm. Moist 10YR 5/4. Fine to medium sand. Dry loose, structureless with common pores. No cracks. Rapidly moisture absorbent. No roots. At 180 cm a Calcium pan 7 cm thick. Abundant mica.

Calcorthidic Orthustent
Saline/Alkaline

Pit: 2204

Location:

Topography: Even and sloping.

Cultivation and Land Use: Nil.

Vegetation: Nil at pit site. At 50 m few Capparis decidua.

Surface: Abundant kankars. Abundant hard grey Calcium Carbonate concretions. Hard crust.

Profile description:-

0 - 15 cm. Moist 10YR 4/4. Sandy loam. Dry loose structureless with few pores. Rapidly moisture absorbent. Sparse roots. Common fine gravel. Abundant kankars. Common hard Calcium Carbonate concretions. Common mica.

15 - 35 cm. Moist 10YR 3/4. Sandy loam. Dry soft, crumble with common pores. Rapidly moisture absorbent. No roots. Common hard Calcium Carbonate concretions. Abundant kankars. Few fine gravel. Common mica.

35 - 125 cm. Moist 10YR 5/4. Sandy loam. Dry hard, structureless with common pores. Rapidly moisture absorbent. No roots. Common to abundant Calcium Carbonate streaks and hard concretions. Common mica.

125 - 200 cm. Moist 10YR 4/4. Loam. Dry slightly hard, structureless with common pores. Rapidly moisture absorbent. No roots. Common Calcium Carbonate concretions. Few black stains (Manganese?). Common mica.

Calcorthidic Orthustent
extremely Saline/extremely Alkaline

Pit: 2081

Location:

Topography: Undulating, uneven.

Cultivation and Land Use: None.

Vegetation: Very sparse Acacia ehrenbergiana. Sparse Aristida sp.

Surface: Common stones and gravel. Thin hard broken crust. Common cracks.

Profile description:-

0 - 40 cm. Moist 5YR 3/4. Loam. Dry slightly hard, weak fine subangular blocky with common fine cracks and common pores. Rapidly moisture absorbent. Common roots. Few big stones. Common gravel. Few mica.

40 - 68 cm. Moist 5YR 3/4. Loam. Dry hard, weak fine subangular blocky with few cracks and common pores. Abundant gravels and stones after 65 cm. From 40 - 65 cm common gravels and few stones. Few small Calcium Carbonate concretions. Few mica.

Lithic Orthustent
Non Saline/Non Alkaline

Pit: 2087

Location:

Topography: Flat uneven. Sloping.

Cultivation and Land Use: None

Vegetation: Common Acacia ehrenbergiana.

Surface: Loose quartz coarse sand (± 3 cm loose). Abundant gravel and few stones.

Profile description:-

0 - 15 cm.	Moist 5YR 4/8. Medium coarse sand. Dry slightly hard, structureless with few pores. Rapidly moisture absorbent. Common fine gravel. Few fine and large roots.
15 - 38 cm.	Moist 5YR 4/4. Gravelly loam. Dry slightly hard, structureless with common pores. Rapidly moisture absorbent. Common gravel. Few mica. Few fine roots.
38 - 54 cm.	Moist 5YR 4/4. Stony loam. Dry slightly hard, cemented, with common pores. Abundant gravels, and stones. Sparse fine roots.

Lithic Orthustent.
Non Saline/Non Alkaline

Pit: 2106

Location:

Topography: Uneven and sand dunes.

Cultivation and Land Use: Nil.

Vegetation: Sparse Acacia tortilis, Common Panicum turgidum.

Surface: Loose quartz sand.

Profile description:-

0 - 150 cm. Moist 10YR 4/4. Fine to medium sand. First 40 cm Dry loose and slightly moist loose, structureless with sparse pores. Rapidly moisture absorbent. Few fine gravel. Common fine roots up to 40 cm, after this few fine roots.

150 - 200 cm. Moist 10YR 4/3 - 4/4. Slightly loamy sand. Slightly moist loose, structureless with common pores. Rapidly moisture absorbent. Few fine gravel. Few fine Calcium Carbonate streaks. Few big roots.

Orthic Psammustent
Non Saline/Alkaline

Pit: 2040

Location:

Topography: Uneven and very gently sloping.

Cultivation and Land Use: None.

Vegetation: Common Capparis decidua on relic mounds.

Surface: ± 10 cm dust sand. Very coarse, gravelly sand. Common kankars. Very few stones.

Profile description:

0 - 117 cm. Moist 10YR 4/4. Loamy sand. Dry loose, structureless single grain with few pores (after 22 cm. common pores). Very rapidly moisture absorbent. Common roots. Few very coarse sand. Common mica. Few roots from 87 to 117 cm.

117 - 140 cm. Moist 10YR 4/3. Gravelly sandy loam. Dry loose, structureless, single grain, with common pores. Rapidly moisture absorbent. Common gravels. Common kankars. Few hard Calcium Carbonate concretions.

140 - 165 cm. Moist 10YR 4/3. Sandy loam. Dry slightly hard, structureless. Rapidly moisture absorbent. Common semi-hard Calcium Carbonate concretions. Common mica.

165 - 200 cm. Moist 10YR 4/3. Sandy loam. Dry loose structureless single grain. Rapidly moisture absorbent. Few soft Calcium Carbonate concretions. Common mica.

Orthustentic Psammustent
Non Saline/Non Alkaline

Pit: 2061

Location:

Topography: Uneven. Sand dunes.

Cultivation and Land Use: None.

Vegetation: Abundant Panicum turgidum

Surface: Few kankars. Loose quartz sand.

Profile description:-

0 - 53 cm.	Moist 7,5YR 4/4. Loamy sand. Dry loose structureless. Common pores. Rapidly moisture absorbent. Common long roots.
53 - 78 cm.	Moist 10YR 4/3. Loamy sand. Dry loose structureless. Common pores. Rapidly moisture absorbent. Common long roots. Few mica.
78 - 171 cm.	Moist 10YR 4/3. Sandy loam. Dry soft structureless. Common pores. Rapidly moisture absorbent. At 100 - 120 cm. some manganese mottles? and few mottles 5YR 4/6. Very sparse small soft Calcium Carbonate concretions. Few mica. Few roots up to 100 cm.
171 - 200 cm.	Moist 10YR 5/4. Loamy sand. Dry loose structureless. Rapidly moisture absorbent. Few mica.

Orthustentic Psammustent
Non Saline/Non Alkaline

Pit: 2001

Location: 5 Km SW of Shendi along railway line and SW of the village El Galeah.

Topography: Flat and level.

Cultivation and Land Use: Very sparse grazing, not cultivated.

Vegetation: Scattered *Acacia Nubica*.

Surface: 0-5 cm Dry loose sand mixed with gravels. Common dark Calcium Carbonate concretions.

Profile description:-

5 - 25 cm. Moist 10YR 3/2. Silty Clay Loam. Moist firm, moderate fine to medium subangular blocky with frequent wide vert. cracks, infilled with loose sand. Common fine roots. Few Calcium Carbonate streaks. Rapidly moisture absorbent.

25 - 75 cm. Moist 10YR 3/3. Silty Clay Loam. Moist firm, moderate medium subangular blocky with common wide cracks, infilled with loose sand. Rapidly moisture absorbent.

75 - 120 cm. Moist 10YR 4/4. Sandy Loam. Moist firm, moderate medium subangular blocky with common wide cracks, infilled with loose sand. Rapidly moisture absorbent. Common medium hard Calcium Carbonate concretions.

120 - 200 cm. Moist 10YR 4/3. Sandy Loam. Moist firm moderate medium subangular blocky with fine cracks. Rapidly moisture absorbent. Few hard Calcium Carbonate concretions.

Natrargid
Saline/Alkaline

Pit: 2112

Location:

Topography: Flat and level.

Cultivation and Land Use: Nil.

Vegetation: Few Acacia ehrenbergiana.

Surface: Common kankars. Soft broken crust. Few shells and shell fragments. Few hard Calcium Carbonate concretions.

Profile description:-

0 - 74 cm. Moist 10YR 3/3. Light silty clay loam. Dry slightly hard, moderate medium subangular blocky with common cracks infilled with sand. Few pores. Rapidly moisture absorbent. Few small fragments. Few Calcium Carbonate concretions. Common kankars. Few mica. Salt crystals from 40 cm.

74 - 104 cm. Moist 10YR 3/2. Heavy silty clay loam. Dry hard, moderate medium subangular blocky with common cracks infilled with sand. Few pores. Rapidly moisture absorbent. Common shells and shell fragments. Common kankars. Few common mica. Common salt ard gypsum.

104 - 154 cm. Moist 10YR 3/3. Silty clay loam. Dry very hard, moderate medium subangular blocky with common cracks and few pores. Moderately moisture absorbent. Shells and shell fragments. Common salt crystals and gypsum. Few kankars. Few mica. Few Calcium Carbonate concretions.

154 - 200 cm. Moist 10YR 3/3. Light silty clay loam. Dry hard moderate medium subangular blocky with common fine cracks and few pores. Moderately moisture absorbent. Few shells and shell fragments. Few Calcium Carbonate streaks. Amorphous gypsum. Few hard Calcium Carbonate concretions. Common salt crystals. Few mica.

Natrargid

extremely Saline/Alkaline

Pit: 2117

Location:

Topography: Flat and level.

Cultivation and Land Use: Nil.

Vegetation: Sparse Acacia ehrenbergiana and Calotropis procera.

Surface: Common kankars. Few Calcium Carbonate concretions. Soft broken crust.

Profile description:-

0 - 25 cm. Moist 10YR 4/2. Silt Clay loam. Dry slightly hard moderate medium subangular blocky with common fine cracks and common pores. Rapidly moisture absorbent. Sparse Calcium Carbonate concretions. Common mica.

25 - 75 cm. Moist 10YR 4/2. Silt Clay loam. Dry slightly hard, moderate medium subangular blocky with common fine cracks and few pores. Rapidly moisture absorbent. Common gypsum and salt crystals. Common mica.

75 - 110 cm. Moist 10YR 3/3. Light silty clay loam. Very slightly moist hard, moderate medium subangular blocky with common fine cracks and few pores. Moderately to rapidly moisture absorbent. Few Calcium Carbonate concretions. Sparse gypsum and salt crystals. Common mica.

110 - 160 cm. Moist 10YR 4/2. Silt loam. Very slightly moist hard, weak medium subangular blocky with few cracks and few pores. Moderately moisture absorbent. Few to common salt. Few Calcium Carbonate concretions. Common mica.

160 - 200 cm. Moist 10YR 4/2. Silt loam. Very slightly moist hard, weak medium subangular blocky with few pores. Moderately moisture absorbent. Common Calcium Carbonate concretions and streaks. Amorphous gypsum. Few salt crystals. Common mica.

Natrargid
extremely Saline/extremely Alkaline

Pit: 2145

Location: Extension in new canal.

Topography: Even gently sloping.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Common gravel. At 500 m common to abundant gravel. Common kankars. Thin broken crust.

Profile description:-

0 - 20 cm. Moist 10YR 4/4. Silt loam. Dry soft structureless with common cracks. No pores. Rapidly moisture absorbent. No roots. Common kankars. Few gravel. Common mica.

20 - 115 cm. Moist 10YR 4/4. Silty clay loam. Dry slightly hard, moderate medium subangular blocky with common cracks and few pores. Rapidly moisture absorbent. No roots. Common kankars, Few gravel. Few salt crystals?

115 - 200 cm. Moist 10YR 4/2. Silty clay loam. Dry slightly hard, weak medium subangular blocky with few cracks. No pores. Rapidly moisture absorbent. No roots. Few gypsum? Few gravel. Sparse kankars. Few very small Calcium Carbonate concretions.

Natrargid

Saline/Alkaline

Pit: 2194

Location:

Topography: Uneven with sand dunes (moving)

Cultivation and Land Use: Nil.

Vegetation: Few Acacia tortilis; few Acacia ehrenbergiana and few Capparis decidua.

Surface: Loose sand; abundant small kankars. Shell fragments.

Profile descriptions:

0 - 25 cm. Moist 10YR 4/4 - 3/4. Slightly loamy sand. Dry soft, structureless with common cracks and common pores. Rapidly moisture absorbent. Common roots. Shell fragments. Abundant kankars.

25 - 110 cm. Moist 10YR 4/3 - 3/3. Sandy loam. Dry hard, cemented structureless with common cracks infilled with sand and kankars. Common pores. Rapidly moisture absorbent. Few roots up to 60 cm. Shell fragments. Common Calcium Carbonate streaks. Abundant kankars. Common salt crystals. Gypsum?

110 - 200 cm. Moist 10YR 3/4. Silty clay loam. Dry hard, moderate medium subangular blocky, with common cracks, infilled with sand. Few pores. Rapidly moisture absorbent. No roots, Shell fragments. Abundant salt and gypsum crystals. Few hard Calcium Carbonate concretions. Abundant kankars. Few mica.

Natrargid
Saline/Alkaline

Pit: 2244

Location:

Topography: Flat and sloping to west.

Cultivation and Land Use: Nil.

Vegetation: Nil at pit site. In the Khor nearby common Panicum turgidum and few Acacia ehrenbergiana.

Surface: Thin soft broken crust. Abundant gravel. Common kankars. Few stones.

Profile description:-

0 - 5 cm. Moist 10YR 4/4. Gravelly loam. Dry loose, structureless with common cracks infilled with sand and fine gravel. No pores. Rapidly moisture absorbent. Abundant gravel, Few stones. Common mica.

5 - 40 cm. Moist 10YR 3/2 Clay loam. Dry soft, crumble with common cracks, infilled with sand and fine gravel. No pores. Rapidly moisture absorbent. Abundant fine gravel. Common fine gravel. Common Calcium Carbonate streaks. Gypsum? Common mica.

40 - 120 cm. Moist 10YR 3/1 Clay loam. Dry very hard, moderate, medium subangular blocky with common cracks infilled with sand and fine gravel. No pores. Rapidly moisture absorbent. Abundant fine gravel. Few hard Calcium Carbonate concretions. Abundant gypsum crystals at 110 - 140 cm. Common mica.

120 - 190 cm. Moist 10YR 4/2. Clay loam. Dry very hard, moderate medium subangular blocky with few cracks, infilled with fine gravel and sand. No pores. Rapidly moisture absorbent. Common to abundant hard Calcium Carbonate concretions. Common fine gravel. Few mica.

Natrargid
Highly Saline/Alkaline

Pit: 2247

Location:

Topography: Flat and slightly sloping to the West.

Cultivation and Land Use: Nil.

Vegetation: Nil

Surface: Soft broken crust. Abundant kankars. Few fine gravel.

Profile description:-

0 - 2 cm.	Moist 10YR 4/4. Sandy loam. Dry loose, structureless, rapidly moisture absorbent. Common mica. Common kankars.
2 - 45 cm.	Moist 10YR 3/4 Clay loam. Dry soft, crumble with no cracks and no pores. Rapidly moisture absorbent. Common to abundant gypsum crystals. Abundant Calcium Carbonate streaks. Common hard Calcium Carbonate concretions. Common mica. Sand accumulations.
45 - 80 cm.	Moist 10YR 3/3. Silty clay loam. Dry soft, moderate medium subangular blocky. Common horizontal and vertical cracks. Common pores. Rapidly moisture absorbent. Abundant gypsum crystals. Common Calcium Carbonate streaks and concretions. Common kankars. Common mica.
80 - 195 cm.	Moist 10YR 4/3 - 6/3. Clay loam. Dry hard, structureless with common fine cracks. Common pores. Moderately moisture absorbent. Common to abundant Calcium Carbonate streaks and semi-hard concretions. Common mica.

Natrargid
extremely Saline/extremely Alkaline

APPENDIX 2

Laboratory Analyses of 123 Soil Samples

from 45 Pit Sites.

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/ cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2001	0-25	24	15	23	38	9.78	8.70	6.20	54	4.35	15.2	19.6	31	50
	25-75	24	20	13	43	9.12	8.52	16.00	58	11.89	18.5	30.4	38	48
	75-200	24	37	6	33	9.78	8.82	3.60	114	5.30	18.7	24.0	33	56
2005	0-30	44	25	8	23	9.75	8.80	8.80	48	5.4	13.8	19.2	20	69
	30-110	36	20	16	28	9.62	8.75	14.00	65	12.15	16.6	28.8	28	59
	110-200	28	16	18	38	9.45	8.63	11.00	84	12.39	18.8	31.2	8	235
2014	2-17	24	32	18	26	10.1	8.93	7.50	45	4.10	15.9	20.0	40	40
	17-88	20	27	27	26	9.45	8.58	28.50	42	15.50	28.5	44.0	37	77
	88-170	48	24	7	21	9.97	8.70	18.00	36	7.65	17.9	25.6	21	88
2018	0-28	28	19	12	41	9.18	8.40	0.48	40	0.20	1.4	1.6	37	4
	28-76	24	33	7	36	9.85	8.72	1.12	40	0.20	5.0	5.2	34	15
	76-200	20	42	7	31	10.02	8.80	8.70	61	5.70	11.9	17.6	30	40
2030	0-35	36	41	5	18	10.32	9.30	0.84	37	0.37	6.0	6.4	20	30
	35-85	52	29	6	13	10.35	9.55	4.20	40	1.95	5.2	7.2	16	33
	85-200	36	25	11	28	10.25	9.49	1.10	76	2.66	27.7	30.4	31	89

Pit No.	Depth in cms	Soil Particules %				pH 1:5	pH Paste	E.C. mmhos/ cm	Sat %	Sol.Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2031	0-45	48	31	10	11	9.28	8.55	0.30	23	0.03	0.1	0.2	14	1
	45-160	40	29	8	23	8.75	8.22	0.26	40	0.10	1.1	1.2	24	5
	160-200	48	28	6	18	8.95	8.08	0.27	40	0.05	0.3	0.4	20	2
2037	0-55	16	35	11	38	10.15	9.22	1.14	44	0.50	11.9	12.4	31	38
	55-90	32	19	16	33	10.18	9.03	6.80	76	6.65	22.1	28.8	33	67
	90-180	52	9	13	26	10.28	9.25	5.00	80	5.50	21.7	27.2	30	72
2040	0-117	32	55	2	11	9.12	8.37	0.38	26	0.16	Nil	0.2	11	Nil
	117-140	68	21	3	8	9.33	8.48	0.46	22	0.06	1.1	1.2	10	11
	140-200	20	40	10	30	9.15	8.25	0.43	46	0.06	1.9	2.0	37	5
2045	0-76	16	21	19	44	9.45	8.30	5.60	54	2.97	9.0	12.0	37	24
	76-126	8	74	22	41	9.28	8.37	14.00	60	9.60	14.4	24.0	45	32
	126-200	60	22	4	14	9.60	8.43	3.60	29	2.80	Nil	2.8	10	Nil
2056	0-55	20	25	21	34	9.15	8.57	9.00	46	4.47	5.5	10.0	44	13
	55-75	20	37	17	26	9.35	8.40	32.80	44	14.96	20.2	35.2	29	70
	75-200	28	37	14	21	9.23	8.27	23.20	43	10.70	21.3	32.0	21	100

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/ cm	Sat %	Sol.Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2061	0-78	47	40	2	11	9.30	8.65	0.30	23	0.06	1.1	1.2	8	14
	78-171	40	40	1	19	9.77	8.72	7.20	32	3.12	Nil	2.8	22	Nil
	171-200	36	49	1	14	9.75	8.85	1.14	26	0.25	2.5	2.8	11	23
2062	0-100	0	57	19	24	10.92	10.83	5.20	40	2.80	24.8	27.6	23	104
	100-200	0	32	32	36	10.83	10.77	6.60	60	5.62	37.6	43.2	38	100
2077	0-30	40	35	6	19	8.95	8.24	0.29	28	0.04	0.7	0.8	16	4
	30-113	52	23	4	21	9.23	8.20	0.38	40	0.05	0.3	0.4	17	2
	113-180	60	5	11	24	9.25	8.39	0.48	40	0.10	0.3	0.4	27	1
2081	0-40	28	32	11	29	8.90	8.32	0.27	40	0.05	0.3	0.4	29	1
2087	0-15	56	32	2	10	9.18	8.25	0.25	198	0.05	1.6	1.6	13	13
	15-38	44	29	2	25	8.92	7.95	0.32	41	0.1	1.1	1.2	17	6
2092	0-30	40	43	2	15	9.0	8.22	0.28	254	0.03	0.8	0.8	15	5
	30-110	52	14	9	27	9.3	8.25	0.26	43	0.1	0.7	0.8	22	3
	110-170	28	23	24	25	9.5	8.4	0.36	42	0.1	0.7	0.8	22	3

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/ cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2100	8-40	31	35	12	17	10.2	8.7	3.7	32	1.5	7.3	8.8	18	41
	40-115	28	43	7	22	10.15	8.8	8.0	45	4.4	16.4	20.8	22	74
	115-200	39	50	2	9	10.18	8.98	4.0	44	1.9	21.3	23.2	29	73
2106	0-150	64	29	2	5	9.6	8.9	0.33	204	0.1	1.5	1.6	6	25
	150-200	-	-	24	28	10.20	9.3	0.66	192	0.15	2.3	2.4	16	14
2112	0-74	81	25	22	45	8.5	8.02	29.5	64	17.7	26.3	44.0	40	65
	74-104	0	23	25	52	8.65	8.0	24.0	64	16.6	31.4	48.0	52	60
	104-200	4	14	32	50	8.6	8.1	2.7	65	1.6	44.8	46.4	46	96
2117	0-75	41	44	22	30	9.75	8.98	32.0	56	25.0	27.8	52.8	30	93
	75-110	4	27	29	40	10.32	9.2	5.2	87	6.3	32.5	38.8	40	81
	110-200	28	15	27	30	10.55	9.4	36.0	73	26.8	10.8	37.6	40	27
2123	0-75	36	25	13	26	7.7	7.5	3.2	43	0.7	4.9	5.6	25	20
	75-125	28	43	8	21	7.95	7.65	4.0	47	1.4	5.8	7.2	20	30
	125-175	44	20	13	23	8.2	7.8	3.4	45	1.3	4.7	6.0	18	26

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2130	5-70	16	53	11	20	8.7	8.4	6.2	44	3.35	20.7	24.0	23	63
	70-95	19	53	11	17	8.2	8.0	14.0	51	9.2	22.8	32.0	29	79
	95-125	46	26	11	17	8.48	8.3	7.1	48	4.2	27.4	31.6	30	91
	125-195	50	34	6	10	7.95	7.9	4.0	38	1.9	34.1	36.0	37	84
2137	0-20	49	44	3	13	8.75	8.0	0.68	61	0.4	1.6	2.0	11	15
	20-140	36	18	8	38	8.35	8.1	3.5	62	2.5	13.9	16.4	32	43
	140-185	24	27	6	43	8.25	7.9	6.5	86	6.4	18.8	25.2	37	51
2143	0-40	12	32	13	43	8.1	8.0	1.2	47	0.7	10.7	11.6	41	28
	40-90	13	28	11	48	8.6	8.15	9.0	77	8.7	24.5	33.2	44	56
	90-170	12	27	23	38	8.4	8.1	18.0	70	14.2	25.0	39.2	36	69
2145	0-20	5	24	28	44	8.95	7.9	0.95	42	0.4	3.6	6.0	40	9
	20-115	4	23	19	54	7.8	7.45	9.6	61	8.4	13.2	21.6	52	25
	115-200	0	21	16	63	7.6	7.48	21.3	69	11.7	19.5	31.2	61	32

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/cm	Sat %	Sol.Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2154	15-100	16	27	13	44	8.45	7.85	3.5	70	2.5	8.7	11.2	39	22
	100-135	12	46	13	29	8.35	8.05	13.0	74	10.0	10.0	20.0	32	31
	135-185	30	29	16	25	8.35	7.8	24.0	51	11.4	9.4	20.4	35	27
2160	10-60	13	26	26	35	8.85	8.2	34.0	57	26.0	38.0	64.0	34	110
	60-140	8	26	31	35	8.9	8.35	27.2	71	25.0	46.2	71.2	49	94
	140-185	12	67	2	19	8.94	8.22	12.4	53	9.3	21.9	31.2	32	69
2164	2-110	24	34	11	31	8.88	8.4	11.6	59	10.0	19.6	29.6	31	63
2169	0-180	0	25	26	49	8.45	8.05	3.1	70	2.8	13.2	16.0	43	31
2175	8-45	18	41	26	15	8.85	8.70	18.0	59	18.0	39.0	57.0	45	87
	45-85	24	35	26	15	9.25	8.88	11.6	64	10.9	40.1	50.0	45	89
	85-125	10	67	13	10	9.5	8.96	3.2	66	3.1	58.9	62.0	59	100
	125-200	52	32	6	10	9.6	8.9	3.6	66	2.9	57.1	60.0	58	98
2178	8-135	41	21	21	17	8.8	7.98	3.6	52	1.05	1.8	2.8	36	5

Pit No.	Depth in cms	Sand Particles %				pH 1:5	pH Paste	E.C. mmhos/cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2185	3-75	28	27	13	32	9.2	8.6	6.0	50	4.65	16.6	21.2	30	55
	75-200	20	23	16	41	9.2	8.6	4.8	81	5.6	24.0	29.6	42	57
2190	0-50	8	40	23	29	8.2	7.9	0.44	47	0.2	2.2	2.4	37	6
	50-140	4	36	21	39	8.7	8.1	1.4	59	0.95	7.0	8.0	38	18
	140-180	-	-	16	36	9.05	8.35	2.3	79	2.45	14.5	16.8	44	35
2194	0-25	32	53	4	11	8.45	7.95	0.46	24	0.2	1.0	1.2	12	8
	25-110	30	43	3	24	8.92	8.18	6.4	36	3.0	8.2	11.2	23	38
	110-200	16	29	16	49	9.03	8.36	6.0	73	7.7	26.3	34.0	45	59
2197	0-60		18	38	44	7.12	7.35	0.36	86	0.2	1.0	1.2	42	2
	60-145	0	25	36	39	8.00	7.65	0.34	57	0.2	2.2	2.4	47	5
	145-200	8	35	33	24	8.70	7.85	0.55	45	0.6	1.0	1.6	35	3
2204	15-35	32	43	9	16	9.15	9.15	40.0	28	20.5	19.5	40.0	20	98
	35-125	28	37	16	19	10.1	10.0	6.5	41	4.0	19.2	23.2	20	96
	125-200	8	27	39	26	9.9	9.85	1.7	66	1.9	42.9	44.8	48	89

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2211	0-55	8	50	8	34	8.40	8.0	0.60	24	0.25	2.6	2.8	31	8
	55-145	28	22	11	39	9.15	8.45	1.4	57	1.1	14.9	16.0	38	35
	145-190	8	37	19	36	8.98	8.25	3.6	72	3.65	19.1	22.8	38	50
2216	0-170	9	50	31	10	8.20	8.0	0.46	54	0.15	1.1	1.2	40	3
2221	0-25	26	52	11	11	8.72	8.25	0.6	36	0.15	1.9	2.0	20	10
	25-70	8	45	26	21	8.85	8.35	5.0	49	3.0	11.0	14.0	39	28
	70-175	16	49	21	14	8.85	8.22	5.8	56	3.45	15.7	19.2	36	42
2229	0-27	4	21	35	40	8.5	8.35	46.0	53	42.0	42.8	84.8	43	99
	27-80	4	14	44	38	8.22	7.95	34.0	74	28.0	28.8	56.8	54	53
	80-185	12	18	24	46	8.6	7.99	6.4	76	6.3	17.7	24.0	43	41
2231	0-50	12	33	14	41	7.99	7.8	2.5	51	1.15	2.5	3.6	38	7
	50-130	12	25	15	48	8.4	8.1	12.4	69	10.5	17.1	27.6	44	39
	130-180	12	21	16	51	8.6	8.2	11.2	75	10.0	18.8	28.8	46	41

Pit No.	Depth in cms	Soil Particles %				pH 1:5	pH Paste	E.C. mmhos/ cm	Sat %	Sol. Na Meq/100g Soil	Exch. Na Meq/100g Soil	Total Ext. Na Meq/100g Soil	C.E.C.	E.S.P.
		Sand		Silt	Clay									
		Coarse	Fine											
2237	0-15	8	26	17	49	8.25	7.88	0.72	46	0.25	2.2	2.4	48	5
	15-85	8	21	14	57	8.3	7.8	1.1	61	0.55	2.3	2.8	52	4
	85-190	8	16	15	61	8.46	8.0	7.5	82	7.9	17.7	25.6	52	43
2243	10-75	20	41	9	30	8.8	8.0	12.4	45	7.4	11.0	18.4	28	39
	75-150	24	32	10	34	9.2	8.6	4.0	81	4.8	20.4	25.2	32	63
	150-200	12	27	22	39	9.5	9.25	1.32	106	1.5	30.5	32.0	40	76
2244	5-40	20	29	16	35	8.2	7.8	18.4	55	10.3	13.7	24.0	30	46
	40-120	20	19	17	44	8.5	7.9	18.0	68	13.8	9.8	23.6	46	21
	120-190	12	19	17	52	9.38	8.7	2.5	98	3.8	27.4	31.2	51	54
2247	2-45	16	27	23	34	8.92	8.7	49.5	47	36.5	40.3	76.8	40	100
	45-80	8	24	21	47	9.10	8.7	31.0	73	36.0	52.6	88.6	55	96
	80-195	32	-	29	39	9.40	8.9	4.5	92	5.2	26.4	31.6	46	77

APPENDIX 3

Engineering Reconnaissance

Extensions to Sudan Survey Department Cross Sections

Khartoum to Kareima - Left and Right Banks

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd. Level Metres		Remarks
					Above NMWL	Above Sea Level	
68 L.B.	95 & 275	1	371.53	-	-	-	Section not located
67 L.B.	276	1	371.12	0	15.00	386.12	15 M ISO. Conc. post 349
				0.244	17.40	388.52	
				0.548	18.53	389.65	
				0.833	18.49	389.61	
				1.025	18.96	390.08	Token extension. Angle post C/S 67. 19.0 M.
66 L.B.	275	1	370.72	0	15.00	385.72	15 M ISO. Conc. post 455.
				0.249	16.22	386.94	
				0.525	17.00	387.72	
				0.802	18.45	389.17	Token extension. Angle post C/S 66. 18.5 M.
65 L.B.	271	1	370.31	0	15.00	385.31	15 M ISO. Conc. post 458.
				0.294	16.19		
				0.557	17.32		
				0.780	18.15		
				0.993	19.01		
				1.209	20.00		20 M ISO. Angle post C/S 65. 20 M.
64 L.B.	275	1	369.91	0	15.00	384.91	15 M ISO. Conc. post 457. Section continues through forestry reserve. Entry not permitted. no extension.
63 L.B.	275	1	369.50	0	15.00	384.50	15 M ISO. Conc. post 381
				0.263	16.88	386.38	
				0.564	19.02	388.52	
				0.795	17.84	387.34	
				1.035	18.47	387.97	
				1.254	19.00	388.50	
				1.449	20.00	389.50	20 M ISO. Angle post C/S 63. 20 M.

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
62 L.B.	275	2	369.10	0	15.00	384.10	15 M ISO. Conc. post.
				0.231	15.66	384.70	
				0.513	16.26	385.36	
				0.731	17.74	386.84	
				0.984	19.83	388.93	
				1.136	20.00	389.10	20 M ISO. Angle post C/S 62. 20 M
61 L.B.	275	2	368.69	0	15.00	383.69	15 M ISO. Conc. post 416.
				0.230	15.85	384.54	
				0.491	16.63	385.32	
				0.709	17.29	385.98	
				0.975	18.66	387.35	
				1.122	19.62	388.31	
				1.291	20.00	388.69	20 M ISO. Angle post C/S 61. 20 M
60 L.B.	275	2	368.29	0	15.00	383.29	15 M ISO. Conc. post 162.
				0.308	17.09	385.38	
				0.665	18.94	387.23	
				0.812	20.00	388.29	20 M ISO. Angle post C/S 60. 20 M
59 L.B.	290	2	367.70	0	15.00	382.70	15 M ISO. Conc. post 357.
				0.225	16.75	384.45	
				0.513	17.16	384.86	
				0.721	17.44	385.14	
				0.979	17.54	385.24	Token extension. Angle post C/S 59. 17.5 M.
58 L.B.	296	2	367.26	0	15.00	382.26	15 M ISO. Conc. post 369. Post destroyed.
				0.193	16.33	383.59	
				0.456	18.37	385.63	
				0.657	19.35	386.61	
				0.800	20.00	387.26	20 M ISO. Angle post C/S 58. 20 M
57 L.B.	290	2	366.82	0	15.00	381.82	15 M ISO. Conc. post 384.
				0.203	16.75	383.57	
				0.363	18.23	385.05	
				0.547	20.00	386.82	20 M ISO. Angle post C/S 57. 20 M
56 L.B.	290	2	366.27	0	15.00	381.27	15 M ISO. Conc. post 375
				0.229	16.89	383.16	
				0.458	18.91	385.18	
				0.624	20.00	386.27	20 M ISO. Angle post C/S 56. 20 M

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
55 L.B.	290	2	365.72	0	15.00	380.72	15 M ISO. Conc. post 427.
				0.166	17.23	382.95	
				0.360	19.11	384.83	
				0.388	20.00	385.72	20 M ISO. Angle post C/S 55. 20 M
54 L.B.	290	2	365.17	-	-	-	Section not located.
53 L.B.							
52 L.B.	Sections not extended. Area topographiclly unsuitable.						
51 L.B.							
50 L.B.	314	3	362.97	0	15.00	377.97	15 M ISO. Conc. post 391
				0.224	17.35	380.32	
				0.374	20.00	382.97	20 M ISO. Angle post C/S 50. 20M
49 L.B.	314	3	362.42	0	15.00	377.42	15 M ISO. Conc. post 228.
				0.192	17.07		
				0.390	18.10		
				0.628	20.00		20 M ISO. Angle post C/S 49. 20 M
48 L.B.	314	3	361.87	0	15.00	376.87	15 M ISO. Conc. post 379
				0.231	16.39	378.26	
				0.510	17.26	379.13	
				0.802	18.93	380.80	
				1.033	19.23	381.10	
				1.313	20.00	381.87	20 M ISO. Angle post C/S 48. 20 M
47 L.B.	314	3	361.32	0	15.00	376.32	15 M ISO. Conc. post 374
				0.186	15.88	377.20	
				0.354	16.84	378.16	
				0.510	17.30	378.60	
				0.685	18.02	379.34	
				0.893	18.92	380.24	
				1.009	20.00	381.32	20 M ISO. Angle post C/S 47. 20 M
46 L.B.	314	3	360.77	0	15.00	375.77	15 M ISO. Conc. post 156
				0.241	16.49	377.26	
				0.531	19.02	379.79	
				0.657	20.00	380.77	20 M ISO. Angle post C/S 46. 20 M

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Leve	Remarks
45 L.B.	314	3	360.77	0	15.00	375.22	15 M ISO Conc. post 430
				0.248	16.65	376.87	
				0.552	18.02	378.44	
				0.869	18.70	378.92	
				1.067	18.69	378.91	
				1.311	18.45	378.67	
				1.571	18.39	378.61	
				1.828	18.72	378.94	
				2.083	18.99	379.21	
				2.421	19.22	379.44	
				2.857	19.79	380.01	
				3.003	20.00	380.22	20 M ISO. Angle post C/S 45. 20 M
44 L.B.	351	4	359.67	0	15.00	374.67	15 M ISO. Conc. post 354
				0.289	16.98	376.65	
				0.588	19.63	379.30	
				0.633	20.00	379.67	20 M ISO. Angle post C/S 44. 20 M
43 L.B.	14	4	359.12	0	15.00	374.12	15 M ISO. Conc. post 346
				0.258	16.84	375.96	
				0.531	18.91	379.68	
				0.677	20.00	380.77	20 M ISO. Angle post C/S 43. 20 M
42 L.B.							
41 L.B.		Sections not extended. Area topographically unsuitable.					
40 L.B.							
39 L.B.	316	4	356.92	0	15.00	371.92	15 M ISO. Conc. post 428
				0.158	15.69	372.61	
				0.317	17.28	374.20	
				0.538	18.58	375.50	
				0.684	20.00	376.92	20 M ISO. Angle post C/S 39. 20 M
38 L.B.	316	4	356.37	0	15.00	371.37	15 M ISO. Conc. post 224
				0.178	15.13	371.50	
				0.430	14.87	371.34	
				0.669	16.01	372.38	
				0.939	17.45	373.82	
				1.108	18.41	374.78	
				1.207	20.00	376.37	20 M ISO. Angle post C/S 28. 20 M
37 L.B.	316	4	355.74	0	15.00	370.74	15 M ISO. Conc. post 167
				0.146	16.78	372.52	
				0.268	19.36	375.10	
				0.430	17.69	373.43	

Cont'd

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
37 L.B. Cont'd.	316	4	355.74	0.591	18.43	374.17	
				0.776	19.07	374.81	
				0.999	19.59	375.33	
				1.244	20.00	375.74	20 M ISO. Angle post C/S 37. 20 M
36 L.B.	316	4	355.12	0	15.00	370.12	15 M ISO. Conc. post 380.
				0.227	15.14	370.26	
				0.558	15.83	370.95	
				0.836	16.93	372.05	
				1.077	18.01	373.13	
				1.363	19.17	374.83	
				1.524	20.00	375.12	20 M ISO. Angle post C/S 36. 20 M
35 L.B.							
34 L.B.		Sections not extended. Area topographically unsuitable					
33 L.B.							
32 L.B.	341.30	5	352.62	0	15.00	367.62	15 M ISO. Conc. post 194
				0.189	17.48	370.12	
				0.424	16.90	369.52	
				0.642	17.13	369.75	
				0.852	19.56	372.18	
				0.858	20.00	372.62	20 M ISO. Angle post C/S 32. 20 M
31 L.B.	320.30	5	352.00	0	15.00	367.00	15 M ISO. Conc. post 200.
				0.227	14.84	366.84	
				0.464	15.32	367.32	
				0.756	16.73	368.73	
				1.016	17.45	369.45	
				1.260	18.90	370.90	
				1.340	20.00	372.00	20 M ISO. Angle post C/S 31. 20 M
30 L.B.							
29 L.B.		Sections not extended. Area topographically unsuitable					
28 L.B.							
27 L.B.	293.30	6	349.90	0	15.00	364.90	15 M ISO. Conc. post 255
				0.215	15.99	365.89	
				0.498	17.01	366.91	
				0.710	18.27	368.17	
				0.925	19.35	369.15	
				1.118	20.00	369.90	20 M ISO. Angle post C/S 27. 20 M
26 L.B.	293.30	6	349.49	0	15.00	364.49	15 M ISO. Conc. post 111
				0.270	16.03	365.52	
				0.655	16.83	366.32	
				0.874	17.23	366.72	
				1.077	17.80	367.29	
				1.304	18.05	367.54	
				1.488	18.25	367.74	

Cont'd.

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
26 L.B. Cont'd.	293.30	6	349.49	1.739	19.31	368.80	
				1.987	19.83	369.32	
				2.074	20.00	369.49	20 M ISO. Angle post C/S 26. 20 M
25 L.B.	293.30	6	349.17	0	15.00	364.17	15 M ISO. Conc. post 240
				0.215	15.20	364.37	
				0.451	15.01	364.18	
				0.667	15.02	364.19	
				0.902	16.46	365.63	
				1.094	16.11	365.28	
				1.415	16.81	365.98	
				1.699	16.77	365.94	
				1.980	17.89	367.06	
				2.200	18.20	367.37	
				2.413	18.29	367.46	
				2.600	18.30	367.47	
				2.789	18.74	367.91	
				2.960	18.79	367.96	
				3.144	19.37	368.54	
				3.375	20.00	369.15	20 M ISO. Angle post C/S 25. 20 M
24 L.B.	293.30	6	348.58	0	15.00	363.58	15 M ISO. Conc. post 054 (post destroyed).
				0.183	15.52	364.10	
				0.388	15.71	364.29	
				0.689	16.47	365.05	
				0.953	17.08	365.66	
				1.225	17.10	365.68	
				1.488	17.97	366.55	
				1.798	17.98	366.56	
				2.118	18.72	367.30	
				2.276	20.00	369.10	20 M ISO. Angle post C/S 24. 20 M
23 L.B.	293.30	6	348.33	0	15.00	363.33	15 M ISO. Conc. post 289
				0.236	16.04	364.37	
				0.497	16.48	364.81	
				0.719	16.80	365.13	
				1.000	16.98	365.31	
				1.299	16.98	365.31	
				1.566	17.37	365.70	
				1.819	17.59	365.92	
				2.117	17.81	366.14	
				2.411	18.00	366.33	
				2.756	18.57	366.90	
				3.011	19.08	367.41	
				3.218	19.51	367.84	
				3.574	19.78	368.11	
				3.721	20.00	368.33	20 M ISO. Angle post C/S 23. 20 M

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd. Level Metres Above NMWL	Grd. Level Metres Above Sea Level	Remarks
23 L.B. to 1 L.B. incl.		6, 7, 8.					
70 L.B. to 88 L.B. incl.		8, 9, 10					
1 L.B. to 6 L.B. incl.		12	Sections not extended after 14th March 1964 see 5.6.				
10 L.B. 1 L.B. to 5 L.B.		13					
1 R.B. to 8 R.B.		1 & 2	Sections covered by 1962-63 investigations (Report No. 2)				
9 R.B.	95	2	368.56	0	15.00	383.56	15 M ISO. Conc. post 485
				0.373	17.16	385.72	
				0.730	18.03	386.59	
				1.036	18.83	387.39	
				1.326	20.00	388.56	20 M ISO. Angle post C/S 9. 20 M
10 R.B.	110	2	368.15	0	15.00	383.15	15 M ISO. Conc. post 486
				0.301	16.96	385.11	
				0.636	18.06	386.21	
				0.975	18.52	386.67	Token extension. Angle post C/S 10. 18.5 M.
11 R.B.	110	2	367.75	0	15.00	382.75	15 M ISO. Conc. post 475
				0.318	17.48	385.23	
				0.647	18.26	386.01	
				0.912	18.55	386.30	
				1.209	18.86	386.61	Token extension. Angle post C/S 11. 18.9 M.
12 R.B.	110	2	367.31	0	15.00	382.31	15 M ISO. Conc. post 279
				0.284	16.26	383.57	
				0.660	18.26	385.57	
				0.961	20.00	387.31	20 M ISO. Angle post C/S 12. 20 M

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
13 R.B.	110	2	366.87	0	15.00	381.87	15 M ISO. Conc. post 268
				0.284	16.64	383.51	
				0.591	18.43	385.30	
				0.862	20.00	386.87	20 M ISO. Angle post C/S 13. 20 M.
14 R.B.	110	2	366.65	0	15.00	381.65	15 M ISO. Conc. post 275
				0.328	16.39	383.04	
				0.703	18.29	384.94	
				0.987	19.23	385.88	
				1.268	20.00	386.65	20 M ISO. Angle post C/S 14. 20 M
15 R.B.	110	2	366.23	0	15.00	381.23	15 M ISO. Conc. post 269.
				0.310	15.93	382.16	
				0.654	16.35	382.58	
				0.947	17.54	383.77	
				1.242	18.78	385.01	
				1.492	19.31	385.54	
				1.760	20.00	386.23	20 M ISO. Angle post C/S 15. 20 M
16 R.B.	110	2	365.77	0	15.00	380.77	15 M ISO. Conc. post 496
				0.288	16.39	382.16	
				0.644	17.29	383.06	
				1.040	18.21	383.98	
				1.214	18.80	384.57	Token extension. Angle post C/S 16 18.8 M
17 R.B.		Section not extended. Area topographically unsuitable.					
18 R.B.		2					
60 R.B. to 48 R.B. incl.		3 & 4	Sections not extended after 14th March 1964, see 5.6				
47 R.B.	161.30	4	358.24	0	15.00	373.24	15 M ISO. Conc. post 355
				0.196	16.97	375.21	
				0.254	20.00	378.24	20 M ISO. Angle post C/S 47. 20 M
46 R.B.	171	4	357.74	0	15.00	372.74	15 M ISO. Conc. post 352
				0.194	16.33	374.07	
				0.418	17.40	375.14	
				0.628	18.52	376.26	
				0.902	20.00	377.74	20 M ISO. Angle post C/S 46. 20 M
45 R.B.		4					No section

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
44 R.B.	143	4	356.74	0	15.00	371.74	15 M ISO. Conc. 359
				0.215	15.70	372.44	
				0.428	16.63	373.37	
				0.601	17.49	374.23	
				0.812	18.41	375.15	
				0.978	18.86	375.60	
				1.185	19.33	376.07	
				1.440	19.85	376.59	
				1.672	20.00	376.74	20 M ISO. Angle post C/S 44. 20 M
43 R.B.	145	4	356.24	0	15.00	371.24	15 M ISO. Conc. post 360.
				0.194	17.00	373.24	
				0.388	16.39	372.63	
				0.515	16.78	373.02	
				0.712	17.56	373.80	
				0.961	18.56	374.80	
				1.113	20.00	376.24	20 M ISO. Angle post C/S 43. 20 M
42 R.B.	185	4 & 5	355.74	0	15.00	370.74	15 M ISO. Conc. post 415
				0.223	16.04	371.78	
				0.449	17.74	373.48	
				0.640	19.04	374.78	
				0.668	20.00	375.74	20 M ISO. Angle post C/S 42. 20 M
41 R.B.	159.30	5	355.24	0	15.00	370.24	15 M ISO. Conc. post 292
				0.198	16.54	371.78	
				0.224	16.80	372.04	
				0.645	17.07	372.31	
				0.766	17.55	372.79	
				0.842	17.80	373.04	Token extension. Angle post C/S 41. 17.8 M
40 R.B.			Section not located.			—	
39 R.B.	159.30	5	354.24	0	15.00	369.24	15 M ISO. Conc. post 220
				0.242	15.70	369.94	
				0.515	16.94	371.18	
				0.656	17.46	371.70	
				0.911	18.32	372.56	
				1.155	19.22	373.46	
				1.310	20.00	374.24	20 M ISO. Angle post C/S 39. 20 M
38 R.B.	159.30	5	353.74	0	15.00	368.74	15 M ISO. Conc. post 191
				0.274	16.49	370.23	
				0.519	18.25	371.99	
				0.800	20.00	373.74	20 M ISO. Angle post C/S 38. 20 M

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
37 R.B.	136	5	353.24	0	15.00	368.24	15 M ISO. Conc. post 266 Post destroyed
				0.208	15.92	369.16	
				0.438	16.50	369.74	
				0.787	17.40	370.64	
				1.026	18.35	371.59	
				1.291	19.35	372.59	
				1.433	20.00	373.24	20 M ISO. Angle post C/S 37. 20 M
36 R.B.	159.30	5	352.14	0	15.00	367.74	15 M ISO. Conc. post 170
				0.214	15.75	368.49	
				0.469	16.58	369.32	
				0.654	18.06	370.80	
				0.922	19.40	372.14	
				1.032	20.00	372.74	20 M ISO. Angle post C/S 36. 20 M
35 R.B.	189	5	351.60	0	15.00	366.60	15 M ISO. Conc. post 236
				0.222	15.86	367.46	
				0.446	15.91	367.51	
				0.668	16.79	368.39	
				0.897	17.26	368.86	
				1.122	18.08	369.68	
				1.344	18.70	370.30	
				1.427	18.80	370.40	
				1.754	18.95	370.55	
				1.921	19.33	370.93	
				2.119	20.00	371.60	20 M ISO. Angle post C/S 35. 20 M
34 R.B.	189	5	351.36	0	15.00	366.36	15 M ISO. Conc. post 226
				0.269	16.01	367.37	
				0.535	16.70	368.06	
				0.768	17.60	368.96	
				0.976	18.19	369.55	
				1.200	19.55	370.91	
				1.396	20.00	371.36	20 M ISO. Angle post C/S 34. 20 M
33 R.B.	189	5	351.04	0	15.00	366.04	15 M ISO. Conc. post 143. Post destroyed.
				0.184	15.00	366.04	
				0.448	15.35	366.39	
				0.676	15.66	366.70	
				0.897	15.60	366.64	Token extension. Angle post C/S 33. 15.6 M
32A R.B.		10 M and 15 M isopotamon not located.					

Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
32 R.B.	155	5	350.76	0	15.00	365.76	15 M ISO Conc. post 071 Post destroyed.
				0.214	15.19	365.95	
				0.471	15.29	366.05	
				0.717	15.46	366.22	
				0.900	15.94	366.70	Token extension. Angle post C/S 32. 15.9 M.
31 R.B.			Section not located.				
30 R.B.	127	6	350.20	0	15.00	365.20	15 M ISO. Conc. post 037
				0.233	16.27	366.47	
				0.492	18.02	368.22	
				0.731	19.80	370.00	
				0.824	20.00	370.20	20 M ISO. Angle post C/S 30. 20 M
29 R.B.	125.30	6	350.18	0	10.00	360.18	10 M ISO. Conc. post 298. 15 M ISO. not located.
				0.249	10.61	360.79	
				0.493	11.45	361.63	
				0.786	12.82	363.00	
				1.072	14.65	364.83	
				1.346	17.12	367.30	
				1.478	20.00	370.18	20 M ISO. Angle post C/S 29. 20 M
28 R.B.		Section not extended. Area topographically unsuitable.					
27 R.B.			Section not located.				
26 R.B.	116	6	349.08	0	10.00	359.08	10 M ISO. Conc. post 124
				0.242	10.15	359.23	
				0.489	11.40	360.48	
				0.567	15.65	364.73	
				0.792	17.58	366.66	
				0.912	15.14	364.22	
				1.061	13.80	362.88	
				1.369	15.26	364.34	
				1.622	14.79	363.87	
				1.845	17.30	366.38	Token extension. Angle post C/S 26. 17.3 M.
25 R.B.	111	6	348.80	0	10.00	358.80	10 M ISO. Conc. post 065 15 M ISO. not located.

Cont'd.

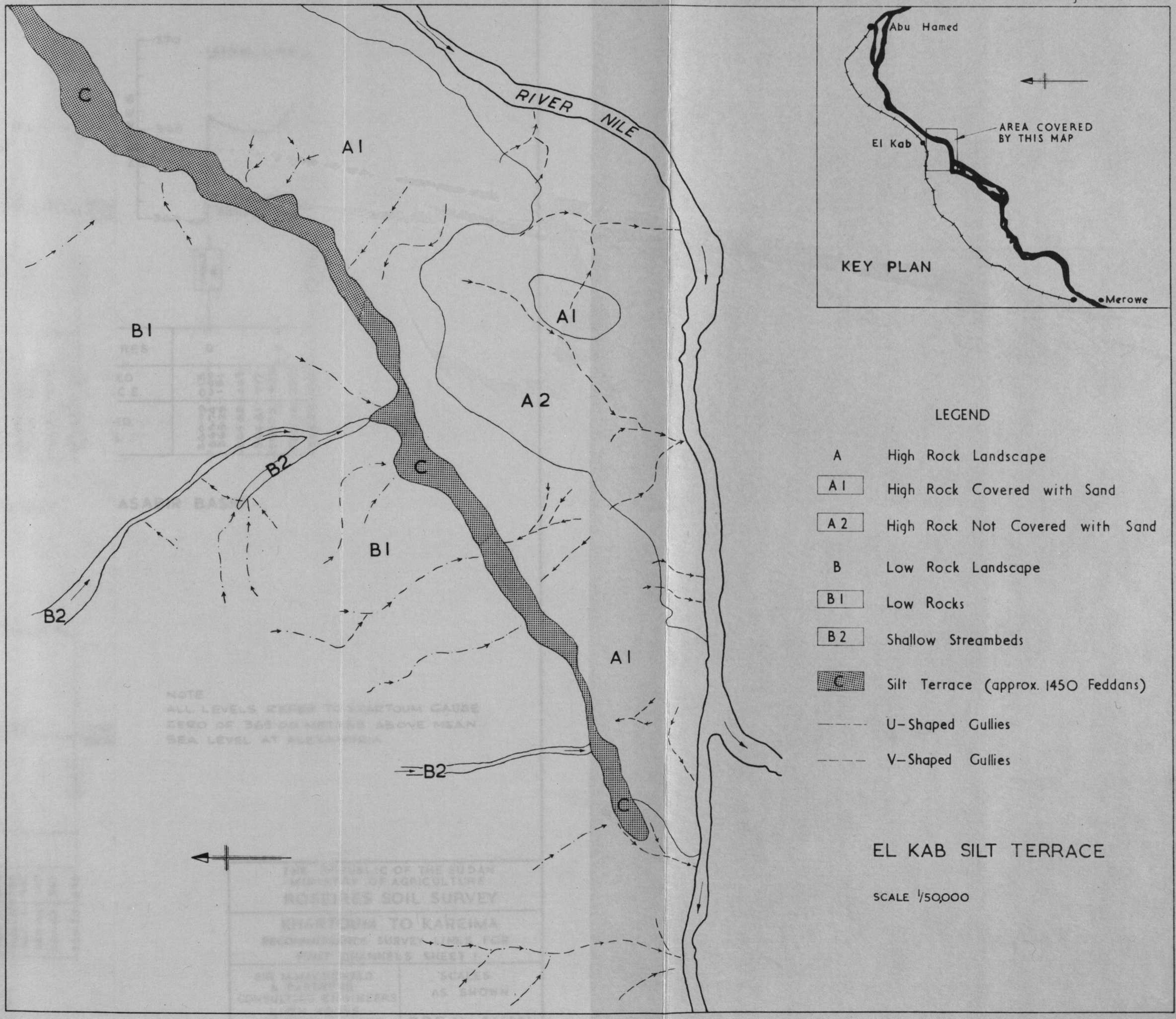
Cross Section No.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
25 R.B.	111	6	348.80	0	10.00	358.80	10 M ISO. Conc. post 065. 15 M ISO. not located.
				0.221	10.69	359.49	
				0.497	12.06	360.86	
				0.772	13.23	362.03	
				1.064	14.37	363.17	
				1.420	15.78	364.58	
				1.717	16.92	365.72	
				2.078	18.62	367.42	Token extension. Angle post C/S 25. 18.6 M.
24 R.B. to 21 R.B. incl.		Sections not extended. Area topographically unsuitable.					
18 R.B. to 1 R.B. incl.		7 & 8		Sections not extended after 14th March 1964, see 5.6			
70 R.B. to 92 RB. incl.		8, 9 & 10					
				RIVER ATBARA			
1 R.B. to 9 R.B. 1 L.B. to 11 R.B.		Sections not extended after 14th March, see 5.6					

APPENDIX 4

Notes on the El Kab Area

The El Kab Area is in Berber District, between Abu Hamed and the Fourth Cataract. This elongated narrow strip of silt, probably representing a former old river channel through rocky land, can be traced over a distance of about 20 km. from the railway line near El Kab station to the broken gullied land beside the Nile. This land was not investigated in the 1954 survey and there are no cross sections nor 1:100,000 scale maps. Figure 14, which has been prepared as a tracing from air photographs, shows the main features of the area as determined by photo-interpretation.

Figure 14



RIVER NILE
C
A1
B1
A2
B2
KEY PLAN
Abu Hamed
El Kab
AREA COVERED BY THIS MAP
Merowe
LEGEND
A High Rock Landscape
A1 High Rock Covered with Sand
A2 High Rock Not Covered with Sand
B Low Rock Landscape
B1 Low Rocks
B2 Shallow Streambeds
C Silt Terrace (approx. 1450 Feddans)
U-Shaped Gullies
V-Shaped Gullies
EL KAB SILT TERRACE
SCALE 1/50,000