THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

ROSEIRES SOIL SURVEY

REPORT No. 3

THE NILE
FROM KAREIMA TO THE THIRD CATARACT

SOILS AND ENGINEERING RECONNAISSANCE

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

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

SEPTEMBER 1963

THE REPUBLIC OF THE SUDAN

MINISTRY OF AGRICULTURE

ROSEIRES SOIL SURVEY

REPORT No. 3

THE NILE
FROM KAREIMA TO THE THIRD CATARACT

SOILS AND ENGINEERING RECONNAISSANCE

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

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

SEPTEMBER 1963

Sir M. MacDonald & Partners.
CHARTERED CIVIL ENGINEERS

PARTNERS:
R. H. MACDONALD, M.A., M.I.C.E.,
A. A. MIDDLETON, B.SC., M.I.C.E.
R. G. SMITH, B.SC., M.I.C.E., M.I.MECH.E.
Members of the Association of CONSULTING ENGINEERS
CONSULTANTS:
F. NEWHOUSE, F.C.G.I., B.SC., M.I.C.E., M.CONS.E.
G. LACEY C.I.E., F.C.G.I., B.SC., M.I.C.E., M.CONS.E.
A. M. R. MONTAGU, C.I.E., F.C.G.I., M.I.C.E.

YOUR REF. ....

OUR REF. ....

Lion House
Red Lion Street
London, W.C.1

TELEPHONES: CHANCERY 5747-8-9
TELEGRAMS: SCREETAN, LONDON
CABLEGRAMS: SCREETAN, LONDON

15th October, 1963.

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

Your Excellency,

ROSEIRES SOIL SURVEY.

We have pleasure in submitting our Report No. 3 for the Roseires Soil Survey Project, the study of which was entrusted to us by the Contract for the Survey of Irrigable Lands in the Sudan, signed on 27th September, 1962.

The Report contains the results of the reconnaissance soil and engineering survey carried out for the initial part of the Area referred to in the Contract as Area 4. It was agreed with the Ministry of Agriculture, on 8th December 1962, that the programme for the reconnaissance survey of Area 4 would give priority to that section lying between Kareima and the Third Cataract, accordingly the Report of the survey for the remaining Kareima to Khartoum section will be submitted following this forthcoming 1963/64 season of fieldwork.

The Report, which is accompanied by an album of maps, contains the results of the reconnaissance soil survey, land classification and engineering survey.

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.

We are, Excellency,

Your obedient Servants.

SIR M. MACDONALD & PARTNERS.

CONTENTS

APPENDICES

TABLES IN TEXT

FIGURES IN TEXT

PLATES

PLATE NO. 1 RECONNAISSANCE SURVEY LINES
FOR PUMP CHANNELS: - SHEET 1

PLATE NO. 2 RECONNAISSANCE SURVEY LINES
FOR PUMP CHANNELS: - SHEET 2
(Includes a Key plan)

REFERENCES

GENERAL REFERENCES

BARBOUR, K.M. - The Republic of the Sudan. 1961 University of London Press. London.

KNIGHT, R.L. & BOYNS, B.M. - Agricultural Science in the Sudan. A Bibliography with Abstracts. 1950, Buncle. Arbroath, Scotland.

REPUBLIC OF THE SUDAN, CENTRAL OFFICE OF INFORMATION, SUDAN ALMANAC. - Annual Handbook.

REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE - Annual Reports.

REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE, ADVISORY COMMITTEE ON AGRICULTURAL RESEARCH IN THE SUDAN - Annual Reports of the Research Division.

REPUBLIC OF THE SUDAN, MINISTRY OF IRRIGATION & H.E.P. - Annual Reports.

REPUBLIC OF THE SUDAN, MINISTRY OF IRRIGATION & H.E.P. - IRRIGATION BY PUMPS FROM THE NILE IN THE SUDAN. 1955 Survey Dept. Khartoum.

REPUBLIC OF THE SUDAN, MINISTRY OF IRRIGATION AND HYDRO-ELECTRIC POWER - Sudan Irrigation. 1957, Survey Dept. Khartoum.

TOTHILL, J.D. - (Editor) - Agriculture in the Sudan, by Numerous Authors. 1952, Oxford University Press, London.

OTHER REFERENCES

ANDREWS, F.W. - The Flowering Plants of the Anglo-Egyptian Sudan. 3 volumes. 1950, 1952 and 1956, Buncle, Arbroath, Scotland.

ANONYMOUS / - Notes on the Major Basins of Dongola District. Mimeographed Report, Dongola Rural District Council, c.1939.

AUDEN, J.B. / - Geological Note on Kerma Basin. Mimeographed Report, Irrigation Advisers' Office, Sudan Irrigation Department, June 15th, 1954.

GLENNIE, J.F. / - Report on Kerma Basin. Irrigation Adviser's Office, Sudan. Irrigation Department. June 15th 1954.

JESSUP, R.W. - The Stoney Tableland Soils of the South-Eastern Portion of the Australian Arid Zone and their Evolutionery History. Journal of Soil Science, Volume II, Pages 188 - 196. 1960.

MIDDLETON, K.R. - Various Methods for Chemical Examination of Soils. Government of the Sudan, Ministry of Agriculture Miscellaneous Paper No. 70. 1955.

PLUMMER, A.W. - Report on Irrigation Development Possibilities of Kerma Basin and Vicinity. Mimeographed Report, Dongola Rural District Council, June 1960.

SMITH, J. - Distribution of Tree Species in the Sudan in Relation to Rainfall and Soil Texture. 1949, Sudan Government, Ministry of Agriculture, Bulletin No. 4.

U.S. DEPARTMENT OF AGRICULTURE - Soil Survey Manual. Handbook No. 18. 1951, Government Printing Office, Washington, D.C.

U.S. DEPARTMENT OF AGRICULTURE - The Diagnosis and Improvement of Saline and Alkali Soils. Handbook No. 60. 1953, Government Printing Office, Washington, D.C.

U.S. DEPARTMENT OF AGRICULTURE - Soil Classification, a Comprehensive System, 7th Approximation. 1960, Government Printing Office, Washington, D.C.

U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION - Irrigated Land Use, Volume 5, 1961, Government Printing Office, Washington, D.C.

WORRALL, G.A. - Features of Some Semi-Arid Soils in the District of Khartoum. (I) The High Level Dark Clays. Journal of Soil Science, Volume 8 (2), Pages 193 - 202. 1958.

ACKNOWLEDGEMENTS

The compilation of a report of this kind cannot be completed without reference to 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 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 Director of Agriculture, the Assistant Director (Projects) and the Chief Research Officer, with their staff in Khartoum and Wad Medani, for their helpfulness in many matters affecting the conduct of the survey.

The members of the Ministry of Irrigation and Hydro-Electric Power including the Director of Irrigation and the Assistant Director (Development) with their staff, for their help.

The members of the Survey Department, the Sudan Gezira Board, the Geological Survey Department and the officers of local administration and police, for practical help and technical advice in obtaining our results.

University of Khartoum:

Professor D. Drover, Head of the Department of Agricultural Chemistry and Pedology, and Mr. E.L. Strmecki of this Department, for their help with the laboratory analyses. Professor K.N.G. MacLeay, Head of the Botany Department, for identifying our plant specimens.

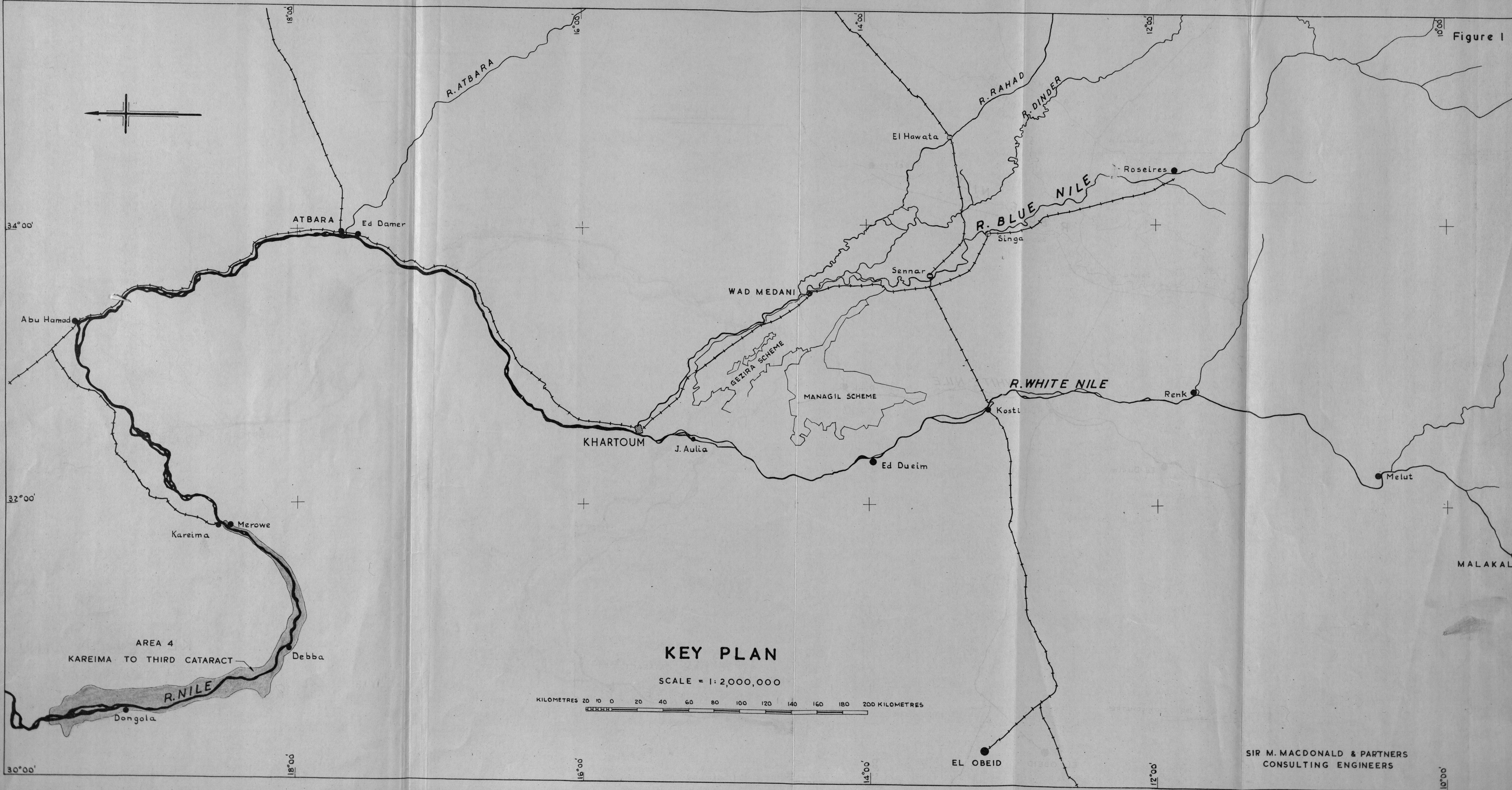


Figure 1
KEY PLAN
SCALE = 1: 2,000,000
KILOMETRES 20 10 0 20 40 60 80 100 120 140 160 180 200 KILOMETRES
SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
AREA 4
KAREIMA TO THIRD CATARACT
R. NILE
R. ATBARA
R. RAHAD
R. DINDER
R. BLUE NILE
R. WHITE NILE
GEZIRA SCHEME
MANAGIL SCHEME
ATBARA
Ed Damer
Abu Hamad
KHARTOUM
J. Aulia
Ed Dueim
WAD MEDANI
Sennar
Singa
El Hawata
Roseires
Kosti
Renk
Melut
MALAKAL
EL OBEID
Merowe
Kareima
Debba
Dongola
34°00'
32°00'
30°00'
18°00'
16°00'
14°00'
12°00'
10°00'

CHAPTER 1

SUMMARY

1.1 The reconnaissance soils and engineering survey of Area 4a covers a gross area of about 600,000 feddans of land in the Merowe and Dongola Districts of the Northern Province of the Republic of the Sudan.

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 Kareima at the foot of the Fourth Cataract downstream to the Third Cataract, a distance of 340 kilometres. This is the northern section of Area 4 as defined in the Contract.

1.3 The upper limit of survey is defined as the 20 metre isopotamon. The surveys showed that there is no irrigable land above this level. In fact, the dissected desert plateau of sandstone and basalt is usually encountered below the 20 metre isopotamon and the upper limit of the irrigable silt terraces occurs at about the 15 metre isopotamon.

1.4 The project area lies within the Desert region of the Sudan where the rainfall is negligible; Dongola and Kareima receive less than 50 mm of rain per year. The summers are very hot and dry, as the southerly winds do not bring rain to the region. The winters are cooler but are characterised by strong drying northerly winds which cause serious sand drift from the north-easterly direction which results in the formation of large dunes as for instance in the Wadi el Khowi area.

1.5 Because of the desert climate there is very little vegetative cover on the lands not flooded or irrigated. The commonest desert shrub is "sallam" bush (Acacia ehrenbergiana.) In the basins and along the river there are trees forming clumps and occasional forests: - "sunt" (Acacia nilotica), "talh" (Acacia seyal), "haraz" (Acacia albida), dom palm (Hyphaene thebaica) and "terfa" (Tamarix articulata).

1.6 The total population is about 300,000 people. There are three larger urban centres: - Dongola, Kareima and Merowe, a number of smaller towns: - Kerma, Argo, Khandaq, El Goled, El Ghaba, Debba and Korti, and a large number of villages, mostly located on the river bank. The whole population is dependent for a livelihood on irrigated farming.

1.7 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 after subsidence of the annual Nile flood. The chief crops grown are dura, dukhn, maize, wheat, lupins, haricot beans, barley and forage crops.

Saqia cultivation, powered by oxen, is carried out on lands close to the river. There are an estimated three to four thousands saghiyas which together irrigate about 14,000 feddans of land. The chief crops are dates, wheat, dura and forage.

Private pump schemes (about 400) with perennial restricted or flood licences have permission to irrigate about 78,000 feddans of land. The actual area irrigated is about 70,000 feddans and the chief crops grown are similar to those under saqia cultivation.

Government pump schemes at Nuri, Gureir, Kulud, Ghaba and Bergeig irrigate a gross area of nearly 16,000 feddans. Water rates are charged according to the crops grown: - wheat, Egyptian beans, dura, berseem, lubia, dates, vegetables and, at Nuri, horticultural crops such as dates, citrus, mango, guava, etc.

Basin irrigation varies greatly from year to year: in an average year the total area irrigated is about 33,200 feddans in the following basins: -

Kerma (27,500 feddans), Letti (4,900 feddans), Affat (300 feddans), Argi (200 feddans) and Bakri (300 feddans). Most of the basin land in Kerma and Letti basins is forest or grazing land; less than ten per cent is cropped and much of this is under matara irrigation.

Tubewell irrigation from six experimental installations on terrace silts east of Kerma basin was tried in the 1955-62 period. Although this experiment encountered difficulties which caused it to be discontinued, it would be useful to make a further study of this method of irrigation in Dongola and Merowe Districts.

1.8 The soil survey reveals that the soils of Area 4a are different in origin and morphology from those of the Gezira. Whereas the Gezira soils are mostly Vertisols (cracking clays), the soils of Area 4a are mostly Entisols (stratified silts and sands without natural genetic horizons).

Because of the arid environment these Entisols belong to the suborder of Ustents. The Ustents are then further subdivided into sandy soils (Psammustents) and loamy soils (Orthustents).

The Psammustents originated in one of two ways, either as sands of alluvial origin filling old river channels as in the Wadi el Khowi, or as sands of eolian origin forming sand sheets and flattened dunes adjacent to the plateau of Nubian sandstone. Both types are characterised by a very low content of silt and clay, a slightly alkaline reaction and variable amounts of calcium carbonate. Unless found in marshes they are non saline, non alkali soils.

The Orthustents are moderately calcareous stratified silty soils in which the silt fraction is often greater than the clay fraction. They may be saline or non saline. The soil reaction ranges from slightly to strongly alkaline. They are subdivided into the following sub-groups: -

Orthustents Sub-Group	Characteristic
orthic	non saline, non alkali loam
vertic	non saline, non alkali clay
psammustentic	with a sandy horizon
calcorthidic	with a highly calcareous horizon
natrargidic	alkali loam
matrargidic vertic	alkali clay
litchic	stony or rocky within 50 cm.

1.9 In addition to the Entisols there are a few sites belonging to the soil order of Aridisols. These are highly saline soils (Salorthids) which are found in sands at the edges of basins where ground water evaporates freely to leave a noticeable salt crust at the surface.

1.10 The engineering surveys were concerned primarily with establishing the 20 metre isopotamon and the nature and position of major topographic obstacles such as the edge of the desert escarpment or high sand dunes where these were encountered between the 20 metre level and the river.

The position of the 20 metre isopotamon, where needed, was established by office and field studies, using as a basis the cross sections at 4 kilometre intervals established by the 1951-52 survey of the Sudan Survey Department which covered the ground up to the 15 metre isopotamon. Data from the Argo and Merowe river gauges (normal ten day means) provided the basis for computing mean low water level for the 1951-52 survey.

1.11 In addition to the establishment of the 20 metre isopotamon the engineering investigations were concerned with a preliminary selection of possible irrigable areas. This was followed by field and office studies using air photography to locate suitable sites for pump stations and to design the layout of a canal system with or without a rising main. After the completion of the reconnaissance soil survey the engineering proposals were revised to include only those lands recommended for semi-detailed soil survey.

1.12 The land suitability classification was concerned with agricultural, engineering and land tenure considerations. Agricultural aspects of land selection were concerned chiefly with the physical bases of potential agricultural production. As in Areas 1 & 3, impeded drainage was rarely a limiting factor. Topographic limitations were encountered in areas of moving and fixed dunes mostly in the Wadi el Khowi area and in gullied lands where a narrow silt terrace is bordered by a sandstone escarpment as in the Akkad plain and the Merowe-Debba section. Soils limitations were due to excessive sandiness, the presence of surface stones and subsoil rock, high salinity and excessive exchangeable sodium (high alkalinity). Because of the relatively high permeability of the Area 4 Entisols leaching of soluble salts should be possible in many cases but it is not known whether leaching would also reduce the exchangeable sodium without the use of costly amendments.

Considerations of land tenure led to the elimination of small areas of land adjacent to registered lands or government pump projects (not included in the survey) which could not justify an independent pumping installation.

1.13 The lands recommended for semi-detailed soil survey and land suitability classification in Area 4a are as follows: -

Locality	Map Sheet No.	Area (feddans)
Fitna	17S	300
Gureir Extension	17S	5,800
Korti	18	500
Kulud Extension	18, 19	3,300
Affat Basin	19	3,800
Letti Basin	21	12,500
El Bakri Plain	21	27,900
Urbi Plain	22	3,500
Dongola	23	8,900
Kerma Basin	23, 24S	29,300
Total Area		~~102,000~~ 95,800

1.14 Preliminary layouts for irrigation of these lands have been prepared by the reconnaissance engineer. They are of use at this stage in evaluating the relative merits of the different areas, although it is recognized that substantial revision will be necessary when the results of the semi detailed soil survey and close levelling surveys are available.

CHAPTER 2

THE ENVIRONMENT

2.1 LOCATION AND GENERAL DESCRIPTION OF THE PROJECT AREA

The area covered by our reconnaissance, a 340 kilometre reach of the Nile Valley is in a remote part of the Northern Sudan. It extends from Kareima at the foot of the Fourth Cataract downstream to the Third Cataract, and comprises the northern part of Area 4 in the Contract for the Roseires Soil Survey. This is defined as "On both banks of the Main Nile from Khartoum to north of Dongola" a total length of more than 1000 kilometres.

Situated in the Northern Province the area forms part of the Merowe-Dongola District and lies between Latitudes 17^{o} 58'N and 18^{o} 45'N and Longitudes 30^{o} 15'E and 31^{o} 50'E. The width of the area from the Nile varies from nil in places where the desert of sand or rock borders on the river bank to a maximum of 8 kilometres where the alluvial terraces are widest. The land consists of a series of river terraces of various ages, bounded by dissected plateaus of sandstones and igneous rocks. The most recent river terraces, still subject to occasional or annual flooding, are all under cultivation, the irrigation water being brought up by saghias or pumps during the dry season. Villages and towns are scattered along these terraces. The older terraces are generally above flood level and are bare or sparsely vegetated; no attempt is made to cultivate them. Certain parts of these terraces are basins, below flood level. Canals have been dug to divert the Nile flood waters into the basins, and some crops are grown. Also they provide timber and firewood. The high ground above the river terraces, is sparsely vegetated sand and rock with no cultivation or habitation.

In the course of the reconnaissance surveys the lands up to the 20 metre isopotamon were examined except for registered lands and lands occupied by private or government pump schemes.

No precise figures for population of the area are available but it can be assumed that a large part of the population of Merowe-Dongola District, 303,839 persons, is included in the area. There are three main urban centres, Dongola in the north and at the eastern end of the area Kareima and Merowe on opposite sides of the river. Administration of the area is divided between Dongola Rural Council which serves the northern part covering 170 kilometres of the river valley and Merowe Rural Council which serves the remainder of the area. There are a number of smaller towns:- Kerma, Argo, Khandaq, El Goled and El Ghaba in the Dongola area and Debba and Korti in Merowe area. There are government Rest Houses for travellers at Bergeig, Seleim, Dongola, El Goled Bahri, Ed Debba, Korti and Merowe.

Communications within the area are difficult. The Sudan Railway system extends only to Kareima. The reach between Kareima and Dongola is served by a twice weekly steamer service which extends to Kerma when the river levels are high. There is a weekly air service from Khartoum and Atbara to airfields at Merowe and Dongola.

Access for motor vehicles is by ungraded earth roads which are continuous along the left bank of the Nile from Merowe to the Third Cataract. Near Debba this road is joined by the desert road from Omdurman which is traversed mostly by trucks and other vehicles with four wheel drive. There is no continuous road along the right bank of the Nile from

Kareima to Kerma but the Meheila earth road crosses the desert to link Dongola with the rail head at Kareima. There are no bridges over the Nile between the Third and Fourth Cataracts so that the Nile must be crossed by boat. There are car ferries at Argo, Dongola and Merowe. There is also a car ferry at Amentego, near Letti Basin, but this ferry is used as a relief at Dongola and Argo while the other ferry boats are overhauled at Kareima. Access to the Kerma Basin is good from Seleim and Bergeig rest-houses. The Bergeig Pump scheme is just over an hour's drive from Seleim Rest House. The Dongola area can be reached from Dongola Rest House, or Seleim Rest House, which is one kilometer upstream of the ferry on the East bank. The Urbi and El Bakri plains can be covered from El Goled Bahri Rest House. Letti Basin can also be reached from this rest house, across the ferry. There is a small rest house, in an advanced stage of decay, at the south end of this Basin. El Ghaba and Kulud can be reached from Ed Debba. The Affat basin can only be reached by felucca from Goshabu, near Ed Debba, or overland from Kareima. Gureir and the small area at Fitna can be reached from Merowe.

2.2 PHYSIOGRAPHY

The Dongola-Akkad Plain, the Kerma Basin and the Wadi el Khowi comprise the terraces on both sides of the river near Dongola. They are terminated in the North by a series of ridges of ancient metamorphic rocks which cut across the Nile Valley in an East-West direction.

The Dongola-Akkad Plain is on the west bank of the river, 2 to 3 kilometres wide, extending from the north of the area to a point about 10 kilometres south of Dongola. To the west is a high, much dissected gravel ridge with some sandstone outcrops. A smaller gravel ridge occurs as an island in this plain about 15 kilometres north of Dongola. The general slope of the plain is eastwards, towards the river and it is crossed by occasional gullies.

On the east bank of the river is the Kerma Basin, southern limit of which is about 6 kilometres south of Dongola and merges into the Active Flood Plain of the river at Bergeig. The Basin is mainly below the flood level of the river, and the topography is uneven with broad shallow depressions connected by steep-sided gullies. The northern end of the basin is occupied by the Bergeig Pump Scheme. South of Bergeig, the basin is separated from Argo Island by a narrow high strip of sand dunes and opposite Dongola there is a clay plain about 2 kilometres in width between the basin and the river. A canal has been cut through this plain at Seleim to provide supply channel into the basin during the flood season.

East and south of the Kerma Basin is a broad plain of silt and sand, up to 15 kilometres wide, which extends southwards to opposite El Goled Bahri. This plain is known generally as the Wadi el Khowi. It is bordered on the east by the steep scarp of a much dissected sandstone plateau. Some higher gravelly ridges occur in this plain, especially north-east of Dongola, and close to the river between Dongola and El Khandaq. Occasional small outcrops of dark coloured ferruginous rock are also found. The topography is somewhat uneven, with silt ridges and sandy depressions. Immediately south-east of the Kerma basin is the remnant of an ancient canal, about 50 yards wide and over six feet deep in parts.

South of Seleim, colonies of sand dunes cover the plain close to the river. Further south, these extend right across the plain. Generally each colony is up to 15 kilometre long and one or two kilometre wide, with its long axis roughly north-north-east to south-south-west. In between these colonies are bare flat areas of silt. South of a line opposite El Khandaq the plain is entirely covered by sand dunes.

The west Bank of the Nile south of the Dongola - Akkad plain rises steeply to a high, much dissected sandstone and gravel plateau. At Urbi there is a narrow alluvial terrace about 8 kilometres long and 2 kilometres wide between the river and the sandstone plateau.South of El Khandaq the high sandstone ridge swings away from the river, and is replaced by a broad flat alluvial plain, extending as far as El Baja. To the west of this plain is a broad low undulating firm sandy plain with a few sandstone outcrops. From El Baja to El Ghaba is a low soft, rippled sand plain.

East of the river between El Goled Bahri and El Ghaba is the Letti Basin, about 23 kilometres long, one to two kilometres wide. It merges with the active flood plain at the north and south ends, but the middle is separated from the river by a sandy plain up to 3 kilometres wide.

South of the river between El Ghaba and Ed Debba is an alluvial terrace up to 3 kilometres wide, bounded by a dissected gravel and sandstone plateau, with many sandy wadies.

Between Ed Debba and Merowe, on the left bank of the river, there are scattered small alluvial terraces, notably at Kulud, Korti and Gureir, separated by sandstone plateaus and older alluvial terraces, generally much dissected.

The Affat basin is on the right bank of the river, opposite Goshabi. It is about 5 kilometres long and 2 kilometres wide, and appears to be part of the Active Flood Plain. North of the basin is an alluvial terrace up to 4 kilometres wide, largely covered by sand, extending about 2 kilometres east and 15 kilometres west of the Basin. A second silt terrace extends from opposite Kulud to opposite Korti. This terrace is also largely covered by sand, including some large crescent-shaped 'Barchans'. These terraces are bounded by high sandstone jebels, which appear to be the remnants of a former plateau. Between Korti and Merowe there are no alluvial terraces on the right bank.

The Active Flood Plain of the river is generally narrow, with silt terraces not exceeding 1 kilometre in width. All these terraces are cultivated, and they include the pump schemes at Nuri, Gureir, Kulud and El Ghaba.

2.2. Geology

The Basement Complex of Pre-Cambrian metamorphic rocks outcrops northwards from a point 7 kilometres north of Kerma, and again north of Merowe. Between these points the Basement Complex is overlain by Nubian Sandstones. These sandstones are fossiliferous, with much silicated wood, which has been determined as Dadoxylon, and are attributed to the Lower Cretaceous period.

Near Dongola where there has been some volcanic activity the basalt cores of old volcanoes are exposed as volcanic necks such as Jebel Hafir and Jebel Binna.

The Qaab Depression, West of Dongola, is a low lying area of sandstone and volcanic ash.

Area 4a lies between the 3rd and 4th Cataracts. The 3rd Cataract, where the river flows over the hard rocks of the basement complex, forms a temporary base level from which the river has cut back through the softer sandstones as far as Merowe. The gradient is sufficiently shallow in this reach for lateral erosion to predominate, with the formation of a flood plain.

As the base level has been lowered in the past, the river has cut down through its former flood plains, leaving these as alluvial terraces now above the maximum river level. Some of the older of these terraces are now much eroded, for example a terrace on the left bank north of Korti.

There may recently have been a temporary local base level at El Khandaq, where the gradient of the river is somewhat steeper than elsewhere. This may have confined a lagoon in what is now the Letti Basin. At this time, part of the river may have flowed down the Wadi el Khowi during the annual floods, and the ancient canal South of the Kerma basin used to divert some of this flood water onto higher silt terraces.

The soft sand plain between El Baja and El Ghaba appears to be a former dune belt overlying the Nubian Sandstones. The yellowish brown colours indicate that the sand was not deposited by the Nile. This plain ends abruptly in a series of higher dunes resting on a hard low, level sandstone plain some ten miles west of the river. The southern limit is also abrupt, at the bottom of a shallow wadi just south of El Ghaba.

2.22 Movement of Superficial Sand in the Wadi el Khowi

The movement of sand in the Wadi el Khowi, which has resulted in the formation of large colonies of crescent-shaped sand dunes or Barchans, is likely to provide a serious hindrance to any development projects in the area.

The origin of these dunes is sand, blown from the Nubian sandstones which are exposed along the eastern edge of the Wadi el Khowi. The dunes generally occur in belts parallel to the direction of the prevailing northerly winds. The steep slip faces are on the south sides of the dunes. This is apparent on the aerial photographs used during the survey. These were flown in November 1961, just after the wind had changed from the south to the north, so it appears that the south winds have little effect on the dunes. Also, the dunes abut right onto the north bank of the river between El Khandaq and the Letti Basin, which suggests that the sand movement is predominately to the south.

The extent of this movement was gauged roughly by comparing the aerial photographs flown in 1961 with some flown in 1945 (scale, 1:40,000). The distance of certain dunes from recognisable landmarks was measured and the distance that they had travelled was calculated.

The calculated movements of 5 dunes in various parts of the area is as follows: -

Table 2.22 Distance travelled in 16 years by Sand Dunes

	Size of Dune	Distance Travelled
1.	250 metres x 350 metres	100 metres South-South West
2.	75 metres x 75 metres	300 metres " " "
3.	200 metres x 250 metres	200 metres " " "
4.	200 metres x 250 metres	100 metres " " "
5.	200 metres x 100 metres	100 metres " " "

The bare areas of silt terrace between the dune colonies are swept clear of sand by the wind. Sand accumulates downwind of any obstructions such as bushes or rock outcrops to form a 'sand shadow'. The rate at which this sand can accumulate was observed at a soil pit, DR280, in which sand accumulated to an overall depth of 65 cm. in 24 hours.

While there are very few large sand dunes north of Seleim in the Wadi el Khowi, the south end is completely covered with them. It seems that further south, more sand is blown from the bordering sandstone plateau. This appears to be related to the distance south of the edge of the Basement Complex outcrops north of Kerma, which are resistant to wind erosion. Thus, while the Bergeig pump scheme, which is just south of the basement complex outcrops, is comparatively little affected by sand accumulation, it is probable that this effect will be greater on projects further south. An example is the Letti Basin, where the recent alluvial deposits are covered by a belt of sand about 1 kilometre wide along the eastern margin of the basin.

2.3 CLIMATE

2.31 General

Area 4a is on the southern edge of the Desert region of the Sudan. The climate is dry, and the annual and diurnal variations of temperature are large. Dry, strong northerly winds prevail throughout the winter, and in summer the moist southerly winds just reach this area.

Kareima and Dongola are the only meteorological stations within the area. Data from these two stations has been provided by the Sudan Meteorological Service in Khartoum.

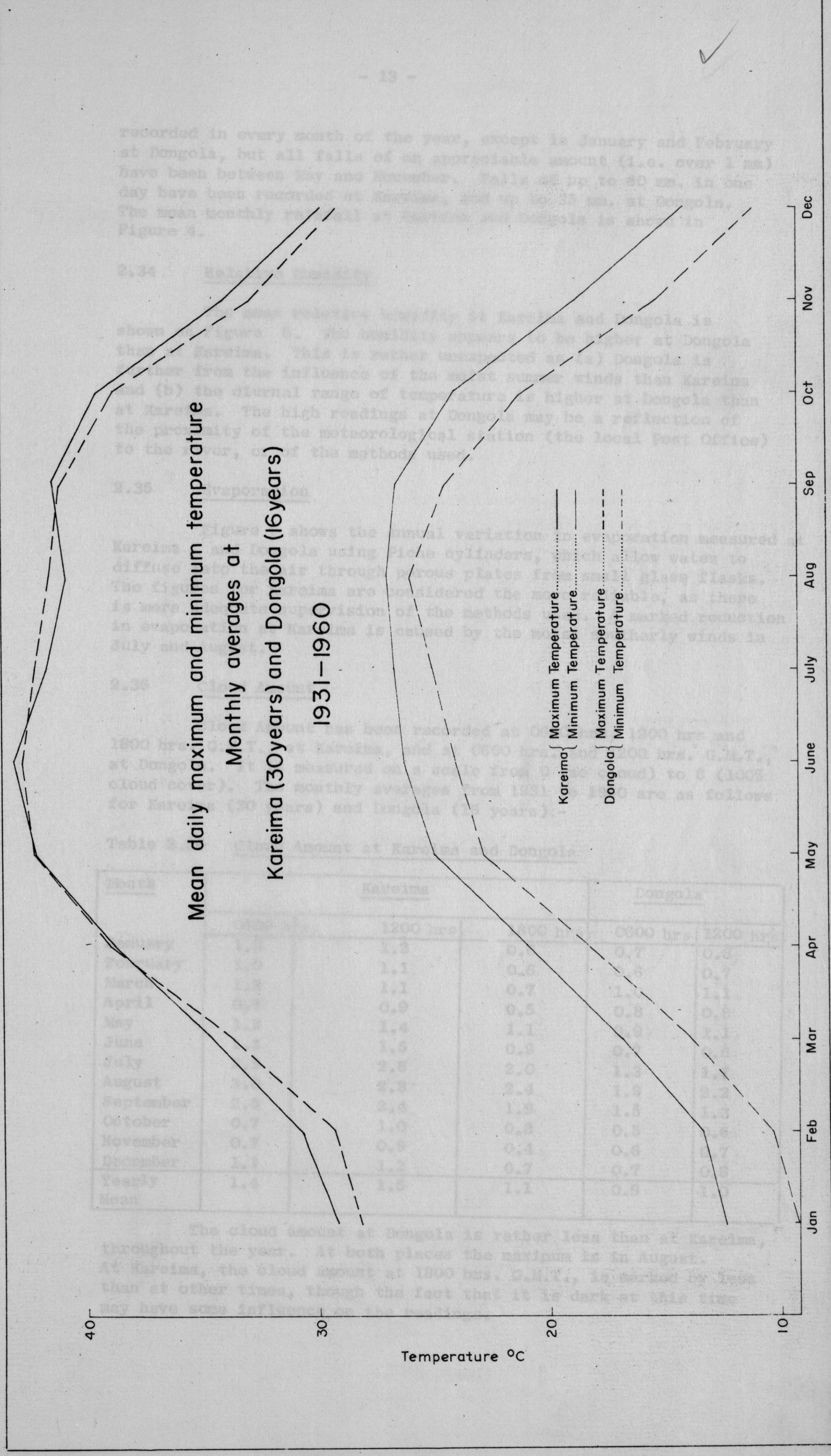
2.32 Temperature

The mean maximum and minimum temperatures at Kareima and Dongola are shown on Figure 3. The highest daily temperatures occur in June. At Kareima the temperatures rise again slightly in September, indicating a slight influence of the moist southerly summer winds. This effect is not felt at Dongola. The lowest temperatures occur in January. The annual range of temperatures is about the same, though the diurnal range is slightly lower at Kareima.

2.33 Rainfall

Rainfall is extremely low and variable in this area. The annual average at Kareima is 38 mm., and at Dongola it is 25 mm. Most of the rain falls in July and August. Traces have been

Figure 3



Mean daily maximum and minimum temperature
Monthly averages at
Kareima (30years) and Dongola (16years)
1931–1960
Kareima { Maximum Temperature
Minimum Temperature
Dongola { Maximum Temperature
Minimum Temperature
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
40
30
20
10
Temperature °C

recorded in every month of the year, except in January and February at Dongola, but all falls of an appreciable amount (i.e. over 1 mm) have been between May and November. Falls of up to 60 mm. in one day have been recorded at Kareima, and up to 35 mm. at Dongola. The mean monthly rainfall at Kareima and Dongola is shown in Figure 4.

2.34 Relative Humidity

The mean relative humidity at Kareima and Dongola is shown on Figure 5. The humidity appears to be higher at Dongola than at Kareima. This is rather unexpected as (a) Dongola is further from the influence of the moist summer winds than Kareima and (b) the diurnal range of temperature is higher at Dongola than at Kareima. The high readings at Dongola may be a reflection of the proximity of the meteorological station (the local Post Office) to the river, or of the methods used.

2.35 Evaporation

Figure 6 shows the annual variation in evaporation measured at Kareima and Dongola using Piche cylinders, which allow water to diffuse into the air through porous plates from small glass flasks. The figures for Kareima are considered the more reliable, as there is more adequate supervision of the methods used. A marked reduction in evaporation at Kareima is caused by the moist southerly winds in July and August.

2.36 Cloud Amount

Cloud Amount has been recorded at 0600 hrs, 1200 hrs and 1800 hrs. G.M.T., at Kareima, and at 0600 hrs. and 1200 hrs. G.M.T., at Dongola. It is measured on a scale from 0 (no cloud) to 8 (100% cloud cover). The monthly averages from 1931 to 1960 are as follows for Kareima (30 years) and Dongola (16 years):-

Table 2.36 Cloud Amount at Kareima and Dongola

Month	Kareima			Dongola	
	0600 hrs.	1200 hrs	1800 hrs	0600 hrs	1200 hrs
January	1.0	1.2	0.6	0.7	0.8
February	1.0	1.1	0.6	0.6	0.7
March	1.2	1.1	0.7	1.0	1.1
April	0.9	0.9	0.5	0.8	0.8
May	1.2	1.4	1.1	0.9	1.1
June	1.3	1.5	0.9	0.7	0.6
July	2.3	2.6	2.0	1.3	1.7
August	3.0	2.8	2.4	1.9	2.2
September	2.5	2.4	1.9	1.5	1.3
October	0.7	1.0	0.8	0.5	0.6
November	0.7	0.9	0.4	0.6	0.7
December	1.1	1.2	0.7	0.7	0.8
Yearly Mean	1.4	1.5	1.1	0.9	1.0

The cloud amount at Dongola is rather less than at Kareima, throughout the year. At both places the maximum is in August. At Kareima, the cloud amount at 1800 hrs. G.M.T., is marked by less than at other times, though the fact that it is dark at this time may have some influence on the readings.

Figure 4

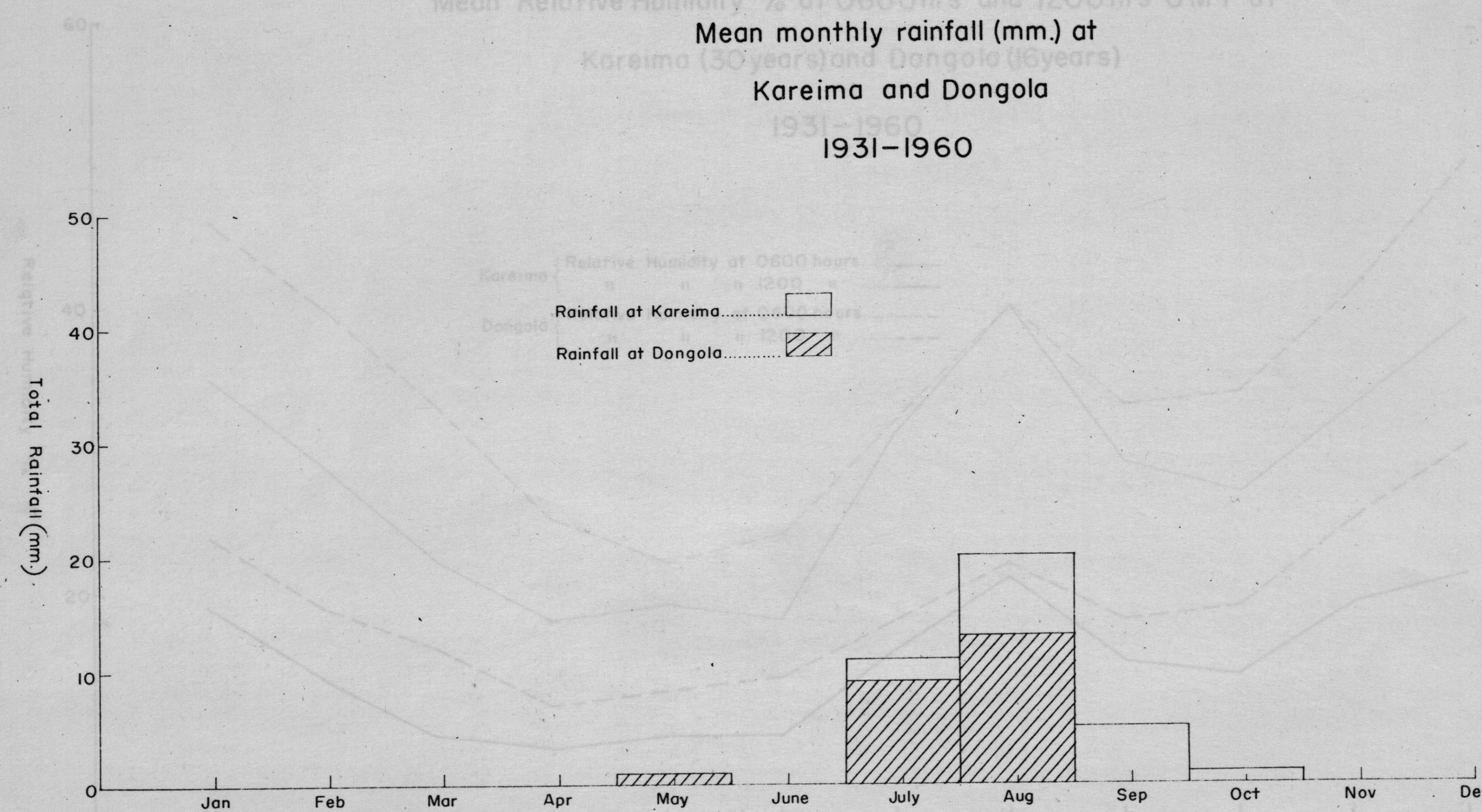

Mean monthly rainfall (mm.) at
Kareima and Dongola
1931-1960
Rainfall at Kareima............
Rainfall at Dongola...........
50
40
30
20
10
0
Total Rainfall (mm.)
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec

Figure 5

Mean Relative Humidity % at 0600hrs and 1200hrs GMT at Kareima (30years) and Dongola (16years) 1931–1960

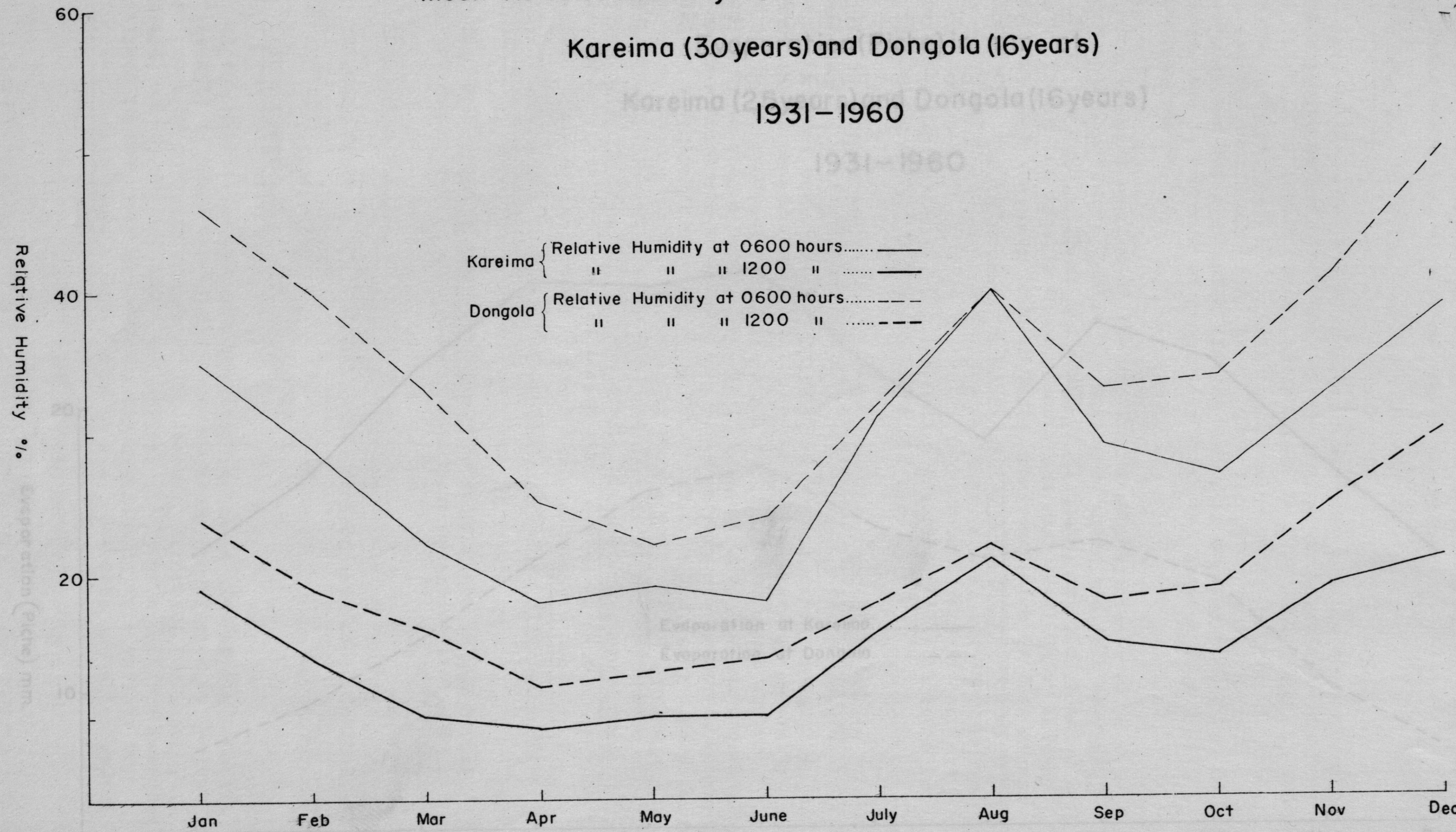
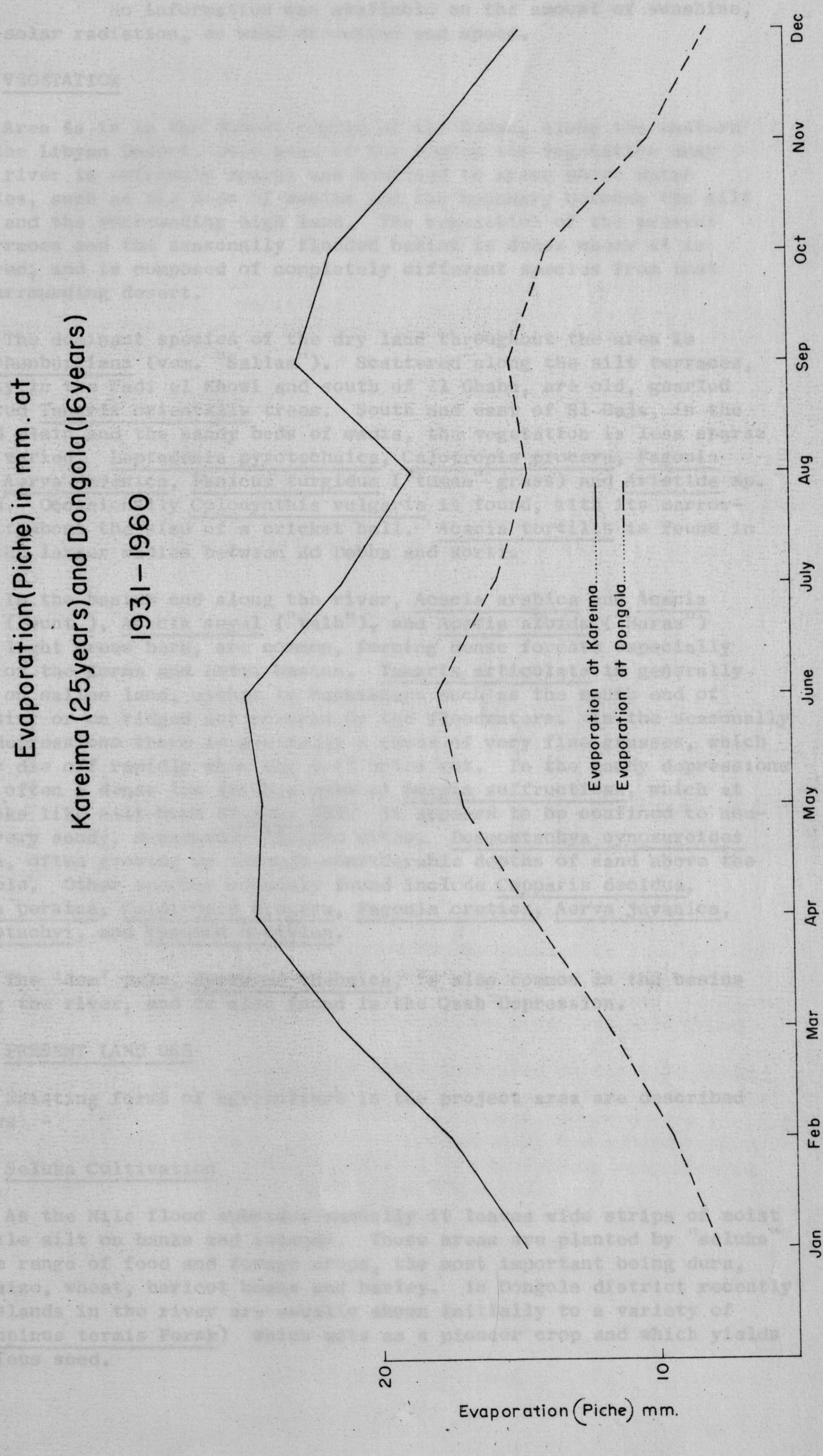


Figure 6



Evaporation (Piche) in mm. at
Kareima (25 years) and Dongola (16 years)
1931–1960
Evaporation at Kareima
Evaporation at Dongola
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
20
10
Evaporation (Piche) mm.

2.37 Other Information

No information was available on the amount of sunshine, solar radiation, or wind direction and speed.

2.4 VEGETATION

Area 4a is in the Desert region of the Sudan, along the eastern edge of the Libyan Desert. Over most of the region the vegetation away from the river is extremely sparse and confined to areas where water accumulates, such as the beds of wadies and the boundary between the silt terraces and the surrounding high land. The vegetation of the present river terraces and the seasonally flooded basins is dense where it is not cleared, and is composed of completely different species from that of the surrounding desert.

The dominant species of the dry land throughout the area is Acacia erhenbergiana (vem. "Sallam"). Scattered along the silt terraces, especially in the Wadi el Khowi and south of El Ghaba, are old, gnarled and stunted Tamarix orientalis trees. South and east of El Baja, in the soft sand plain and the sandy beds of wadis, the vegetation is less sparse and more varied. Leptadenia pyrotechnica, Calotropis procera, Fagonia cretica, Aerva javanica, Panicum turgidum ("tumam" grass) and Aristida sp. are found. Occasionally Colocynthis vulgaris is found, with its marrow-like fruit about the size of a cricket ball. Acacia tortilis is found in some of the larger wadies between Ed Debba and Korti.

In the basins and along the river, Acacia arabica and Acacia nilotica ("sunt"), Acacia seyal ("talh"), and Acacia albida ("Haraz") with its light green bark, are common, forming dense forests especially in parts of the Kerma and Letti basins. Tamarix articulata is generally dominant on saline land, either in backwaters such as the south end of Kerma basin, or on ridges not covered by the floodwaters. In the seasonally flooded depressions there is generally a cover of very fine grasses, which generally die off rapidly when the soil dries out. In the sandy depressions there is often a dense low shrub growth of Bergia suffructiosa, which at first looks like salt-bush (Suaeda sp). It appears to be confined to non-saline, very sandy, seasonally flooded sites. Desmostachya cynosuroides is common, often growing up through considerable depths of sand above the water table. Other species commonly found include Capparis decidua, Salvadora persica, Calotropis procera, Fagonia cretica, Aerva javanica, Cotula kotschyi, and Cynodon doctylon.

The 'dom' palm, Hyphaene thebaica, is also common in the basins and along the river, and is also found in the Qaab Depression.

2.5 PRESENT LAND USE

Existing forms of agriculture in the project area are described as follows: -

i) Seluka Cultivation

As the Nile flood subsides annually it leaves wide strips of moist and fertile silt on banks and islands. These areas are planted by "seluka" to a wide range of food and forage crops, the most important being dura, dukhn, maize, wheat, haricot beans and barley. In Dongola district recently formed islands in the river are usually shown initially to a variety of lupin (Lupinus termis Forsk) which acts as a pioneer crop and which yields a nutritious seed.

The lands cultivated by "seluka" form a large aggregate area and make a sizeable contribution to the economy of the province. Besides food crops these lands produce much forage to feed the oxen that drive the water wheels (saqias) for lift irrigation.

ii) Saqia Cultivation

Lands close to the river are irrigated by the "saghiya" or Persian water wheel which can raise water to heights of 3 to 8 metres. The area which a saqia can irrigate varies considerably with the lift. At high Nile with a lift of about 2 metres, about 4 to 5 feddans can be cropped; during the winter about 2½ feddans, and at low river when the weather is hottest and crop requirements therefore greatest, about 1½ feddans.

In Dongola and Merowe Districts the date crop is most important to the "saqia" farmers. Wheat and dura are grown for home consumption, and fodder crops for the oxen, but the cultivators' cash income is derived chiefly from the sale of dates.

iii) Private Pump Schemes

The private pump schemes are a more recent development than the Government schemes mentioned below. Only a small number of schemes were in operation before the Second World War but the number has been increasing continually. The total number of schemes in Northern Province which have Perennial Licences and are therefore using stored water is given in Table 2.51.

TABLE 2.51 Pump Schemes in Northern Province with Perennial Licences

Year	1937	1944	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
No. of Schemes	77	191	402	454	533	579	646	693	775	808	892	976

These figures give a good indication of the rapid growth of private schemes in the Province as a whole.

Although in many cases the schemes owners themselves farm part of the land, most of the area irrigated is farmed by private tenants who contribute half the crops produced in return for water supplied. Wheat is the main crop, with considerable areas of Egyptian beans and peas grown.

In 1962 there were 411 private pumps installed on the Nile banks in the Dongola to Merowe reach. This figure is actually the total for the reach of river between the Third and Fourth Cataracts and so covers a short length upstream the limit of the area covered by our reconnaissance. The gross area licenced for private pumps is 77,623 feddans according to Ministry of Agriculture 1962 records, see Table 2.52.

Table 2.52 Nile Valley between Third and Fourth Cataracts, Private Pumps Licenced, Gross Area in Feddans. (from Ministry of Agriculture Records)

District	Total Feddans	Location of Area			Type of Licence		
		Left Bank	Righ Bank	Islands	Perennial	Restricted	Flood
Dongola	51,374	29,845	12,775	8,754	7,921	600	42,853
Merowe	26,249	15,821	8,401	2,027	7,892	130	18,227
Total	77,623	45,666	21,176	10,781	15,813	730	61,080

All pumps in the Sudan, which take water from the Nile or its tributaries, are required to be licenced under the Nile Pumps Control (General) Regulations of 1951. Three types of licence are issued: - Perennial, Restricted and Flood. The Perennial Licence allows pumping throughout the year, the Flood Licence during the flood season only which is from 16th July to 31st December. The validity of the Restricted Licence varies according to district and location on the river system. For the reach of the Nile covered by our Reconnaissance, pumping is allowed;

Dongola District	1st July to 30th April
Merowe District	1st June to 31st March

About half the schemes licenced have a gross area less than 50 feddans; 75 per cent of the schemes do not exceed 200 feddans. Analysis of the areas of schemes licenced is summarized in Table 2.53 below: -

Table 2.53 Licenced Private Pumps - Number of Schemes and Areas

Area of Scheme in Feddans		Number of Schemes
From	To	
0	0	200
51	100	75
101	200	34
201	300	15
301	400	16
401	500	18
501	1000	40
1001	2000	12
2001	3000	1
Total Schemes:		411

The areas shown in Table 2.52 are the licenced gross areas which the scheme owners are allowed to develop for irrigation by pumps. In fact the existing gross area of land irrigated by private pumps is generally less than the area permitted by licence. A study of the mosaics made from the recent air photography of the area together with the 1/100,000 scale map sheets where no mosaic cover was available has enabled us to estimate the actual gross area of irrigated land in use. The estimated areas are given in Table 2.54 and are subdivided by District, River Bank or Island.

Table 2.54 Nile Valley between Third and Fourth Cataracts.
Existing Irrigation - Gross Area of Private Pumps and Saghias (from maps and mosaics)

District	Location of Area			
	Total Area (Feddans)	Left Bank (Feddans)	Right Bank (Feddans)	Islands Feddans
Dongola	64,980	28,230	10,500	26,250
Merowe	19,600	7,950	10,550	1,100
Total	84,580	36,180	21,050	27,350

The figures shown in this table include areas irrigated by saqias from the Nile. It is not possible to distinguish between areas indicated by private pumps or saqias. Although there are still a great number of saqias in the Dongola to Merowe reach, possibly 3000 to 4000, the area of cultivation which can be watered probably ranges from about 3 to 5 feddans, these figures corresponding to low or high Nile. Thus the total area irrigated by saqias may be of the order of 14,000 feddans and by private pumps about 70,000 feddans.

iv) Government Pump Schemes

There are five pump schemes administered by the Government in the Dongola to Merowe reach of the river. These schemes range in size from 2,000 to 4,500 feddans and are sited in basin land or on silt terraces adjacent to the river. The pumping lift does not exceed 10 metres at low river level and in generally less than 5 metres at high river during the flood.

Three of the schemes, Nuri, Gureir and Ghaba, were built during the First World War, Kulud in 1927. Bergeig, which is the largest scheme was built during and after the Second World War, between 1943 and 1946.

The schemes were primarily intended to increase the local production of food stuffs so as to help make the country self-supporting during war-time. The crops grown include wheat, dura, Egyptian, beans, peas, lubia, sesame, berseem, vegetable and fruits.

The location of each scheme is shown on the land suitability and engeneering reconnaissance mapsheets in the Album and also on Figure 7. The approximate gross areas included in each scheme are given in Table 2.55 below: -

Table 2.55 Government Pump Schemes

District	Scheme	Gross area in Feddans		
		Govt. land	Private land	Total
Merowe	Nuri	3408	583	3991
"	Gureir	468	1514	1982
"	Kulud	700	2300	3000
"	Ghaba	1033	1235	2268
Dongola	Bergeig	4500	-	4500

The Government land is divided into tenancies of 10 feddans each, the cost of administering and operating the scheme being secured by charging water rates on the various crops grown. At Bergeig typical water rates charged are given below

	L.S.	
Wheat	6/300	per feddan
Egyptian beans	4/890	" "
Dura	4/890	" "
Berseem	15/-	" "
Lubia	3/240	" "
Date palm bearing	0/040	each
Homestead Garden	6/300	for garden

The Nuri scheme has a large area under horticultural crops - dates, citrus, mango, guava etc. There is here an excellent horticultural station which propogates improved varieties and grafts for distribution to farmers of the Northern Province.

The other Government pump schemes produce mainly food and forage crops:- wheat, dura, Egyptian beans, peas, lubia, sesame, berseem, vegetables, etc. In these schemes fruit trees are grown largely to supply the farmer's own requirements.

v) Basin Irrigation

In the Sudan the riverain lands is not subject to annual flooding as in Egypt and conditions favourable to basin irrigation exist only where chance depressions are found in the old flood plain. The river rises about 7 metres at the peak of the flood and, at this stage, the flood water is led into the basins through canals excavated for the purpose. The area irrigated each year depends on the height and duration of the flood and varies within wide limits. There are five such basins in the Dongola and Merowe Districts:-

Basin	Approximate Area (Feddans)
Kerma	70,000
Letti	9,300
Affat	800
Argi	500
Bakri	1,500
Total	82,100

Letti and Kerma basins have a system of demarcation into 100 feddan plots which are held by tenants on lease from the government. For administrative purposes each group of 64 plots is included in a hod measuring one square mile, and a group of hods (from 4 to 22) forms a gism . There were originally 9 gisms in Kerma basin and 4 gisms in Letti basin.

The system of irrigation is simple in theory and applies generally to most of the basins. Each basin has its feeder canal, one or more drains or escapes to release the water, cross banks at the lower end, and guide banks to train the flood. The larger basins, such as Kerma have cross banks which divide the basin land into 'Gisms'. On arrival of the flood at a suitable level the feeder canal is opened and the basin allowed to fill to good irrigation level (Tammam Rai'). This level is generally considered to be that which covers the ground to a depth of from 70 centimetre to 1 metre. After holding 'Tammam Rai' for 30 days the water is released as the river level falls, by opening the drain. Where the basin is divided into hods, 'Tammam Rai' is held first in the upper section then released after 15 to 20 days to the lower hod, raising its level.

In practice the success of basin irrigation depends on the Nile flood. In years of low floods the areas irrigated are negligible, whereas with a high flood the areas are quite extensive.

The extent of this variation in area flooded is given in Table 2.56 below and this clearly indicates the unreliability of this method of irrigation.

Table 2.56

Basin Areas Flooded (Dongola to Merowe Reach)

Basin	Area flooded in Feddans													
	MEAN 1944/55	HIGH 1946	LOW 1941	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Kerma	27,550	52,410	4,070	19,490	25,400	32,800	23,500	21,000	17,200	27,650	30,000	7.000	37,700	31,700
Letti	4,880	9,300	430	4,700	4,800	6,490	5,600	4,400	5,380	6,760	6,635	2,700	7,500	5,000
Affat	300	800	-	200)		(800	350	150	200	1,500	650	-	1,200	150
Argi	200	500	-	100)	1,300	(500	150	30	150	400	420	-	475	150
Bakri	300	1,500	-	50)		(1,200	400	60	130	1,500	1,050	80	1,000	200
Total	33,230	65,610	4,500	24,430	31,500	41,790	30,000	25,640	23,060	37,810	38,755	9,780	47,875	37,200

The area cropped in Kerma and Letti basins is less than 10% of the area flooded; the main crops are beans, lupins, wheat, chickpeas and barley. The rest of the flooded area is forest or grazing land. The principal tree species are sunt (Acacia nilotica), talh (Acacia seyal) and two species of tamarix called terfa (Tamarix nilotica) and itl (Tamarix articulata). The principal grazing plant in Kerma basin is kiteih (Trigonella laciniata Linn), whilst in Letti basin grazing is provided by atawil and saeda. A feature of the Kerma basin is the large number of saqias which lift water from Mataras (shallow wells) to irrigate small plots of cropped and garden land especially on the eastern side of the basin. The ground-water is replenished each year by the flood water whilst the basin provides forage for the working oxen and timber for the manufacture of the mataras. There are also a few mataras in the southern end of Letti basin.

When the basins were first opened in the years before the first world war it was with the intention of producing large crops of agricultural produce on the lines of the Egyptian basins. The results have been disappointing because of difficulties associated with unsuitable soils, uneven terrain, poor water control and insufficient drainage, but in effect from 1928 they have been operated, on a care and maintenance basis only.

The basins are administered by the Province authorities whilst the Irrigation Department is responsible for the operation and maintenance of the flood irrigation system. Since 1914 the tendency has been to convert basins to pump irrigation, as at Bergeig and Argo; it would seem that this trend will continue where the lands are shown to be capable of justifying further expenditure on irrigation and drainage structures.

vi) Experimental Tube wells in Wadi el Khowi Area

The June 1954 report of the Ministry of Irrigation and Hydro-Electric Power on Kerma Basin contained the conclusion that development of the Kerma Basin area would be more successful and economical if tubewell irrigation was introduced rather than by pumping irrigation water from the river. The Report recommended that six experimental borings should be made at Bergeig, Kinhar, Hamadnarti, Seleim and two more on an east-west line at points 5 and 10 kilometres east of Hamadnarti.

Subsequently the drilling of six boreholes was undertaken by the Ministry of Work's Drilling Division under the supervision of the Ministry of Irrigation. This was completed during the 1955/56 period. With the exception of one borehole, T.W.12, which is sited about 3 kilometres south of Seleim Canal and on the western edge of Kerma Basin, the others were all sited in the Wadi el Khowi area. The sites chosen, indicated on Engineering Reconnaissance Sheets 23 and 24S, are in the desert at points from 2 to 9 kilometres east of Kerma Basin.

In the 1955/56 Ministry of Irrigation Annual Report it is stated that each tubewell is intended to irrigate 150 feddans. The average yield expected from each well was given as 100,000 gallons per hour. It was also stated that one of the wells, when tested with two 4 inch pumps, yielded 42,000 gals. per hour. The inference given was that this was probably the maximum output of the pumps used and that a larger pump would be needed to determine the true yield. We have not seen any other reference to the yields obtained from these wells under test.

In the 1957/58 Ministry of Irrigation Annual Report it was stated that four out of the six schemes had been completed, including buildings, and that pumping had started. A lot of difficulties were reported including the problem of wind blown sand filling the channels and an attempt was made to provide windbreaks to overcome this hazard. The following year it was reported that the six schemes had been completed but that the pumps could not be run at design speed for technical reasons and this caused a reduction in the cultivable area.

There is no reference to these experimental wells in more recent Ministry of Irrigation Annual Reports and no evidence that any cultivation has in fact been successfully established at any of the sites.

In January 1963 all the sites were found to be abandoned. Tubewell No.3, close to the north end of Kerma Basin, was stated to have been in use until October, 1962. There was evidence of a very small area of about one feddan having been watered.

The reconnaissance soil survey has shown that all the tubewells are located in areas of saline-alkali soils. It would be useful to study further the records of this project to find out the reasons for its lack of success and to ascertain if there are reasonable prospects of using groundwater to increase the irrigated area in Dongola District.

CHAPTER 3

SOIL SURVEY METHODS

3.1 AERIAL PHOTO INTERPRETATION

On a reconnaissance survey, in order to be able to base a reasonably accurate soil map on the limited number of sites that can be investigated, it is essential to correlate as completely as possible the information obtained from field soil descriptions with the various features that can be seen on the aerial photographs.

The method used on this survey was to site the bores or pits, within the framework of a 10.5 square kilometre grid, on as wide a variety of visible surface patterns as possible, and to attempt to correlate the data obtained with these patterns. As only a limited number of sites was sampled, this correlation has been based on the soil characteristics observed in the field.

Final mapping was carried out with the aid of stereoscopic examination. This was found useful in defining the edges of the alluvial terraces, where there is normally a sharp change in relief.

On the alluvium, areas of sand dunes are clearly visible as white patches, often coalescing in a diffuse 'herringbone' pattern, on the grey silt surface. These areas, and high gullied land, were eliminated by photo-interpretation without any further investigations.

On the terraces themselves, it was not found possible to separate soil types accurately at any level by photo-interpretation. It was found that whereas the soils of the basins, where they are flooded annually and appear dark on the prints, are normally non-saline and low in exchangeable sodium, those which are not flooded and are very sparsely vegetated are generally saline and high in exchangeable sodium. It was not possible to separate sandy soils (other than loose sand dunes) from silts or clays by photo-interpretation, as these all appear light coloured except where they are flooded.

3.2 SOIL SURVEY PROCEDURE

Aerial Photographs of Area 4a (excluding the area between Kulud and Merowe) were flown by the Sudan Survey Department in 1961-62 at a scale of 1:25,000, and were compiled into mosaics at a scale of 1:50,000 by Fairey Air Surveys Ltd., in 1963.

As the mosaics were not available until the end of the survey, the Sudan Survey 1:100,000 maps dated 1952, overprinted with the cross-sections of the Survey of Irrigable Areas, were used as field base maps.

The reconnaissance survey was commenced in January 1963, and completed in April 1963. In order to ensure the required intensity of investigation of one auger hole or pit per 2,500 feddans, a 10.5 sq.-kilometre grid was marked out on the base maps, one site to be investigated within each square of the grid. This grid was transferred to the aerial photographs as the survey progressed and the photographs could be located accurately with reference to the somewhat limited information on the base maps. The sites were then selected within the grid to cover as wide a range as possible of the landforms that could be differentiated on the photographs. The following investigations were carried out.

1. All obviously unsuitable areas such as gullied, hilly country or areas of sand dunes were eliminated by photo-interpretation.

2. In the remaining areas, bores were augered to a depth of 2 metres, and the profiles described. These were not sampled.

3. Pits were dug to a depth of 2 metres at selected sites, representative of the different soil types found in the area. These were sampled at the rate of one sample per horizon described (normally two samples were taken from any horizon over 50 cm. thick).

A total of 203 bores and 35 pits was investigated, and 198 samples were taken for the following laboratory analyses: -

Mechanical analysis (international fractions).
Incorporated Carbonate.
pH on soil paste and 1:5 suspension.
Salinity test (E.C. on saturation extract).
Soluble sodium in saturation extract.
Exchangeable sodium content.

No field permeability studies were carried out during this survey.

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 250 ml. water and 11 ml. of 10 per cent sodium hexamotaphosphate solution overnight; next morning dispersed in electric stirrer for 10 minutes, transferred to 1 litre measuring cylinder, shaken 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.

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 Solubridge on saturation extract or soil paste as required.

3.34 Carbonate as Incorporated Calcium Carbonate

Gasiometrical determination in Collins calcimeter (ref. Collins S. H. 1906, J.Soc. Chem. Ind. 25 518). The volume of CO_2 generated from a known weight of the soil is reduced to standard conditions, and calculated as if the total volume were derived from calcium carbonate only.

3.35 Soluble Sodium in Saturation Extract

Appropriately diluted saturation extract is analysed on flamephotometer for Na.

3.36 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 times) by decantation. Then the soil is 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.

3.4 MAP COMPILATION

3.41 The Base Maps were compiled from the Sudan Survey 1:100,000 maps dated 1952, overprinted with the cross-sections of the survey of irrigable areas, sheets 16 to 25, covering the Nile from the 4th Cataract to the 3rd Cataract.

The base maps were produced by Sir M.MacDonald and Partners at a scale of 1:100,000.

The investigated sites were marked on the base maps as follows: -

2-metre bores.	Not sampled	O
2-metre pits.	Sampled	▲

The sites were numbered from 157 to 394, the numbers being preceded by the letters DR, to avoid confusion with soil descriptions from other surveys.

3.42 The Soil Map

The classification of the individual sites has not been marked on the soil maps. The soil boundaries were determined stereoscopically on the aerial photographs, and then transferred freehand onto the map. The soil classification used is explained fully in Chapter 4.

3.43 The Land Suitability Map

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 with which this survey is concerned are the alluvial terraces along the Nile. The bulk of the material of which they are formed is derived from the Blue Nile, with some fine material from the White Nile and sand from the Atbara. Contributions from local sources consist of wind-blown sand as superficial deposits or layers interbedded with alluvium. Gravel occurs on the surface of some older terraces, which are generally shallow over gravels and sandstones. The surface gravel may have moved upwards, at the same time as the soil was laid down, by a churning process caused by alternate wetting and drying.

Textures vary from coarse sand to clay. The coarse sands are of local origin. The distribution of textures is complex, as is usual in an alluvial plain. In the Active Flood Plain, it appears that the textures are finest at the surface, becoming coarser with depth. In the Kerma Basin, it appears that the broad, seasonally flooded depressions are sandy, while finer textures are found on the ridges. This may be the effect of deflation on a former level surface with a textural gradation similar to that found in the Active Flood Plain. Generally there is a layer of recently deposited clay over the sand in the depressions. This is thickest near the Seleim Canal.

Elsewhere it was not possible to make any observations about the distribution of soil textures on the basis of the information obtained on this survey.

The colours of the alluvial soils are generally brown or greyish brown. The clays are generally very dark grey or grey brown, while the sands are lighter coloured. The soils of local origin are generally yellowish brown. The moist colour is generally darker than the dry colour, though the colour of some clays becomes lighter on moistening. Some rust mottling and manganese stains are found in the subsoil of the clays.

The structure and consistency of the soil appears to vary according to its texture and location,eg.soils in or near the basins are affected by the annual floods. In the basins, the silts and clays of the ridge, which are not flooded for long, are somewhat poorly structured, with a firm finely cracked surface. In places the surface has developed into a solonchak 'puff'. In the depressions, the clay surface soil is very widely cracked. The cracks become narrower with depth and increasing moisture content. Where there is a shallow deposit of clay on sand, the clay may be cracked into separate blocks resting on the sand (e.g. DR207). When this happens, the sand dries out rapidly to a considerable depth, and any plants that have germinated after the floods receded die out through lack of moisture. It would seem that a soil more beneficial to crop production on the residual moisture from the Nile floods could be obtained by mixing the surface soil with at least an equal amount of the underlying sand.

Away from the basins, the structure of the silts and clays follows a fairly constant pattern. The surface soil is very soft, generally beneath a thin sandy crust, to a depth of at least ten centimetres, with a fine crumb or weak platy structure. Generally the remains of an old prismatic structure is visible, with wide polygonal cracks infilled with sandy material. With depth, the soil becomes harder, and the structure coarser. Blocky or prismatic structures appear. In some clays, very pronounced blocky structures are found, with slickensides and inclined structures in the subsoil, which suggests that in the past these soils may have been self-mulching (Worrall, 1961).

It was found that the surface horizons of the clays were moderately or rapidly water absorbent, the structure breaking down immediately. In the lower horizons, some clays were found to be very rapidly water absorbent, the blocky aggregates swelling and breaking up rapidly into a fine friable tilth, while others were slowly water absorbent, the surfaces of the aggregates becoming saturated and smeared while the centres remained hard and dry. This difference in ability to absorb water does not appear to be associated with any characteristics in the chemical analyses of the samples.

Secondary accumulations of salts are common throughout the area calcium carbonate is most common, and is found in almost all profiles except the lower parts of the basins. Hard nodular concretions are common on the surface of the older terraces, and in places remains of caliche layers have been exposed by deflation. In the profile, fine whitish "mycelia" of calcium carbonate are found in old pores and root channels in most profiles. In the sandy soils of the older terraces, highly calcareous bands of silt or clay are found. In the clays, solid bands of caliche are found in old cracks.

Gypsum is found in the clays of the older terraces. It is found in various crystal forms in the subsoil. Commonly it is found as rod-shaped crystals lining old cracks. Sometimes these crystals are white and opaque, and appear to have been dehydrated since their formation. Occasionally very long fine hairlike gypsum crystals are found in the subsoil.

Sodium salts are not commonly found as visible accumulations. In some parts of the basins, particularly Kerma basin, the soil surface is developed into a saline 'puff', with a salt crust and salt crystals immediately below the surface. Sodium chloride was found in a few clay profiles in the Wadi el Khowi (e.g. DR252) as shiny stains on pedon faces in the subsoil.

4.2 SOIL CLASSIFICATION SYSTEM

The soils of the project area have been classified according to the specifications of the U.S. Department of Agriculture (1960), the Seventh Approximation. See Table 4.2 and the soil maps. The soil orders, suborders, great groups and subgroups are defined as follows: -

Entisols are soils either without natural genetic horizons or with only the beginnings of horizons. The horizons present are so weakly expressed that they fail ro 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 in age 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 centimetre 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.

Orthustentic Psammustents have a layer with textures as fine or finer than very fine sand within 75 centimetre and have more than 5 per cent of the sand fraction that is soluble in water or contains iron or aluminium in the clay lattice. 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. In the Northern Province of the Sudan they are found on the old river terraces where the coarse textured alluvium has been partially covered by desert sand. These soils are an integrade towards the great group of Orthustents.

Lithic Psammustents have hard rock (usually ferruginous sandstones) at shallow depth in the profile. This soil pattern is found on the desert upland at higher levels than the old silt terraces of the Nile valley. Desert sands subject to wind movement partially cover the Nubian sandstones and Tertiary basalts. There are frequent rock outcrops. Loose stones and gravel are often found strewn on the surfaces.

Orthustents include dry, loamy soils with textures finer than loamy fine sand extending to 50 centimetre 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 lime, gypsum or salts may be seen as efflorescences or mycelin. 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 undusturbed, consists of annuals and zerophytic perennials.

Orthic Orthustents are loamy soils extending to 30 centimetre 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. 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 have more than 40 per cent expanding lattice clay but lack the cracks, slickensides, gilgai or structure diagnostic for Vertisols. In other parts of the world these soils are generally shallow over basic rock. In the project area, however, they consist of isolated mounds of wind blown material aggregated to fine sand.

Psammustentic Orthustents have a layer of sand or loamy sand in the upper 50 centimetre of the profile. They are found in the Kerma Basin where a layer of Nile silt overlies previously desert sand and on high lying old river terraces, now desert, where a layer of sand overlies terrace silts. These soils are an integrade towards the great group of Psammustents.

Calcorthidic Orthustents have a layer containing more than 15 per cent calcium carbonate within 50 centimetre 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 qualify as a cambic horizon.

Natrargidic Orthustents have 15 per cent or more exchangeable sodium in some part of the upper 50 centimetre. These soils are an intergrade towards the Natrargid great group of the Order of Aridisols; they do not, however, show indications of clay migration or the formation of an argillic horizon.

Natrargidic Vertic Orthustents have 15 per cent or more extractable sodium in some part of the upper 50 centimetre 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 an intergrade towards the Order of Vertisols and, as well, towards the Natrargid Great Group of the Order of Aridisols.

Lithic Orthustents have hard rock (usually ferruginous sandstones) at shallow depths in the profile. 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 called 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.

Orthids are the Aridisols that have an ochric epipedon and a cambic horizon, a duripan or an illuvial horizon of water soluble material (a calcic, gypsic or salic horizon). The Othids do not have an argillic, spodic, oxic or natric horizon.

Salorthids are the Orthids that have a salic horizon (E.C. greater than 50 millimhos/cm at 25°C) at a depth of less than 50 centimetre. They were previously called Solonchaks. They are frequently associated with zones of high water table. When dry at the surface they usually possess a salt crust. Vegetation is sparse and salt loving. Salts usually appear as an efflorescence on the walls of pits dug in damp soil as the soil dries out. Where salts have come to the surface by capillary rise, the soil just below the surface is very fluffy and there is a microrelief of 15 to 30 centimetres. These soils are usually found on flood plains, terraces, fans and deltas in arid regions.

TABLE 4.3

SOIL CLASSIFICATION CHART

U.S.D.A. 1960 SYSTEM

Area 4a

Order	Sub Order	Great Group	Sub Group
1. Entisol	1.3 Ustent	1.31 Psammustent	Orthic Psammustent Orthustentic Psammustent Lithic Psammustent
		1.32 Orthustent	Orthic Orthustent Vertic Orthustent Psammustentic Orthustent Calcorthidic Orthustent Natrargidic Orthustent Natrargidic Vertic Orthustent Lithic Orthustent
4. Aridisol	4.1 Orthid	4.14 Salorthid	

4.3 SOIL CLASSES

The soils described in Section 4.1 have been classified as follows (see Table 4.3): -

The soils of the alluvial terraces have been classified as Orthustents and Psammustents on the basis of the soil texture. The classification of Salorthids, and the division of the Orthustents into the Orthic and Natrargidic subgroups, are dependent on the chemical analyses of the samples. It appears from the profiles that have been analysed, that most of the Orthustent profiles of the older river terraces are Natrargidic, while those of the basins are Orthic. Salorthids appear to be relatively uncommon, and are found both in the basins and on the higher terraces.

Lithic Orthustents are found on some of the older alluvial terraces, where the Nile alluvium is shallow over rock outcrops. The surface of these soils is generally covered with gravel and stones. Lithic Psammustents are found on the dissected sandstone plateaus, where the surface is covered by a thin mantle of sand and gravel.

The sampled soil pits described in the Appendix cover all the soil types found except Orthic Psammustents, Lithic Psammustents, Lithic Orthustents and Calcorthidic Orthustents. No pits were dug in Orthic Psammustent profiles because (a) they are unsuitable for further investigation on the basis of texture, and chemical analyses would be superfluous, and (b) they tend to form conical depressions when excavated, making a proper examination of the profile difficult. The following is a typical Othic Psammustent profile, described from a hole excavated to a depth of 1 metre: -

Bore: DR266		
*Location:	360,000:150,000	Date: 14.3.63.
Topography:	Low ridge just west of a broad depression with some rock outcrops in it.	
Land Use:	Nil.	
Vegetation:	Nil.	
Surface:	Dry, firm, sandy with much fine gravel.	

Profile Description: -

0 - 100 cm.	Dry 2.5Y5-3, moist 2.5Y4-3. Sand. Dry, loose, structureless. River origin. Rapidly water absorbent. Some calcium carbonate, apparently in old root channels. Common mica.

No profiles were described on Lithic Psammustents, as all the soils of this type were eliminated by preliminary photo-interpretation. Some lithic Orthustent profiles were described, however, of which the following is an example: -

Bore:	DR286	
Location:	360,000:118,000	Date: 12.3.63.
Topography:	Flat, with some gravel ridges nearby.	
Land Use:	Nil.	
Vegetation:	Some fine grass (Aristida sp.) in a depression nearby.	

* See Appendix for explanation of Location System.

Surface:	Dry, firm with much loose sand and fine gravel.

Profile description: -

0 - 1 cm.	Dry 10YR6-4, moist 10YR5-4. Sand. Dry, loose, structureless. Rapidly water absorbent. No salts.
1 - 10 cm.	Dry 10YR5-4, moist 10YR4-3. Clay Loam. Dry, soft, weak medium platy with few cracks and many fine pores. No salts.
10 - 50 cm.	Dry 10YR4-2, moist 10YR3.5-2. Loam, Dry, hard, structureless with no cracks or pores. Moderately water absorbent. Much gravel. Few light grey calcium carbonate concretions.
50 - 80 cm.	Dry 10YR6-8, moist 10YR5-8. Sandstone (Loamy sand). Dry, hard rapidly water absorbent. Common white calcium carbonate streaks.

(Augering given up at this depth).

The following profile is a Calcorthidic Orthustent from a high, somewhat dissected terrace, probably of alluvial origin:-

Bore:	DR201
Location:	356,000:182,000 Date:22.2.63.
Topography:	Gently undulating gravelly terrace.
Land Use:	Nil.
Vegetation:	Widely scattered <u>Acacia erhenbergiana</u> bushes.
Surface:	Dry, firm, sandy, with much loose gravel.

Profile description: -

0 - 30 cm.	Dry 7.5YR5-4, moist 7.5YR4-4. Gravelly Clay Loam. Dry, slightly hard, weak medium subangular blocky with no pores and common cracks. Rapidly water absorbent. Many fine white Calcium Carbonate streaks. Soil effervesces strongly with Hydrochloric Acid.
30 - 50 cm.	Dry 10YR6-4, moist 10YR4-4. Gravelly Loam. Dry, slightly hard, structureless with no pores or cracks. Rapidly water absorbent. Many Calcium Carbonate streaks. Soil effervesces strongly with Hydrochloric Acid.
50 - 100 cm.	Dry 10YR7-3, moist 10YR5-4. Gravelly Loam. Dry, slightly hard, structureless. Rapidly water absorbent. Practically pure limestone.

Soil samples were collected and analysed as follows: -

Depth cm.	Soil Particles %			Incorporated Carbonate %	pH	
	Sand	Silt	Clay		Soil Paste	1:5 Soil Suspension
0- 30	65	17	18	3.80	8.20	8.52
50-100	67	18	15	19.14	8.03	8.85

Depth (Continued)	E.C. Sat.Extr.	Sol. Na. Meq. per litre	Exch. Na. Meq. per 100 gm. Soil
0- 30	1.0	0.3	1.10
50-100	3.0	1.2	3.15

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 topographic obstacle is encountered between 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 Area 4, started work in Khartoum on 11th December 1962. The initial period was spent in the collection and examination of maps and survey data prepared for the 1951/52 Northern Province Survey of Irrigable Areas.

Fieldwork in the area commenced on 5th January 1963 and continued until 17th April 1963. During this period the engineering reconnaissance was completed on both banks of the Nile for kilometres between Kareima and the Third Cataract.

5.2 MAPS AND SURVEY DATA AVAILABLE

The maps available consisted of a set of 1/100,000 scale sheets dated July 1952 and titled "Cross Sections of the Survey of Irrigable Areas Northern Province". The sheets are numbered from 16 to 25 inclusive and based on cadastral maps at 1/50,000 scale with additions from current 1/250,000 series and American air survey compilation. These sheets showed the cross section at 4 kilometres interval, established by the 1951/52 survey by the Sudan Survey Department, covering ground up to the 15 metre isopotamon.

In addition vertical airphotography at scale 1/25,000 and mosaics at scale 1/50,000 were available for most of the area studied. The extent of the map and photographic cover is shown on Figure 7.

Also available was a map entitled "Irrigable Areas Khartoum - Abu Hamed, Atbara River, Merowe, Kerma", numbered 1.A/158 at scale 1/1,000,000. This map showed the area recommended for irrigation development by the Soil Section of Ministry of Agriculture Research Division and was accompanied by a short report referenced SOIL/5.A.17 dated 2nd November 1954.

5.3 REFERENCE DATUM

The reference datum used for the sections established during the 1951/52 Survey of Irrigable Areas is the zero for the river gauge at Khartoum. The recently established value for the gauge zero, 363,00 metres above mean sea level at Alexandria, was used for the 1951/52 survey and is being used for our reconnaissance surveys throughout the project area north of Khartoum.

The method used by the Sudan Survey Department for establishing bench marks on individual cross sections has been to assume a uniform slope of the river between river gauges at Argo and Merowe the Mean low water level at Argo and Merowe having been computed from the Normal Ten Day Mean gauge readings.

5.4 ACCURACY OF SURVEY DATA

Differences of up to one metre are apparent in the normal minimum low water level computed for corresponding points on opposite banks of the river. The computed value for low water level varies up to a maximum of 1.0 metre above or below the assumed uniform slope between the gauge sites. In the majority of cases however the datum for cross sections is probably within 0.5 metre of the assumed uniform slope.

5.5 HYDROLOGY

The Main Nile is formed at Khartoum by the confluence of the Blue and White Niles. 320 kilometres further downstream the Main Nile is joined by the Atbara, this being the last tributary to join the Nile on its course to the sea. The section of the river downstream of the Atbara confluence conveys a larger volume of water than any other part of the Nile system, the mean annual discharge is 2720 cumecs.

Between Khartoum and Aswan, a distance of 1840 kilometres measured along the river, the six cataracts are the most significant features in the channel profile. Each cataract consists of a series of rapids extending over a distance of up to 20 or 30 kilometres.

The 340 kilometres of the river covered by our reconnaissance extends over most of the reach between the Third and Fourth Cataracts. The Third Cataract is 700 kilometres upstream of Aswan and the Fourth Cataract is 750 kilometres downstream of Khartoum.

The main river channel is generally between 750 and 1500 metres in width. A feature of the Nile in this reach is the large islands, of which Argo, Badein and Tangasi are the most prominent. Where these occur the river width between banks may be several kilometres. At low river extensive areas of sandbanks occur and the water section is reduced to one or more shallow channels. The position and extent of these sandbanks often changes very considerably during the period of high river.

River gauges are maintained at Argo, Seleim and Merowe. The seasonal variations of the river are summarised in Table 5.5.

Table 5.5 Seasonal Variation of the Main Nile at Argo and Merowe.

Gauge Site	Range in Metres		Duration of Period	
	Average	Maximum	High River	Low River
Argo	4.75	5.75	Aug.- Oct.	Nov.- July
Merowe	7.25	9.75	Aug.- Oct.	Nov.- July

The mean discharge ranges from a minimum of 600 cumecs to a maximum of 9,000 cumecs and the corresponding water surface slope varies from 8.1 centimetres/kilometre at low river to 9.0 centimetres per kilometres at high river.

A profile of the river valley is shown in Figure 8. The normal minimum and maximum water levels shown in this Figure are the lowest and the highest Ten Day Mean for the period 1912 to 1947 at Argo and Merowe gauges. The river is at its lowest in mid May. It rises steadily during June and July and reaches its peak early in September after which it drops quickly until the end of November when it approaches the low river condition.

5.6 SECTIONS SURVEYED

Field studies commenced with the location and checking positions of the concrete beacons marking the 10 and 15 metre isopotamon points on the Sudan Survey Department cross sections established in 1951/52. The sections are at approximately 4.0 kilometre intervals on both banks of the river throughout the project area except in places where there is no ground adjacent to the river below the 15 metre isopotamon.

Location of the beacons proved a straightforward task except in cases where the concrete posts had been destroyed or damaged. The 10 and 15 metre beacons were found intact for about 95 per cent of the section lines within the areas.

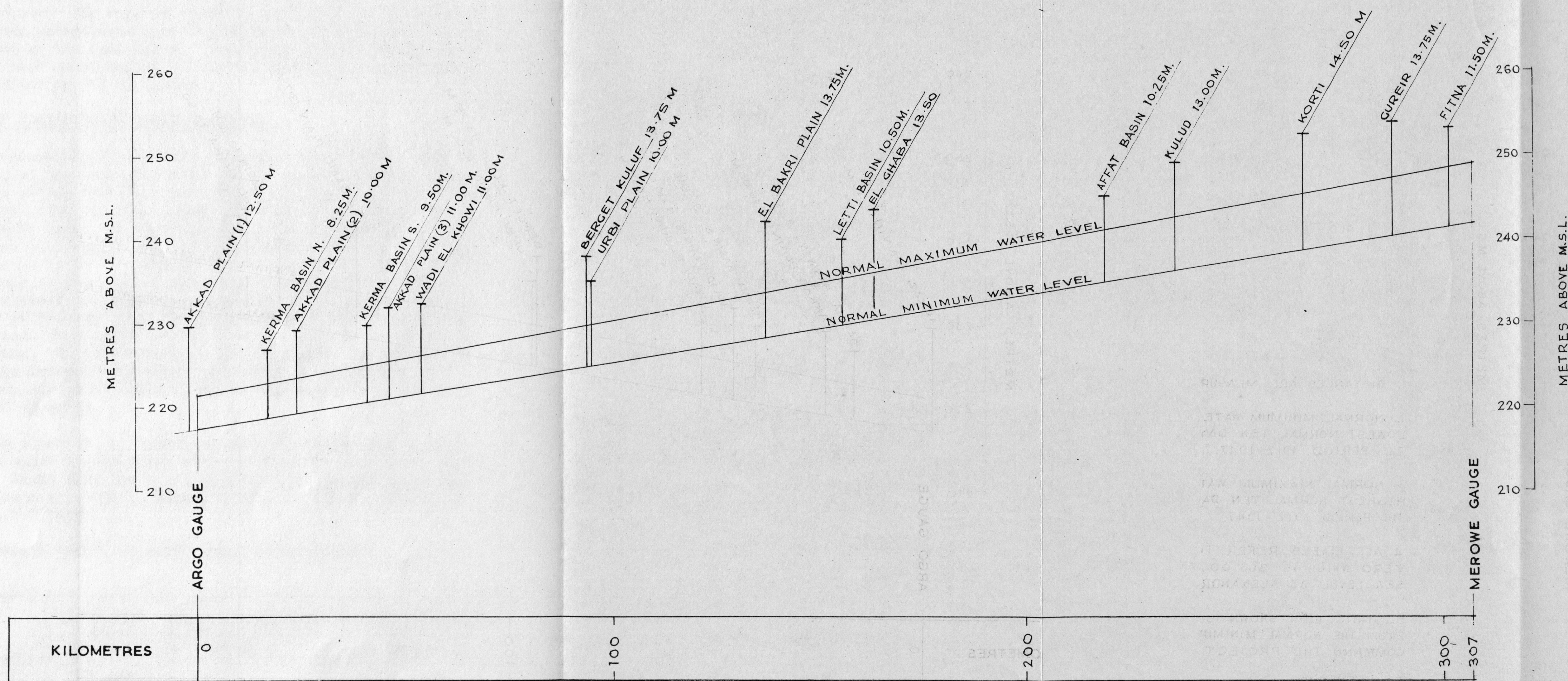
Differences were found in the beacon positions recorded on a number of cross sections when compared with their actual locations on the ground. In these cases the section location was corrected on the maps and the section extended along the true bearing. The Sudan Survey Department cross sections were extended from the 15 to the 20 metre isopotamon for all parts of the area when there appeared to be a possibility of irrigation development. In high rocky desert or sand dune areas where no irrigation development was possible, sections were not extended. In other areas where the 15 metre isopotamon was definitely beyond the limit of irrigable land a limited extension of 0.6 to 1.0 km. length was surveyed to indicate the topography.

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

Figure 8

RIVER NILE PROFILE ARGO - MEROWE

SHOWING STATIC LIFT FOR IRRIGABLE AREAS DEFINED



1. DISTANCES ARE MEASURED FROM ARGO GAUGE

2. NORMAL MINIMUM WATER LEVEL TAKEN AS LOWEST NORMAL TEN DAY GAUGE READING FOR THE PERIOD 1912 - 1947.

3. NORMAL MAXIMUM WATER LEVEL TAKEN AS HIGHEST NORMAL TEN DAY GAUGE READING FOR THE PERIOD 1912 - 1947

4. ALL LEVELS REFER TO KHARTOUM GAUGE ZERO WHICH IS 363.00 METRES ABOVE MEAN SEA LEVEL AT ALEXANDRIA.

5. STATIC LIFT SHOWN IS THE LIFT REQUIRED FROM THE NORMAL MINIMUM WATER LEVEL TO COMMAND THE PROJECT AREA.

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS

Sections	extended to the 20 metre isopotamon	95
-ditto-	limited extension only	15
-ditto-	not extended	44
	TOTAL NO.	154

The 20 metre isopotamon was marked by a 2" x 2" x ¼" mild steel angle driven into the ground and painted white, the section number and 20M. were painted on in red in each case. The end of the limited extensions were marked by a cairn or an angle post.

At the same time as the fieldwork locating and extending the sections was being carried out the survey results were plotted on the plans at scale 1/100,000. The relevent data for the sections established in 1951/52, comprising ground levels at one kilometre intervals, was also obtained and included on the same plans. Reconnaissance contours at one metre interval were then drawn making use of any additional topographical information obtained during the fieldwork.

5.7 PRELIMINARY SELECTION OF IRRIGABLE AREAS

With the reconnaissance contours completed and with the aid of the air photography, it was possible to select the more favourable areas which might later be proved suitable for irrigation projects. These areas were indicated on the 1/100,000 scale plans and then field inspections made to locate suitable sites for pump stations. At the same time, the method of supply from the pumping site to the possible project area was considered. In some cases it is possible for the pumps to deliver directly into a discharge basin at the head of the supply canal which is sited close to the pump station. Elsewhere, in cases where the ground level is low in the vicinity of the pump site it is usually necessary to include a length of rising main to deliver the irrigation supply to the canal head sited on higher ground. At possible sites selected along the reach between Kareima and the Third Cataract the length of rising main required is generally between one and two kilometres but at one site a four kilometre rising main would be required.

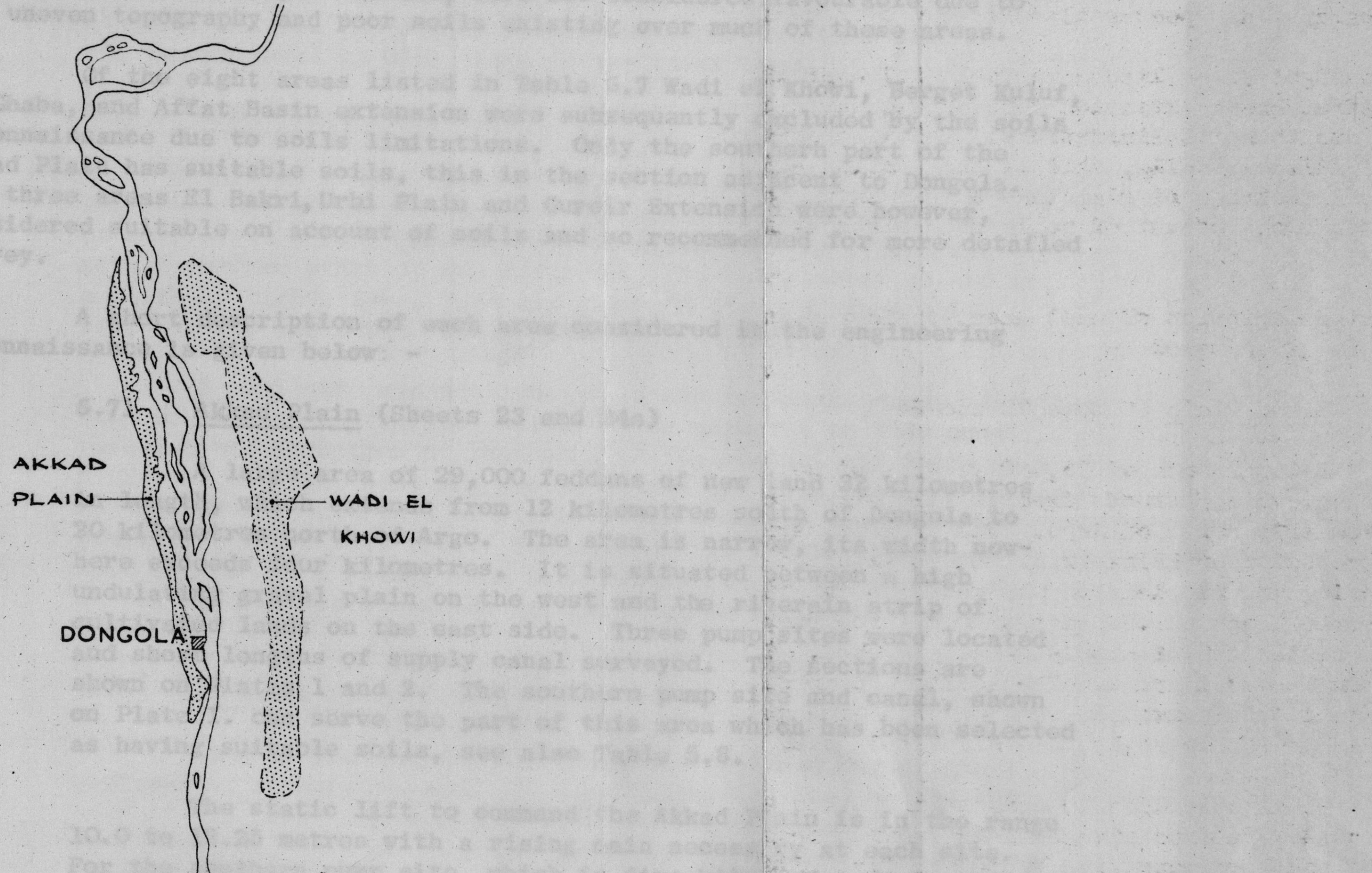
During this stage of the reconnaissance more emphasis was given to the selection of possible irrigable areas on lands which are not used at all at present. Eight areas were selected as being favourable. The location of these areas is shown in Figure 9. and the survey results are summarised in Table 5.7 below.

Table 5.7 Areas selected in Engineering Reconnaissance

Area	New Land Gross Feddans	Irrigation Supply by Pumps	
		Sites Surveyed (Number)	Static Lift (Metres)
Akkad Plain	29,000	3	(1) 12.25 (2) 10.00 (3) 11.00
Wadi el Khowi	Not Defined	1	11.00
Berget Kuluf	13,000	1	13.25
Urbi Plain	2,000	-	10.00
El Bakri Plain	33,000	1	13.75
El Ghaba Extension	5,000	1	13.50
Affat Basin Extension	5,000	-	12.25
Gureir Extension	5,000	-	13.75

Figure 9

PRELIMINARY SELECTION OF IRRIGABLE AREAS



Scale: 1:1,000,000

SIR M. MACDONALD & PARTNERS

Date: August 1963

It will be noted that the basin areas, which are to a small extent used for cultivation after flooding, are not included in this table. Kerma and Letti, the two largest basins, were not considered favourable due to the uneven topography and poor soils existing over much of these areas.

Of the eight areas listed in Table 5.7 Wadi el Khowi, Berget Kuluf, El Ghaba, and Affat Basin extension were subsequently excluded by the soils reconnaissance due to soils limitations. Only the southern part of the Akkad Plain has suitable soils, this is the section adjacent to Dongola. The three areas El Bakri, Urbi Plain and Gureir Extension were however, considered suitable on account of soils and so recommended for more detailed survey.

A short description of each area considered in the engineering reconnaissance is given below: -

5.71 Akkad Plain (Sheets 23 and 24s)

A large area of 29,000 feddans of new land 32 kilometres in length, which extends from 12 kilometres south of Dongola to 20 kilometres north of Argo. The area is narrow, its width nowhere exceeds four kilometres. It is situated between a high undulating gravel plain on the west and the riverain strip of cultivated lands on the east side. Three pump sites were located and short lengths of supply canal surveyed. The sections are shown on Plates 1 and 2. The southern pump site and canal, shown on Plate 1. can serve the part of this area which has been selected as having suitable soils, see also Table 5.8.

The static lift to command the Akkad Plain is in the range 10.0 to 12.25 metres with a rising main necessary at each site. For the southern pump site, which is five kilometres south of Dongola, the static lift required is 11.0 metres and length of rising main 1.75 kilometres.

5.72 Wadi el Khowi (Sheets 23 and 24s)

The possibility of irrigation development in the Wadi el Khowi area was considered during the reconnaissance. With this end in view a suitable pump site and headreach of supply canal were located. The pump site is 14 kilometres south of the Seleim canal head. This location was found to provide the only possible canal route through the extensive sand dunes around the southern end of Kerma Basin. The static lift required is 11.0 metres and a canal on embankment between 3.0 and 3.5 metres in height for 1.25 kilometres would dispense with the necessity of a rising main.

The irrigable area which could be supplied from this site was not defined but much of the Wadi el Khowi area could be commanded.

5.73 Berget Kuluf (Sheet 22)

This area of 13,000 feddans is on the right bank of the Nile opposite to Urbi. It is about 20 kilometres in length. The area is widest near its southern and where the boundary is about two kilometres from the river bank. The eastern boundary is close to the Wadi el Khowi escarpment.

The topography of this area is very favourable for irrigation as the plain has a gentle slope away from the river. The fall in ground level is about 5 metres over the area defined. A good pump site has been located where the static lift required is 13.25 metres. No rising main is necessary at this site as the ground level is high close to the river bank.

5.74 Urbi Plain (Sheet 22)

This is a small area of 2,000 feddans on the left bank of the river 50 kilometres south of Dongala. The land which could be investigated is a narrow tract 10 kilometres in length and with a maximum width of one kilometre. It is adjacent to and at a slightly higher level than the riverain strip of land which is about one and a half kilometres in width here.

A pump site was not located in the reconnaissance. Ecamination of the air photography of the river adjacent to this area revealed the formation of sandbanks in the channel and there is a risk that the left bank may become closed off from the main stream in the future. It would be difficult to locate a good site for pumping to serve this area. The static lift required would be 10.0 metres and a rising main 1.25 kilometres in length needed at the site indicated on the engineering reconnaissance plan Sheet 22.

5.75 El Bakri Plain (Sheet 21)

This is the largest area which was defined during the engineering reconnaissance. El Bakri plain is sited on the left bank of the river opposite the northern end of Letti Basin and 90 kilometres south of Dongola. It is 32 kilometres in length up to 6.5 kilometres in width and totals 33,000 feddans.

The area is bounded in the north by an escarpment which approaches the left bank of the river and in the south and west by thick sand and high ground. A central ridge of high ground extends from the south over most of the length of the area.

A good pump site was located near the southern end of the area. A static lift of 13.75 metres, is needed to command this area and 2.0 kilometre rising main to reach the ridge of high ground.

5.76 El Ghaba Extension (Sheet 20)

A possible extension area of 5,000 feddans was considered south-west of the government pump scheme at El Ghaba on the left bank. The ground rises comparitively steeply away from the existing scheme and the extension area would not be easy to canalise. A pump site and canal line was located at the southern end of the area where static lift of 13.5 metres and rising main about two and a half kilometres in length would be necessary.

5.77 Affat Basin Extension (Sheet 19)

A flat terrace of 5000 feddans situated north-west of Affat Basin on the right bank. The terrace is three to four metres higher than the basin land. Extensive areas of sand which surround Affat Basin would make it difficult to maintain a supply canal to this extension area. A pump site and canal line was not located in the reconnaissance.

5.78 Gureir Extension (Sheet 17s)

An extension of 5,000 feddans was defined as a flat terrace adjacent to the southern boundary of the government pump scheme at Gureir. The area measured eight kilometres in length with a maximum width of three kilometres. A good site for pumping could be obtained about two kilometres to the north of the area where high ground approached the river bank. This site cannot be utilised owing to the presence of a wide drainage line which leads to the river close to the northern boundary of the proposed extension. Probably the most satisfactory solution is to utilise the existing scheme pump site at which a static lift of 13.75 metres would be required delivering through a rising main 4.0 kilometres in length.

5.8 THE SELECTED PROJECT AREAS

The areas which have been selected as suitable for further study as a result of both soils and engineering reconnaissance are indicated by shaded areas on the engineering plans. For each area a preliminary canalisation layout has been prepared, based on the reconnaissance contours. These layouts would most certainly require substantial revision when more detailed topographical surveys, necessary for designing the canalisation systems, are carried out. They are, however, of value at this stage in evaluating the relative merits of the different areas and their use should be limited to this purpose.

In some cases the canalisation shown does not cover the whole of the area recommended for semi detailed soil survey. This is due to the difficulty of obtaining command of higher ground near the scheme boundary from a single pumping installation designed to serve the area as a whole. If sufficient land of good quality is found to exist at a higher level then the inclusion of a secondary pump to serve the area of high land could be considered.

Some details of the possible projects located in the reconnaissance are summarized in Table 5.8 below.

Table 5.8 Project Areas

Area	Map Sheet No.	Gross Area in Feddans			Pumps Static Lift (Metres)
		New Land	Registered Land	Total	
Kerma North Basin	23,24s	13,400*	-)	29.300	8.25
Ditto South		15,900*	-)		9.50
Dongola	23	8,900	5,900	14,800	11.00
Urbi Plain	22	3,500	1,500	5,000	10.00
El Bakri Plain	21	27,900	8,000	35,900	13.75
Letti Basin	21	12,500 *	-	12,500	10.50
Affat Basin	19	-	3,800*	3,800	10.25
Kulud Extension	18,19	3,300	-	3,300	13.00
Korti	18	500	-	500	14.50
Gureir Extension	17s	5,800	-	5,800	13.75
Fitna	17s	300	-	300	11.50
Total Areas	-	92,000	19,200	111,200	-

* Basin land subject to flood irrigation.

Where registered land now under cultivation by private pump schemes or saghias is readily commandable this has been included within the project area. The project areas do not include any land occupied by Government pump schemes, but do show to what extent they could be extended in the cases of Kulud and Gureir.

5.81 Kerma Basin (Sheets 23 and 24s)

The basin lands in Gisms 2 to 6 inclusive, comprising 29,300 feddans are to be considered for development by conversion to perennial pump schemes and are recommended for semi-detailed soil survey. This area represents most of the Kerma basin land now subject to annual flooding. The area is on the right bank of the Nile and extends from opposite Dongola in the south to Argo in the north. It measures 45 kilometres in length and has an average width of between three and four kilometres.

The overall slope of the basin land from south to north is very flat and the ground surface is very uneven. These two conditions make canalisation of the basin more difficult. It is not possible to provide a pumped supply which will serve the whole area from a single pump site. A preliminary layout is shown on the engineering reconnaissance plans (Sheets 23 and 24s).

The southern part of the basin area, 15,900 feddans, can be commanded from a pump channel 22 kilometres in length, sited along the western edge of the basin with the distributary canals conveying water across the area. The supply for this channel is obtained from pumps sited on the river bank close to the Seleim canal head. The pump site is on a stable reach of the river channel. The static lift required is 9.5 metres which can be delivered at the canal head without need of a rising main.

Supply for the 13,400 feddans in the northern part of the basin is more difficult than for the southern part owing to the presence of Argo island which isolates this area from the main river channel. Argo island is 30 kilometres in length and so it is not feasible to site pumps to north or south of the island. The presence of extensive areas of sand dunes along the western edge of the basin also adds to the difficulties. Probably the most satisfactory method of supply is to site pumps on the island river bank 17 kilometres south of Argo town where a static lift of 8.25 metres is required. The pump channel crosses Argo island and Khor Argo to reach the Kerma area where it is likely that secondary low lift pumps will be required to raise the level to gain command of the project lands. The supply canal, 18 kilometres in length, is sited near the western edge of the basin for three kilometres, south of an extensive area of sand dunes, it then crosses part of the basin to follow a ridge of high ground which leads from the centre to the eastern boundary of the basin land. The canal alignment is continued along the eastern side to its tail.

5.82 Dongola Area (Sheet 23)

This area, on the left bank of the river, is the southern part of the Akkad Plain which was described in Section 5.71. The project area is 20 kilometres in length and 2 kilometres wide with the northern boundary 8 kilometres north of Dongola town. The gross area is 14,800 feddans of which 8,900 feddans is new land and 5,900 feddans registered land.

A suitable pump site was located at a point five kilometres south of Dongola and a short length of supply canal from this site was surveyed, see Plate 1. The static lift required to command the area is 11.0 metres with a rising main 1.75 kilometres in length.

5.83 Urbi Plain (Sheet 22)

This area was defined in the engineering reconnaissance as a gross area of 2,000 feddans of new land, see section 6.74. As a result of the soils reconnaissance the area has been extended in the south. With the inclusion of registered land the gross project area is 5,000 feddans of which 3,500 feddans is new land. The pump site and static lift remain the same as described in section 5.74 where it was noted that it is difficult to locate a satisfactory site for this area.

5.84 El Bakri Plain (Sheet 21)

The large area of 33,000 gross feddans which was defined in the engineering reconnaissance is slightly reduced in width but extended a few kilometres in the south by the soils reconnaissance. The gross areas recommended for inclusion in the project are 27,900 feddans of new land and 8,000 feddans of registered land.

A preliminary canalisation layout to command these areas is shown on Sheet 21. The pump site and supply canal remain as surveyed during the engineering reconnaissance and described in section 5.75.

5.85 Letti Basin (Sheet 21)

This area has been included as a project area recommended for semi detailed soil survey as a result of the soils reconnaissance. It was not included in the irrigable areas defined during the engineering reconnaissance. The area was, however, covered by the engineering survey and the cross sections in Letti Basin were extended either partially or fully to the 20 metre isopotamon.

A preliminary canalisation layout to command the full area of the basin, 12,500 gross feddans, is shown on Sheet 21. of the engineering plans. The area is a difficult one for canalisation due to its shape and topography. The basin being 24 kilometres in length and varying in width from 1.0 to 2.5 kilometres. The layout shown has the pump site at the southern end and the supply canal aligned along the high ground to the east of the basin. The static lift required is 10.5 metres which is delivered through a rising main 1.25 kilometres in length, which presents no special difficulty. The supply canal as indicated is aligned through an area where moving sand constitutes a major hazard. It would be difficult to provide adequate protection for an irrigation canal on this alignment. It is not possible to command the basin land by sitting the canal on the western side owing to the general ground slope being from east to west. A possible solution is to re-align the canal on lower ground so that it is sited within the basin area and protection obtained by windbreaks established on irrigated land to the east of the canal. If this is done the area commanded from the pumps in the south would be greatly reduced and secondary pumping would be necessary. A satisfactory canalisation layout cannot be prepared until after the results of the semi-detailed soil survey are available.

5.86 Kulud Extension (Sheets 18 and 19)

This area which was selected by the soils reconnaissance was not defined during the engineering survey. It is an area of new land on the left bank of the river, 3,300 gross feddans, adjacent to the Government Pump Scheme at Kulud thus forming an extension to this scheme.

The Kulud Extension can be commanded by pumps sited at the existing government pump station delivering through a rising main 1.0 kilometre long. A static lift of 13.0 metres is needed to command most of the area defined by the soils reconnaissance.

5.87 Korti Area (Sheet 18)

This is a small area of new land, 500 gross feddans, sited on the left bank of the river which was defined in the soils reconnaissance to command this area a pump sited in the vicinity of Cross Section 15 with static lift of 14.5 metres would be necessary. The site was not inspected during the reconnaissance.

If required the area commanded from this pump site could be extended to include the registered land which is already under cultivation between Cross Sections 15 and 18.

5.88 Gureir Extension (Sheet 17s)

This area on the left bank, was defined in the engineering reconnaissance but has been increased slightly in the soils reconnaissance to cover 5,800 gross feddans of new land. The area is adjacent to and forms an extension to the Government Pump Scheme at Gureir. The small increase in area does not alter in any way the method of supply which is described in sections 5.78 of this Chapter.

5.89 Fitna Area (Sheet 17s)

This is a very small area which was defined in the soils reconnaissance. It covers 300 feddans gross area of new land. A pump site was not located in the engineering reconnaissance. A static lift of 11.5 metres is required to command this small area and it is unlikely that a rising main will be necessary.

CHAPTER 6

LAND SUITABILITY CLASSIFICATION

6.1 LIMITING PHYSICAL FACTORS TO LAND DEVELOPMENTS

Similar general specifications for soil, topographic and drainage limitations were used to those in Area 1 (Gezira Extension) and Area 3 (Blue Nile Right Bank). As in Areas 1 & 3, impeded drainage was rarely a limiting factor to land development.

6.11 Topographic Limitations

To land development are a major factor in Area 4a. They are of two kinds, sometimes occurring together, but generally in distinct environments.

Sand Movement Especially in the winter season under the influence of strong northerly winds, is especially prevalent in this desert environment. As the dunes advance from the north east they tend to approach the right bank of the river between Korti and Kerma. The extensive silt terraces of the Wadi el Khowi region are more than half covered by dune systems of great size, some branches being almost 50 metres high. Similarly, the Bergeig pump project, the Kerma basin and the Letti basin suffer from sand encroachment from the eastern side whilst the Affat basin has extensive sand dune systems to the north. Because of the lands they have already covered and rendered useless and because of the threat they present to level lands by their continued movement, the dune systems present a very considerable hazard to the development of the right bank lands. On the left bank the movement of sand is much less and the accumulations are in the form of mounds and low dunes.

Sloping Gullied Lands Are found mostly where a narrow silt terrace is bounded by an escarpment of Nubian sandstone. In spite of the low annual rainfall there is considerable run-off following occasional heavy rains especially in areas of sandstone and basalt outcrops. The Akkad plain is quite severely gullied by occasional run-off from the Jebel Hafir-Jebel Birna plateau. Similarly the left bank lands from Merowe to Ghaba are dissected by quite large wadis originating in the high ground to the west and south. The gullied lands in this area often have the additional hazard of moving sand in mounds and small dunes.

6.12 Soils Limitations

These cover a wider range of characteristics than in the Gezira plain and include physical as well as chemical limitations. They are described as follows :-

Shallow and Stony Soils are found where Nubian sandstones are covered by a thin layer of silt on the old terraces. These occur in a number of places on the Wadi el Khowi plain.

There is also a conspicuous gravel ridge in the middle of the Akkad plain. Another occurrence is on the left bank of the river between Korti and Debba.

Excessive Sandiness is a common deficiency of soils of level areas even where there are no dunes. It is frequently encountered in the Wadi el Khowi plain, in the Kerma basin, on the western and southern parts of the extensive El Bakri plain and on both sides of the river from Merowe to Debba. The very low silt plus clay content of these soils results in very high permeability which would make ordinary irrigation farming virtually impossible.

Salinity is moderate to severe in many of the terrace silts although it is not a problem in the young alluvium of the registered land. Some very high salinities, with E.C. up to 100, were registered in a few cases, generally seepage areas in sands at the edges of basins. Salinities of dry silts ranged from non saline up to E.C. of 40 millimhos which are much higher than anything encountered in the Gezira clays. In some cases where salinity is moderate and permeability is reasonably high it should be possible to leach salts from the soil without great difficulty. For this reason salinity standards for the Area 4a Entisols will be different from those of the Gezira Vertisols in which leaching is practically impossible.

Alkalinity is severe in many of the terrace silts although it is not a problem in the young alluvium of the registered lands. Exchangeable sodium percentage in the Natrargidic Orthustents varies from 15 to over 50. It is not known what effect irrigation would have on the E.S.P. of these old terrace silts. In some soils (as in Iraq) the leaching of salt is accompanied by a lowering of the E.S.P. As high alkalinity occurs in both saline and non-saline terrace silts, however, it would seem that the exchangeable sodium here has accumulated independently of the salt content. Until research workers should establish findings to the contrary, therefore, it must be assumed that the high alkali terrace silts, especially those of low permeability, are not suitable for irrigation development.

6.2 BASIS OF SELECTION OF LANDS FOR FURTHER STUDY

The reconnaissance soils and engineering survey was concerned only with Government land, most of which was undeveloped. The survey included Basin lands but the terms of reference excluded registered lands and Government pump project lands.

The agricultural aspects of land selection were concerned chiefly with the physical bases of potential agricultural production. The limiting physical factors mentioned above in 6.1 were used to reject areas of topographically unsuitable lands and to provide a provisional land classification at each site selected for soil examination. An examination of the base map on which the soil sites had been plotted, together with stereoscopic examination of air photos and photo interpretation of prints and mosaics then enabled a provisional land suitability classification to be worked out.

The engineering surveys were concerned with establishing the position of the 20 metre isopotamon and, as well, with locating suitable pump sites on the Blue Nile and suitable lines for irrigation canals. Consideration of the engineering aspects enabled the elimination of further, mostly marginal, lands requiring a high pump-lift and/or a long supply canal through difficult terrain.

Registered lands (privately owned) line the banks of the Main Nile from Nuri to Najmi's tomb, with a few breaks where the river abuts on high broken ground. Islands in the river are also registered lands. In places there are small strips and pockets of suitable land on the high side of the registered lands which could be served by small extensions of existing private schemes but which are too small to form the nucleous of a new irrigation project.

The lands recommended for further study are those that are found in units large enough to warrant the expense of a pump installation and canal system.

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

The lands recommended for semi-detailed surveys are as follows :-

Locality	Map Sheet No.	Area (feddans)
Fitna	17S	300
Gureir Extension	17S	5,800
Korti	18	500
Kulud Extension	18,19	3,300
Affat Basin	19	3,800
Letti Basin	21	12,500
El Bakri Plain	21	27,900
Urbi Plain	22	3,500
Dongola	23	8,900
Kerma Basin	23,24S	29,300
	Total Area	~~102,000~~ 95,800

These units are described in some detail in 5.8. Some notes on soils and irrigation potential are given below :-

6.31 Fitna Lands 300 feddans

This small isolated terrace area is close to Merowe and the railhead at Kareima. It could be used for intensive fruit production to supply the proposed new canning factory at Kareima if the soils are found suitable. The reconnaissance survey has tentatively classed these soils as Orthic and Natrargidic Orthustents.

6.32 Gureir Extension Lands 5,800 feddans

This extensive terrace lies within easy truck distance of Merowe and Kareima and could, if necessary, be developed for intensive horticulture. The soils are coarse to medium textured and should drain readily. On the high side they merge into sand hummocks and dunes. Site No. DR 378 is a good loam soil, non saline and non alkali. The greater part of the project area has been classed as Orthic Orthustents and there is a smaller area of Orthic Orthustents and Orthic Psammustents.

6.33 **Korti Lands** 500 feddans

This high and rather uneven terrace near Korti could be developed for horticulture if the soils are found suitable. They are tentatively classed as Orthic and Natrargidic Orthustents.

6.34 **Kulud Extension Lands** 3,300 feddans

This high and rather uneven terrace could be developed as an extension to the existing government Kulud pump scheme if there is a sufficient area of suitable soil. The soils are tentatively classed as Orthic and Natrargidic Orthustents. Site No. DR 369, which is classed as a Psammustentic Orthustent, is a slightly saline sandy loam soil with appreciable exchangeable sodium.

6.35 **Affat Basin** 3,800 feddans

This land already receives some water in the flood season but the supply fluctuates widely from year to year and in an average year only 300 feddans is flooded. The soils are considered to be Orthic Orthustents. Site No. DR 336 is a very good silt loam soil, non saline and non alkali. There should be good possibilities of further development in the Affat Basin.

6.36 **Letti Basin** 12,500 feddans

This land already receives a certain amount of flood water in the flood season, the average area flooded each year being 4,880 feddans and the maximum in a high flood being 9,300 feddans. The topography is described as uneven and most of the flood land is used for forest or grazing purposes. The soils are classed as Orthic and Natrargidic Orthustents. Site No. DR 311 is classified as a Vertic Orthustent; it is a good silty clay soil, non saline and non alkali.

6.37 **El Bakri Plain** 27,900 feddans

This extensive plain consists of several silt terraces with two prominent sandy ridges in the northern section. It merges into a slightly undulating sandy plain to the west and south. The soils are mapped as Orthic, and Natrargidic Orthustents. Site DR 341 is a sandy loam soil classed as an Orthic Orthustent. The subsoil is weakly saline but the soil is sufficiently permeable to be leached. The soil also contains about 5 milliequivalents of exchangeable sodium. Site No. DR 324 on the edge of the selected area is classified as an Orthustentic Psammustent. It is a non saline, non alkali loamy sand which would need sprinkler irrigation if it were to be cropped. Site No. DR 316, classified as a Natrargidic Orthustent, is a fine textured soil with a saline - alkali subsoil. In general the soils of the El Bakri plain bend to be of coarse to medium texture and quite permeable so that leaching of salts is feasible.

6.38 **Urbi Plain** 3,500 feddans

This is a small isolated terrace hemmed in between high ground and the river. The soils are mapped as Orthic Orthustants and Orthic Psammustents. Permeability is high and natural drainage should be adequate.

6.39 **Dongola Lands** 8,900 feddans

This elongated narrow terrace extends between registered lands adjacent to the river and the desert plateau on the west. There are some small gullies adjacent to the high ground. The soils are mapped as Orthic and Natrargidic Orthustents. Site No. DR 212 which is classed as an Orthic Orthustent is a good silty loam, non saline and non alkali.

6.40 **Kerma Basin Lands** 29,300 feddans ?

The Kerma Basin has been described elsewhere as a depression in the terrace system to which flood water has been admitted since 1912 via the Seleim Canal. The surface is uneven and there are extensive hummocks in places. The soils have been mapped as Orthic Orthustents and Orthic Psammustents. Site No. DR 182, which is described as a Psammustentic Orthustent, consists of a shallow layer of recent silt overlying sand; it is non saline. It is considered that this soil could be improved by deep ploughing to mix the two layers to produce a homogenous soil with properties intermediate between the two constituents. Soil No. DR 183 from Gism 6, which is classed as a Natrargidic Orthustent, is a slightly saline silt loam containing considerable exchangeable sodium. Reclamation should be possible because of good permeability.

APPENDIX 1

Specimen Soil Profile Descriptions at 35 Sites together with Laboratory Data

		Pit No.
A.	Orthic Orthustent:	DR212
		DR341
		DR365
		DR378
		DR386
B.	Natrargidic Orthustent:	DR161
		DR166
		DR170
		DR176
		DR183
		DR192
		DR219
		DR221
		DR262
		DR268
		DR280
		DR284
		DR290
		DR295
		DR316
		DR359
		DR394
C.	Vertic Orthustent:	DR311
D.	Natrargidic Vertic Orthustent:	DR243
E.	Salorthid:	DR246
		DR252
		DR312
F.	Psammustentic Orthustent:	DR182
		DR199
		DR207
		DR310
		DR330
		DR352
		DR369
G.	Orthustentic Psammustent:	DR324

The soil pits are located with reference to the grid on which the Sudan Survey maps, scale 1:100,000 (1952) are based.

N.B. Abbreviation "Incorp. Carbon." used in table represents Incorporated Carbonate estimated as Calcium Carbonate.

A. Orthic Orthustent.

Pit: DR212

Location: 373,000. 170,000 Date: 4.3.63.

Topography: Southern end of a low gravelly ridge surrounded by silt.

Cultivation and Land Use: Nil.

Vegetation: Widely scattered very small *Acacia erhenbergiana* bushes.

Surface: Dry, soft, with much loose sand, gravel and stones.

Profile description:-

0 - 4 cm. Dry 10YR5-3, moist 10YR4-3. Gravelly Sandy Loam. Dry, soft, structureless with weak laminations. Rapidly water absorbent. No roots. No salts.

4 - 18 cm. Dry 10YR5-2, moist 10YR3.5-2. Silty Clay Loam. Dry, slightly hard, weak very fine subangular blocky with common fine cracks and no pores. Rapidly water absorbent. Rare roots. No salt.

18 - 75 cm. Dry 10YR5-2, moist 10YR3.5-2, with some 10YR5-6 mottles and black stains. Silty Clay Loam. Dry, slightly hard moderate medium subangular blocky with many fine cracks and no pores. Rapidly water absorbent. Rare roots. No salts.

75 - 102 cm. Dry 10YR5-2, moist 10YR3.5-2 with common 10YR5-6 mottles. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. Rare roots. No salts.

102 - 137 cm. Dry 10YR5-2, moist 10YR3.5-2 with common 10YR5-6 mottles. Silty Clay Loam. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts.

137 - 151 cm Dry 2.5Y5-2, moist 2.5Y4-2. Loamy Very Fine Sand. Dry, soft to loose, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts.

151 - 170 cm. Dry 10YR5-6, moist 10YR4-4. Stony Sand. Dry, loose desert sand and stones.

Laboratory Analyses:-

Depth (cm)	Soil Particles %			Incorp. Carbon. %	pH		E.C.	Soluble Na.	Exch. Na.
	Sand	Silt	Clay		Soil Paste	1:5 Soil sus-pension.	Sat. Extr.	m. eq. per litre	per 100 gm soil
0- 4	62	23	15	2.21	8.61	9.45	0. 6	0.3	4.60
4-18	55	32	13	0.88	8.45	9.10	0.75	0.5	4.00
18-75	67	23	10	0.85	7.78	8.40	0.75	0.5	2.90
75-102	60	27	13	0.88	7.89	8.52	0.38	0.3	4.20
102-137	70	25	5	1.46	7.58	8.41	0.42	0.3	3.50
137-151	85	10	5	0.73	7.60	8.20	0.22	0.1	1.47

Orthic Orthustent.
Non-saline
Land Class 2.

Pit: DR341

Location: 348,000. 68,000 **Date:** 1.4.63.

Topography: Flat, with sandy mounds up to 15 ft. high around bushes.

Cultivation and Land Use: Nil.

Vegetation: Scattered clumps of Acacia erhenbergiana bushes

Surface: Dry, firm, sandy, level. Much loose gravel. Many small stones.

Profile description:-

0 - 3 cm. Dry 10YR5-2, moist 10YR4-2, with 10YR4-3 patches. Loam. Dry, soft, weak fine platy with few cracks and fine pores. Rapidly water absorbent. No roots. No salts.

3 - 26 cm. Dry 10YR4.5-2, moist 10YR3-2. Sandy Loam. Dry, soft, weak medium subangular blocky with few cracks and many fine pores. Rapidly water absorbent. No roots. Few fine white Calcium Carbonate streaks.

26 - 84 cm. Dry 10YR5-4, moist 10YR4-3. Sandy Loam. Dry, slightly hard, structureless with few cracks and common pores. Rapidly water absorbent. No roots. Few fine white Calcium Carbonate streaks.

84 - 135 cm. Dry 10YR5-4, moist 10YR4-4, Loamy Sand. Dry, soft, structureless with few cracks and common pores. Rapidly water absorbent. No roots. Common fine white Calcium Carbonate streaks. Some gravel.

135 - 178 cm. Dry 10YR5-4, moist 10YR4-3. Sand. Dry, very soft, structureless with no cracks or pores. Rapidly water absorbent. No roots. Few Calcium Carbonate streaks. Common mica.

Laboratory Analyses:-

Depth (cm)	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol. Na. meq. per litre	Exch. Na per 100gm soil
0- 3	72	13	15	2.08	9.03	9.48	0.48	0.3	4.0
3- 26	72	15	13	0.98	8.73	9.22	1.25	0.8	8.4
26- 55	72	8	20	0.83	7.70	8.12	10.0	4.8	5.5
55- 84	75	12	13	1.02	7.82	8.63	6.5	3.2	5.5
84-135	82	8	10	0.83	7.95	8.45	4.0	2.4	5.1
135-178	85	2	13	0.45	8.21	8.89	2.3	1.1	3.2

Orthic Orthustent
Saline
Land Class 3

Pit:	DR365.	
Location:	307,000. 36,000.	Date: 5.4.63.
Topography:	Flat.	
Cultivation and Land Use:	Nil.	
Vegetation:	Nil. Some *Acacia erhenbergiana* bushes 1 km. away.	
Surface:	Dry, soft.	

Profile description:-

0 - 5 cm.	Dry 10YR5-3, moist 10YR4-3. Loam. Dry, soft, moderate medium subangular blocky with common cracks and no pores. Rapidly water absorbent. No roots. Few dark Calcium Carbonate concretions.
5 - 16 cm.	Dry and moist 10YR4-2. Clay Loam. Dry, very soft, strong very fine crumb with some fine vertical cracks infilled with sand. Moderately water absorbent. Few fine roots. Common white Calcium Carbonate streaks.
16 - 44 cm.	Dry 10YR5-1.3, moist 10YR4-2. Clay Loam. Dry, slightly hard, moderate medium subangular blocky with common cracks and few pores. Rapidly water absorbent. Few roots Many white Calcium Carbonate streaks and concretions.
44 - 89 cm.	Dry 2.5Y5-3, moist 2.5Y4-3. Loamy Fine Sand. Dry, soft, structureless with no cracks and few pores. Rapidly water absorbent. No roots. Many large light grey Calcium Carbonate concretions.
89 - 122 cm.	Dry 2.5Y5-3, moist 2.5Y4-3. Loamy Sand with some thin loam layers. Dry, soft, structureless with no cracks and few pores. Rapidly water absorbent. No roots. Many large light grey Calcium concretions, and a Caliche layer about 3 cm. thick at the top of this horizon.
122 - 167 cm.	Dry 2.5Y5-3, moist 2.5Y4-3. Loamy Fine Sand. Dry, soft, structureless with no cracks and common pores. Rapidly water absorbent. No roots. Common light grey Calcium Carbonate concretions.
167 - 178 cm.	Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, very soft, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts.

Laboratory Analyses:-

Depth cm.	Soil Particles %			Incorp Carbon %	pH		E.C. Sat. Extr.	Sol. Na Meq.per litre	Exch. Na Meq. per 100 gm. Soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 5	60	10	30	4.15	8.52	9.02	0.70	0.3	3.1
5-16	52	13	35	5.93	8.45	9.23	0.57	0.3	5.6
16-44	62	13	25	7.75	8.79	9.38	0.60	0.3	7.1
44-89	77	10	13	9.25	8.51	9.12	0.80	0.4	5.2
89-122	80	7	13	1.89	8.42	9.07	1.2	0.5	4.7
122-167	82	8	10	3.26	7.89	8.37	4.8	2.1	4.5
167-178	90	2	8	2.10	7.80	8.52	3.4	1.5	6.7

Orthic Orthustent
Non-saline
Land Class 2.

Pit: DR378

Location: 239,000. 66,000. **Date:** 7.4.63.

Topography: Flat, with low sandy mounds around bushes.

Cultivation and Land Use: Nil.

Vegetation: Widely scattered clumps of *Acacia erhenbergiana* bushes.

Surface: Dry, firm beneath a thin soft sandy and gravelly layer. Many small dark Calcium Carbonate concretions.

Profile Description:-

0 - 9 cm. Dry 10YR6-3, moist 10YR4-4. Loam. Dry, soft, strong fine subangular blocky with many cracks and few pores. Rapidly water absorbent. No roots. No salts.

9 - 30 cm. Dry 10YR5-3, moist 10YR4-4. Gravelly Loam. Dry, soft, structureless with no cracks and many fine pores. Rapidly water absorbent. Few roots. No salts.

30 - 84 cm. Dry 10YR4-3, moist 10YR3-4. Clay Loam. Dry, slightly hard, weak fine subangular blocky with few cracks and many fine pores. Rapidly water absorbent. No roots. Some gravel. Many fine white Calcium Carbonate streaks.

84 - 153 cm. Dry 10YR5-4, moist 10YR4-4. Sandy Gravel with some thin bands of Clay Loam. Dry, soft to loose, structureless with no cracks or pores. Rapidly water absorbent. No.roots. No salts.

Laboratory Analyses:-

Depth	Soil Particles %			Incorp Carbon %	pH		E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch. Na Meq. per 100 gm. soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 9	74	12	14	1.98	8.02	8.42	2.50	0.8	2.5
9- 30	65	8	27	2.77	8.35	8.43	0.33	0.1	0.8
30- 84	65	21	14	8.64	7.02	7.62	3.90	0.7	0.3
84-153	84	2	14	3.20	7.80	8.29	0.50	0.1	0.6

Orthic Orthustent
Non-saline
Land Class 2.

Pit: DR386

Location: 295,000. 35,000. Date: 9.4.63.

Topography: Flat, with irrigation channels.

Cultivation and Land Use: Uncultivated patch near some small abandoned fields.

Vegetation: Much *Calotropis procera* and *Bergia suffructiosa*. Many small *Acacia nilotica* bushes.

Surface: Dry, soft and dusty to 5 cm. Much trodden. No cracks. No gravel or stones.

Profile description:-

0 - 4 cm. Dry 10YR4-3, moist 10YR3-2. Silt Loam. Dry, loose, structureless trodden surface material. Rapidly Water absorbent. No salts.

4 - 16 cm. Dry 10YR4-3, moist 10YR3-2. Silt Loam. Dry, very soft, very weak fine subangular blocky with no cracks or pores. Rapidly water absorbent. Many fine roots. No salts.

16 - 31 cm. Dry 10YR4-3, moist 10YR3-2.5. Silty Clay Loam. Dry, soft, moderate fine subangular blocky with many fine cracks and few pores. Rapidly water absorbent. Many fine roots. No salts.

31 - 46 cm. Dry 10YR4-3, moist 10YR3-2. Loamy Sand. Dry, soft, structureless with no cracks and few pores. Rapidly water absorbent. Many fine roots. Few Calcium Carbonate specks.

46 - 94 cm. Dry 10YR5-3, moist 10YR3.5-2. Sand. Dry, very soft, structureless with no cracks and few pores. Rapidly water absorbent. Common fine roots. No salts.

94 - 117 cm. Dry 10YR5-3, moist 10YR3.5-2. Sandy Loam. Dry, soft, structureless with no cracks and common pores. Rapidly water absorbent. Common coarse roots. No salts. Some fragments of pottery.

117 - 177 cm. Moist 10YR3-2. Silt Loam. Slightly moist, firm, structureless with no cracks and common pores. Rapidly water absorbent. Common coarse roots. Common light grey Calcium Carbonate in old root channels.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbonate %	pH		E.C. Sat. Extr.	Sol.N_a Meq. per litre.	Exch.Na Meq.per 100 gm Soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil Suspension			
0 - 4	54	22	24	2.05	7.78	8.08	0.68	0.1	0.25
4 - 16	44	29	27	1.69	7.62	8.03	1.40	0	0.35
16- 31	27	41	32	3.71	7.68	8.12	0.40	0.05	0.3
31 - 49	65	16	19	2.52	7.72	8.13	0.57	0.02	0.3
49 - 94	89	2	9	1.67	7.90	8.25	0.48	0.06	0
94 -117	74	9	17	4.97	8.01	8.62	0.60	0.2	1.55
117 -177	62	21	17	2.74	8.23	9.02	0.60	0.4	7.9

Orthic Orthustent
Non-saline
Land Class 2.

B. Natrargidic Orthustent.

Pit: DR161

Location: 370,000. 216,000 **Date:** 11.2.63.

Topography: Flat.

Cultivation and Land Use. Nil.

Vegetation: *Acacia erhenbergiana* bushes on low sandy mounds. 100 to 200 yds. away.

Surface: Dry, soft to loose beneath a thin soft crust. Rippled by the wind into small ripplies 1 to 2 in. high. Much fine gravel. Many small dark Calcium Carbonate concretions

Profile description:-

0 - 7 cm. Dry 10YR5-2, moist 10YR4-2. Gravelly Clay Loam. Dry, loose and structureless. Rapidly water absorbent. No roots. Many small hard dark Calcium Carbonate concretions. Many small white Calcium Carbonate flecks.

7 - 28 cm. Dry 10YR5-2, moist 10YR4-2. Silty Clay Loam. Dry, soft, weak fine prismatic with common fine cracks and no pores. Rapidly water absorbent. No roots. Many small white Calcium Carbonate flecks. Old wide cracks infilled with material from above.

28 - 83 cm. Dry 10YR4-1.5, moist 10YR4-2. Silty Clay Loam. Dry, slightly hard, strong, fine prismatic with many fine cracks and vertical cracks up to 1 cm. wide. Rapidly water absorbent. No roots. Many small soft white Calcium Carbonate flecks.

83 - 180 cm. Dry 10YR4-1, moist 10YR3-2. Silty Clay Loam. Dry, hard, strong fine prismatic with many fine cracks but no wide vertical cracks. Rapidly water absorbent (soil softens rapidly to a fine tilth). Common faint greyish Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm.	Soil Particles % Sand	Silt	Clay	Incorp. Carbon %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre.	Exch. Na Meq per. 100 gm. Soil.
0- 7	50	27	23	4.63	8.12	8.25	4.75	3.0	6.05
7- 28	42	30	28	2.52	8.05	8.12	18.00	16.8	18.70
28- 83	30	40	30	4.07	8.30	8.69	18.00	18.4	33.80
83-130	35	40	25	5.92	8.02	8.81	20.80	15.2	26.60
130-180	64	22	14	6.51	8.32	9.28	5.00	4.0	20.4

Natrargidic Orthustent.
Saline.
Land Class 6.

Pit: DR166

Location: 367,000. 208,000. Date: 13.2.63.

Topography: Depressions and low ridges 3 to 4 ft. high. Pit sited on a ridge.

Cultivation and Land Use: Nil.

Vegetation: Nil. Some Acacia erhenbergiana bushes 200 to 300 yards away.

Surface: Dry, soft, covered by a thin layer of sand. Many small greyish Calcium Carbonate nodules. Scattered stones (igneous: possible human influence).

Profile Description:-

0-9 cm. Dry 10YR4-1.5, moist 10YR3-2. Silt Loam. Dry, soft, weak very fine platy. Plates easily break up to powder. Many fine cracks. Rapidly water absorbent. No roots. Many small greyish Calcium Carbonate nodules.

9 - 44 cm Dry 10YR4.5-2, moist 10YR3-2. Silty Clay Loam. Dry, slightly hard, moderate medium prismatic with many fine cracks and no pores. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Common white Calcium Carbonate streaks.

44 - 97 cm. Dry 10YR4.5-2, moist 10YR4-2, with 10% mottle 10YR4-4 (moist). Silty Clay Loam. Dry, hard, moderate medium angular blocky with many fine cracks and no pores. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Common grey nodules and white streaks of Calcium Carbonate.

97 - 174 cm. Dry 2.5Y5-2, moist 2.5Y3-2 with 2.5Y3-3 mottles. Silt Loam. Dry, hard, moderate medium angular blocky with many fine cracks and pores. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Many grey nodules and streaks of Calcium Carbonate.

174 - 195 cm. Dry 2.5Y5-2, moist 2.5Y4-2 with 2.5Y4-4 mottles. Very Fine Sandy Loam. Dry, soft, structureless with no cracks and common fine pores. Rapidly water absorbent. No roots. Common grey Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm.	Soil Particles % Sand	Silt	Clay	Incorp Carbon %	pH Soil Paste	1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch.Na Meq.per 100 gm. soil.
0- 9	40	27	33	1.85	8.56	8.87	13.00	12.0	28.30
9- 44	55	30	15	1.92	7.72	8.01	13.50	8.8	17.60
44- 97	50	37	13	3.74	7.92	8.56	5.70	4.6	12.60
97-135	80	12	8	1.35	8.61	9.14	0.88	0.6	8.10
135-174	70	17	13	4.81	8.28	9.22	3.80	2.2	11.40
174-195	77	15	8	2.22	7.95	8.79	2.60	1.6	9.9

Natrargidic Orthustent
Saline
Land Class 6.

Pit: DR170

Location: 365,000. 205,000 Date: 14.2.63.

Topography: Very low ridges and shallow depressions. Sandy mounds around bushes.

Cultivation and Land Use: Nil.

Vegetation: Acacia erhenbergiana bushes 20 to 50 yds. apart.

Surface: Dry, soft, sandy to 1 cm. Many small light grey Calcium Carbonate nodules.

Profile description:

0 - 21 cm. Dry 2.5Y4.5-2, moist 2.5Y4-2. Silty Clay Loam. Dry, slightly hard, strong very fine angular blocky with many fine cracks and common fine pores. Rapidly water absorbent, softening rapidly to a fine tilth. No roots. Many small grey Calcium Carbonate nodules.

21 - 29 cm. Dry 2.5Y4.5-2, moist 2.5Y4-2. Silt Loam. Dry, slightly hard, weak medium subangular blocky with few fine cracks and pores. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate streaks. Common Calcium Carbonate nodules.

29 - 55 cm. Dry 2.5Y4.5-2, moist 2.5Y4-2 with 2.5Y4-4 mottles. Very Fine Sandy Loam. Dry, soft, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many soft white Calcium Carbonate infills in old root channels.

55 - 83 cm. Dry 2.5Y4.5-2, moist 2.5Y4-2 with 2.5Y4-4 mottles. Silt Loam. Dry, slightly hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Salts as above.

83 - 103 cm. Dry 2.5Y4.5-2, moist 2.5Y4-2 with 2.5Y4-4 mottles. Loamy Fine Sand. Dry, soft to loose, structureless with no cracks or pores. Rapidly water absorbent. No roots. Salts as above.

103 - 176 cm. Thin bands of the following:-

(i) Dry 2.5Y4-2, moist 2.5Y3-2. Very Fine Sandy Loam. Dry, hard, structureless. Rapidly water absorbent. Cemented by Calcium Carbonate.

(ii) Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, loose. River origin.

(iii) Dry 10YR6-4, moist 10YR5-4. Coarse Sand. Dry, loose. Desert origine.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch. Na Meq. per 100 gm. soil
0- 21	52	20	28	3.40	8.80	9.51	1.00	0.8	13.50
21- 29	70	15	15	3.22	8.59	9.50	1.95	1.3	11.20
29- 55	85	7	8	0.53	8.12	8.75	3.60	2.6	7.30
55- 83	70	20	10	2.26	8.02	8.60	6.00	5.2	12.20
83-103	50	12	38	4.38	8.02	8.61	6.00	6.0	12.80
103-176*	88	7	5	8.07	8.49	9.12	2.80	1.8	7.40

* (only the Very Fine Sandy Loam layers)

Natrargidic Orthustent.
Non-saline
Land Class 4.

Pit: DR176

Location: 361,000. 202,000 Date: 15.2.63.

Topography: Flat

Cultivation and Land Use: Nil.

Vegetation: Scattered *Acacia erhenbergiana* bushes with very low sandy mounds around them.

Surface: Dry, sandy, loose beneath a soft crust ½ cm. thick. Much loose gravel and small stones.

Profile description:-

0 - 1 cm. Dry 10YR6-3, moist 10YR5-3. Gravelly Sandy Loam. Dry, soft, structureless. Laminated (wind-deposited). Moderately water absorbent. No roots. No salts.

1 - 28 cm. Dry and moist 10YR4-1. Clay Loam. Dry, very soft, weak medium prismatic with few fine cracks and few pores. Moderately water absorbent. Few fine roots. Common white Calcium Carbonate streaks.
Old wide cracks infilled with: Dry and moist 10YR4-2. Sandy Clay Loam. Dry, very soft, structureless. Moderately water absorbent. Few fine roots. No salts.

28 - 55 cm. Dry and moist 10YR4-1. Clay Loam. Dry, slightly hard, moderate medium prismatic with no pores and common fine cracks. Moderately water absorbent. No roots. Common white Calcium Carbonate streaks. Old wide cracks infilled as above.

55 - 68 cm. Dry 5Y5-1, moist 5Y5-2. Sandy Loam. Dry, slightly hard, structureless with no pores or cracks. Moderately water absorbent. No roots. There are a few very thin horizontal bands of dark Silty Clay near the base of this horizon. No salts.

68 - 136 cm. Dry and moist 10YR6-3. Gravelly Sand. Dry, soft, structureless. Rapidly water absorbent. No roots. No salts. Some of the gravel has a very hard, shiny coating.

136 - 150 cm. Dry 2.5Y5.5-4, moist 2.5Y5-4. Gravelly sand. Dry, soft, structureless. Rapidly water absorbent. No roots. A few soft white Calcium Carbonate accumulations.

150 - 180 cm Gravel.

(Between 55cm. and 136cm. there is no effervescence with Hydrochloric Acid, but the soil turns light green).

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch. Na Meq. per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil Suspension			
0- 28	80	12	8	2.22	8.45	9.35	0.52	0.3	6.15
28- 55	77	3	20	1.10	7.72	8.24	10.00	6.4	8.50
55- 68	90	5	5	0.28	8.42	9.02	3.00	2.2	6.50
68-136	97	0	3	0.24	9.30	8.32	1.55	0.5	0.37
136-150	95	0	5	0.29	10.02	9.75	4.00	2.0	5.30

Natrargidic Orthustent
Slightly saline
Land Class 4.

Pit: DR183

Location: 370,000. 201,000. Date: 19.2.63.

Topography: Flat: close to a channel in the Kerma Basin.

Cultivation and Land Use: Some grazing.

Vegetation: A small grove of *Acacia nilotica*. Much *Calotropis procera*, *Tamarix articulata*, and *Bergia suffructiosa*.

Surface: Dry, hard, finely cracked.

Profile description:-

0 - 8 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Silty Clay Loam. Dry, hard, moderate medium subangular blocky with many fine cracks and few pores. Rapidly water absorbent. Common roots. No salts.

8 - 38 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Silt Loam. Dry, soft, structureless with no cracks and common pores. Rapidly water absorbent. Many fine roots. Many small soft grey Calcium Carbonate concretions.

38 - 72 cm. Dry 2.5Y5-2, moist 2.5Y4-2 with common 10YR4-1 mottles. Silty Clay Loam. Dry, slightly hard, structureless with no cracks and common pores. Rapidly water absorbent. Many fine roots. Few small soft grey Calcium Carbonate concretions.

72 - 97 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Thin bands of Silt Loam and Very Fine Sandy Loam. Dry, soft, structureless with no cracks and common pores. Rapidly water absorbent. Few roots. Common fine Calcium Carbonate streaks ("mycelia").

97 - 140 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Silt Loam with thin bands of Silty Clay Loam. Dry, slightly hard, structureless. Rapidly water absorbent. No roots. Silty Clay Loam bands are very calcareous, inclined at about 10° to the Horizontal.

140 - 175 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Loamy Fine Sand. Dry, very soft, structureless. Rapidly water absorbent. Common Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch. Na Meq. per 100 gm. soil
0- 8	65	13	22	6.15	8.15	9.10	6.0	8.0	21.20
8- 38	74	13	13	2.39	8.29	9.10	1.95	1.4	12.50
38- 72	62	25	13	2.62	8.20	8.95	1.95	1.7	11.20
72- 97	87	8	5	0.70	8.15	9.03	1.55	1.0	6.15
97-140	67	20	13	5.52	7.95	8.37	3.9	3.8	10.60
140-175	95	0	5	0.52	8.45	9.08	0.42	0.3	5.80

Natrargidic Orthustent
Slightly saline
Land Class 4.

Pit: DR192

Location: 363,000. 195,000. Date: 21.2.63.

Topography: Slightly undulating - low ridges about 1 metre high.

Cultivation and Land Use: Nil.

Vegetation: *Acacia erhenbergiana* bushes on low mounds about 100 yds. apart.

Surface: Dry, soft, sandy, rippled. Scattered large ripples up to 6 inches high. Many small dark Calcium Carbonate concretions.

Profile description:

0 - 6 cm. Dry 10YR6-4, moist 10YR4-3. Sand (desert origin). Dry, soft to loose, structureless. Laminated (wind-deposited). Rapidly water absorbent. No roots. No salts.

6 - 15 cm. Dry 10YR5-2, moist 10YR4-2. Silty Clay Loam. Dry, soft, moderate very fine platy. Old vertical cracks infilled with sand. Rapidly water absorbent. No roots. No salts.

15 - 46 cm. Dry 10YR4.5-2, moist 10YR3.5-2. Silty Clay Loam. Dry, slightly hard, strong very fine subangular blocky, with vertical cracks up to 2 cm. wide infilled with sand. Rapidly water absorbent. No roots. Common small white Calcium Carbonate streaks.

46 - 81 cm. Dry 10YR4-2, moist 10YR3-2. Silt Loam. Dry, hard, strong fine angular blocky, with vertical cracks infilled with sand. Rapidly water absorbent. No roots. Many grey Calcium Carbonate streaks and hard concretions.

81 - 134 cm. Dry 10YR4-2, moist 10YR3-2. Silt Loam. Dry, slightly hard, weak medium subangular blocky, with few vertical cracks. Rapidly water absorbent. No roots. Many white Calcium Carbonate streaks. Few hard concretions.

134 - 169 cm. Dry 10YR5-2, moist 10YR3-2. Silt Loam with bands of Loamy Fine Sand. Dry, slightly hard to loose, structureless, with many fine pores. Rapidly water absorbent. No roots. Many white Calcium Carbonate streaks (in the Silt Loam only). Few rust mottles.

169 - 180 cm. Dry 2.5Y5-2, moist 10YR3-2. Sand. Dry, loose, structureless. River origin. Rapidly water absorbent. No roots. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch. Na Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 6	90	5	5	0.71	8.85	8.95	0.34	0.2	1.37
6- 15	72	18	10	1.46	8.68	9.52	1.22	0.8	7.20
15- 46	32	38	30	2.10	8.00	8.91	5.25	4.0	18.80
46- 81	47	38	15	3.31	8.12	9.03	3.2	3.0	16.40
81-134	72	18	10	3.35	8.02	8.65	6.0	3.8	10.20
134-169	77	13	10	1.66	8.31	9.30	4.0	2.6	12.2

Natrargidic Orthustent
Slightly saline.
Land Class 4.

Pit: DR219

Location: 378,000. 198,000. Date: 6.3.63.

Topography: Very slight slope to West, with a shallow gully 200 yds. North

Cultivation and Land Use: Nil.

Vegetation: Nil. *Acacia erhenbergiana*. bushes along the gully.

Surface: Dry, very soft beneath a thin soft finely cracked cap. Many small dark and light grey Calcium Carbonate concretions.

Profile description:-

0 - 3 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Gravelly Loam. Dry, very soft, weak fine platy. Laminated. Rapidly water absorbent. No roots. Many small dark and light grey Calcium Carbonate concretions.

3 - 15 cm. Dry 10YR5-2, moist 10YR4-2. Silty Clay Loam. Dry, very soft, weak fine crumb. Remnants of old prismatic structures. Moderately water absorbent. No roots. Many small dark and light grey concretions and fine white "mycelia" of Calcium Carbonate.

15 - 30 cm. Dry 10YR5-2, moist 10YR4-2, with 10YR4-3 material infilled in old cracks. Silty Clay Loam. Dry, soft, moderate coarse prismatic with common vertical cracks and no pores. Moderately water absorbent. Few fine roots. Few light grey concretions and many white "mycelia" of Calcium Carbonate.

30 - 80 cm. Dry 10YR4-1, moist 10YR3-2. Silty Clay. Dry, very hard, strong medium angular blocky with many cracks and no pores. Moderately water absorbent. Many soft greyish concretions, common hard concretions and "mycelia" of Calcium Carbonate. Common shell fragments.

80 - 106 cm. Dry 10YR4.5-2, moist 10YR3.5-2. Silt Loam. Dry, hard, moderate medium angular blocky with common cracks and many fine pores. Rapidly water absorbent. No roots. Many soft grey Calcium Carbonate concretions.

106 - 163 cm. Dry 2.5Y5-3, moist 2.5Y4-3. Loamy fine Sand. Dry, soft, structureless with no cracks and many pores. Rapidly water absorbent. No roots. Common white Calcium Carbonate streaks.

Laboratory Analyses:

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch. Na Meq. per 100 gm. soil.
0- 3	57	23	20	7.74	7.93	8.05	2.4	0.8	2.80
3- 15	40	32	28	2.45	8.12	8.25	3.8	3.8	7.60
15- 30	15	35	50	2.08	8.52	8.72	26.0	29.4	39.40
30- 80	35	35	30	7.96	7.85	8.65	10.2	10.2	18.20
80-106	57	28	15	16.43	8.15	9.23	3.0	2.6	10.60
106-163	87	8	5	3.34	8.30	9.25	2.9	1.5	5.50

Natrargidic Orthustent
Saline
Land Class 6.

Pit: DR221

Location: 378,000. 192,000. Date: 7.3.63.

Topography: Slope, about 1% to East, below a gravel ridge about 200 yds. West.

Cultivation and Land Use: Nil.

Vegetation: Few *Acacia erhenbergiana* bushes to the South-West.

Surface: Dry, firm, level. Many dark Calcium Carbonate concretions. Some stones.

Profile description:-

0 - 15 cm. Dry 10YR5-4, moist 10YR4-3. Silty Clay Loam. Dry, soft, structureless to weak very fine platy. Laminated. Moderately water absorbent. No roots. Common dark Calcium Carbonate concretions.

15 - 64 cm. Dry 10YR5-4, moist 10YR4-3. Silty Clay Loam. Dry, slightly hard, structureless with no cracks and few pores. Rapidly water absorbent. No roots. Common dark concretions and white streaks of Calcium Carbonate.

64 - 104 cm. Dry 10YR4.5-2, moist 10YR3.5-2. Silty Clay Loam. Dry, slightly hard, moderate fine subangular blocky with many fine cracks and few pores. Rapidly water absorbent. No roots. Many fine white soft "mycelia" (Gypsum?).

104 - 139 cm. Dry 10YR4-1, moist 10YR3-2. Silty Clay. Dry, very hard, moderate medium angular blocky with many fine cracks and few pores. Rapidly water absorbent. No roots. Many small white salt accumulations (Gypsum?).

139 - 180 cm. Dry and moist 10YR4-2. Silty Clay Loam. Dry, hard, moderate fine angular blocky with many fine cracks and few pores. Rapidly water absorbent. No roots. Many soft whitish Calcium Carbonate concretions.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch.Na Meq.per 100 gm. soil.
0- 15	57	20	23	6.06	8.50	9.52	0.9	0.6	6.40
15- 64	52	28	20	4.11	8.30	9.12	4.75	3.2	8.60
64-104	47	28	25	3.65	8.02	8.45	6.5	7.2	17.20
104-139	42	30	28	6.79	8.12	8.72	9.0	8.0	18.00
139-180	42	33	25	10.73	8.50	9.40	3.7	2.8	20.20

Natrargidic Orthustent
Slightly saline
Land Class 4.

Pit: DR262

Location: 367,000. 146,000 Date: 14.3.63.

Topography: Slightly undulating gravelly plain.

Cultivation and Land Use: Nil.

Vegetation: Nil (a few bushes in a depression about 1 km. East).

Surface: Dry, firm, with much loose sand, gravel and stones.

Profile description:-

0 - 15 cm. Dry 10YR6-2, moist 10YR4-3. Clay Loam. Dry, soft, moderate medium platy with many fine horizontal cracks and no pores. Rapidly water absorbent. Very few fine roots. No salts. Much gravel and stones.

15 - 27 cm. Dry and moist 10YR4-2. Clay Loam. Dry, loose, strong very fine crumb. Rapidly water absorbent. Very few fine roots. Many very small white salt specks.

27 - 67 cm. Dry and moist 10YR4-2. Clay Loam. Dry, slightly hard, moderate medium angular blocky with common fine cracks and few pores. Rapidly water absorbent. Very few fine roots. Common stones. Common white salt specks.

67 - 118 cm. Dry and moist 10YR3-2. Silty Clay. Dry, hard, strong medium angular blocky with many cracks. Some vertical cracks up to 1 cm. wide. Some old cracks infilled with material from above. Rapidly water absorbent. No roots. Few stones. Many white salt specks.

118 - 155 cm. Dry and moist 10YR4-1. Silty Clay. Dry, hard, strong medium angular blocky with many cracks. Moderately water absorbent. No roots. Few stones. Many Gypsum crystals, some long and hairlike.

155 - 172 cm. Dry 10YR5-3, moist 10YR4-3. Weathered Nubian sandstone with some Silty Clay (10YR4-1) in old cracks. Many Gypsum crystals.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq. per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 15	70	10	20	4.04	8.65	9.68	2.05	1.6	12.4
15- 27	42	23	35	2.65	8.12	8.45	24.0	8.0	24.8
27- 67	37	35	28	2.42	7.78	7.95	28.0	8.8	6.8
67-118	32	25	43	2.64	7.98	8.60	8.5	6.8	9.4
118-155	25	17	58	2.50	8.38	9.15	3.8	4.1	24.5

Natrargidic Orthustent.
Highly saline
Land Class 6.

Pit: DR268

Location: 356,000. 151,000. Date: 15.3.63.

Topography: Low Silt ridge, sloping slightly to the West. (An ancient canal runs along the top of the ridge).

Cultivation and Land Use: Nil.

Vegetation: Many Acacia erhenbergiana bushes and some date palms (Phoenix dactylifera) along the canal. Scattered small Aerva javanica bushes and Aristida sp. at the bottom of the ridge.

Surface: Dry, firm, level. Much loose sand. Many dark and light grey Calcium Carbonate concretions. Scattered small stones.

Profile description:-

0 - 10 cm. Dry 10YR4.5-2, moist 10YR3-2. Silt Loam. Dry, soft, moderate very fine platy, finely cracked. Rapidly water absorbent. No roots. Many dark and light grey Calcium Carbonate concretions.

10 - 55 cm. Dry 10YR4-2, moist 10YR3-2. Silty Clay Loam. Dry, slightly hard, weak medium angular blocky with fine cracks and few pores. Some wide vertical cracks. Rapidly water absorbent. No roots. Many fine white Calcium Carbonate streaks.

55 - 87 cm. Dry 10YR4-2, moist 10YR3-2. Silty Clay Loam. Dry, slightly hard, moderate fine angular blocky with many cracks and few pores. Rapidly water absorbent. No roots. Many fine white Calcium Carbonate streaks.

87 - 147cm. Dry 2.5Y5-2, moist 10YR3-2. Silt Loam. Dry, slightly hard, weak medium subangular blocky with few fine cracks and many pores. Rapidly water absorbent. No roots. Common fine white Calcium Carbonate streaks. Many small dark Calcium Carbonate concretions.

147 - 158cm. Dry 10YR6-3, moist 10YR4-3, Sand. Dry, loose, structureless desert sand. Rapidly water absorbent. No roots. Old root channels.infilled with Loam (Moist 2.5Y4-2). No salts.

158 - 182cm. Dry 2.5Y5-2, moist 2.5Y4-2. Silt Loam. Dry, slightly hard, structureless with no cracks and many fine pores. Rapidly water absorbent. No roots. No salts.

182 - 190cm. Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, loose, structureless, river origin. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 10	42	30	28	2.15	8.39	8.65	14.0	12.0	31.5
10- 55	65	17	18	3.78	8.49	8.89	3.6	2.8	12.2
55- 87	50	32	18	2.90	8.43	9.22	2.3	2.0	15.8
87-147	65	20	15	2.12	8.37	8.62	2.8	1.8	11.6
158-182	72	15	13	1.70	8.15	9.02	3.5	2.0	11.0

Natrargidic Orthustent
Saline
Land Class 6.

Pit: DR280

Location: 360,000. 131,000. Date: 16.3.63.

Topography: Flat

Cultivation and Land Use: Nil

Vegetation: Nil

Surface: Dry, firm, with much loose sand, slightly ripplied in places. Many light grey nodular Calcium Carbonate concretions.

Profile description:-

0 - 17 cm. Dry 2.5Y5-2, moist 10YR3-2. Silt Loam. Dry, soft, moderate fine platy with many fine cracks and few pores. Rapidly water absorbent. No roots. Many grey Calcium Carbonate concretions.

17 - 54 cm. Dry 2.5Y5-2, moist 10YR3-2. Silt Loam. Dry, slightly hard, weak medium angular blocky with few cracks and many pores. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate concretions formed in old root channels.

54 - 87 cm. Dry 2.5Y5-2, moist 2.5Y3-2. Fine Sandy Loam. Dry, soft, structureless, laminated. Rapidly water absorbent. No roots. Many old root channels.infilled with Calcium Carbonate.

87 - 115 cm. Dry 2.5Y5-2, moist 2.5Y3-2. Silt Loam. Dry, slightly hard, structureless with no cracks and many pores. Rapidly water absorbent. Many small Calcium Carbonate concretions.

115 - 145 cm. Dry 10YR4-1.5, moist 10YR3-2. Silt Loam. Dry, slightly hard, moderate fine angular blocky with common fine cracks and few pores. Moderately water absorbent. No roots. Many small Calcium Carbonate concretions.

145 - 172 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Loamy fine sand. Dry, very soft, structureless river sand. Rapidly water absorbent. No roots. No salts. Common mica.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch.Na Meq.per 100 gm. soil.
0- 17	62	23	15	2.26	8.24	8.62	4.5	3.6	12.1
17- 54	69	22	9	5.66	7.59	8.00	16.0	8.8	17.2
54- 87	87	5	8	0.84	8.45	8.92	0.9	0.8	8 .60
87-115	72	15	13	4.85	8.92	9.39	0.9	0.9	10.10
115-145	76	15	9	5.17	9.12	9.34	1.1	0.8	16.40
145-172	91	2	7	0.60	8.98	9.04	0.65	0.5	13.50

Natrargidic Orthustent
Saline
Land Class 6.

Pit: DR284.

Location: 358,000. 122,000. Date: 18.3.63.

Topography: Flat Plain with some wide shallow depressions about 1 ft. deep.

Cultivation and Land Use: Nil.

Vegetation: Small dried-up woody plant "skeletons" in the depressions.

Surface: Dry, soft beneath a thin soft finely cracked crust. Covered with a very thin layer of sand and gravel. Scattered stones and many light grey Calcium Carbonate concretions.

Profile description:-

0 - 2 cm. Dry 10YR6-3, moist 10YR4-3. Loamy sand. Dry, very soft, moderate fine platy with fine cracks and no pores. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate concretions.

2 - 21 cm. Dry and moist 10YR4-1. Clay. Dry, slightly hard, strong very fine angular blocky, with many cracks and few pores. Much sand in the cracks. Rapidly water absorbent. No roots. Many fine white salt flecks. Some Calcium Carbonate concretions.

21 - 56 cm. Dry and moist 10YR4-1. Clay. Dry, hard, strong medium prismatic with many wide vertical cracks infilled with sand. No pores. Moderately water absorbent. No roots. Many soft white salt accumulations.

56 - 103 cm. Dry 10YR4-1, moist 10YR3-2. Silty Clay. Dry, very hard, strong medium angular blocky with many cracks and no pores. Few wide vertical cracks. Little sand. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Common light grey Calcium Carbonate concretions. Few soft white salt accumulations.

103 - 118cm. Dry 10YR4-1, moist 10YR4-2. Silty Clay Loam. Dry, hard, moderate fine subangular blocky with common fine cracks and no pores. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Abundant light grey concretions of Calcium Carbonate.

118 - 175 cm. Dry 10YR5-3.5, moist 10YR4-3. Loamy Sand. Dry, hard, structureless, compact. Apparently cemented by Calcium Carbonate. Many white Calcium Carbonate streaks. Some old animal burrows (Krotovinas) infilled with dark material from above.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 21	27	13	60	2.08	7.90	7.93	9.0	8.0	13.6
21- 56	17	18	65	2.16	7.29	7.38	18.0	25.6	23.2
56-103	30	30	40	6.65	7.60	8.34	13.0	8.4	16.0
103-118	62	25	13	17.90	8.73	9.12	3.0	1.9	12.5
118-175	85	10	5	15.90	8.96	9.42	1.3	0.6	4.8

Natrargidic Orthustent.
Saline
Land Class 6.

Pit: DR290.

Location: 355,000. 110,000. Date: 19.3.63.

Topography: Flat.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Dry, soft beneath a very thin crust. Covered with loose sand. Many dark and light grey Calcium Carbonate concretions. Common shell fragments.

Profile description:-

0 - 1 cm. Dry 10YR6-4, moist 10YR4-4. Sand. Dry, loose, structureless. Rapidly water absorbent. Calcium Carbonate as above.

1 - 15 cm. Dry and moist 10YR4-2. Clay Loam. Dry, soft, strong fine crumb. Remnants of old prismatic structures with much sand in the cracks. Moderately water absorbent. Few fine roots. Many concretions and few streaks of Calcium Carbonate.

15 - 45 cm. Dry and moist 10YR4-2. Clay loam. Dry, soft, structureless with no cracks or pores. Some old cracks up to 4 cm. wide extending to 150 cm., infilled with sandy material (10YR4-3). Rapidly water absorbent. Few fine roots. Common streaks of Calcium Carbonate.

45 - 90 cm. Dry and moist 10YR4-2. Clay Loam. Dry, slightly hard, weak medium subangular blocky with few cracks. Some old shiny surfaces (slickensides) inclined at about 45°. Some old wide infilled vertical cracks. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate concretions. Common transparent crystals of Gypsum.

90 - 173 cm. Dry 10YR3-2, moist 10YR4-2. Silty Clay. Dry, hard, strong medium angular blocky with many cracks and no pores. Old wide infilled vertical cracks disappearing about 150 cm. Rapidly water absorbent (softening rapidly to a fine tilth). No roots. Many dark and light grey Calcium Carbonate concretions and veins in old cracks. Many small white salt specks and fine hairlike crystals of Gypsum.

Laboratory Analyses:-

Depth cm.	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 15	60	15	25	1.65	9.00	9.48	2.2	1.1	9.7
15- 45	77	13	10	0.95	7.93	8.64	3.6	1.7	4.2
45- 90	57	25	18	1.32	7.61	8.01	6.0	3.6	6.6
90-130	45	32	23	2.18	7.61	8.42	5.5	3.6	10.4
130-173	37	38	25	3.28	7.68	8.51	5.0	4.0	10.8

Natrargidic Orthustent.
Slightly Saline.
Land Class 4

Pit: DR295

Location: 350,000. 110,000. Date: 20.3.63.

Topography: Near the bottom of a broad shallow depression.

Cultivation and Land Use: Nil.

Vegetation: Scattered patches of Aerva javanica and tussocks of Aristida sp. None near the pit.

Surface: Dry, soft, with much loose sand and gravel. Scattered stones. Few grey Calcium Carbonate concretions.

Profile description:-

0 - 13 cm. Dry 10YR4-1, moist 10YR3-2. Silt Loam. Dry, very soft to loose, strong very fine crumb. Remnants of old prismatic structures with infilled cracks. Rapidly water absorbent. Common soft white Calcium Carbonate concretions.

13 - 31 cm. Dry 2.5Y5-2, moist 10YR4-3. Silt Loam. Dry, soft, moderate medium angular blocky with common cracks and no pores. Rapidly water absorbent. Many hard light grey Calcium Carbonate concretions.

31 - 85 cm. Dry 10YR4-1.5, moist 10YR3-2 with few 10YR3-4 mottles. Silty Clay Loam. Dry, hard, moderate fine angular blocky with many fine cracks and few pores. Rapidly water absorbent. Many Calcium Carbonate streaks and grey concretions in old root channels.

85 - 104 cm. Dry 2.5Y5-2, moist 10YR3-2 with common 7.5YR4-4 mottles. Very Fine Sandy Loam. Dry, slightly hard, structureless with no cracks and many pores. Rapidly water absorbent. Few Calcium Carbonate streaks.

104 - 131cm. Dry 10YR4.5-2, moist 10YR3-2 with no mottles. Silt Loam. Dry, slightly hard, weak fine angular blocky with common cracks and pores. Rapidly water absorbent. Few Calcium Carbonate streaks.

131 - 150cm. Dry 2.5Y5-3, moist 2.5Y4-2. Very Fine Sandy Loam. Dry, slightly hard, structureless with no cracks and common pores. Rapidly water absorbent. No salts.

150 - 173cm. Dry 2.5Y5-2, moist 10YR4-2 with many 10YR4-4 mottles. Fine Sand. Dry, loose, structureless, river sand. Rapidly water absorbent. No salts. Common mica.

173 - 186cm. Dry 10YR6-3, moist 10YR4-3 Gravelly sand. Dry, loose, structureless, mixed river and desert sand. Rapidly water absorbent. No salts. Common mica.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon.	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil.
	Sand	Silt	Clay	%	Soil Paste	1:5 Soil suspension			
0- 13	57	28	15	1.78	8.43	8.79	2.6	1.8	9.7
13- 31	37	30	33	2.94	8.58	8.61	44.0	54.4	32.6
31- 85	75	15	10	1.74	7.75	8.32	9.0	4.6	10.4
85-104	85	10	5	0.38	7.52	7.98	3.4	1.8	6.4
104-131	74	18	8	0.90	7.53	8.27	3.5	1.8	3.8
131-150	77	15	8	0.75	7.68	8.52	2.3	1.5	7.2
150-173	92	1	7	0.20	7.65	7.52	1.2	0.5	4.7

Natrargidic Orthustent
Highly Saline
Land Class 6.

Pit: DR316

Location: 357,000. 94,000. Date: 27.3.63.

Topography: Slight slope to North-West.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Dry, very soft beneath a thin soft crust. Many small dark Calcium Carbonate concretions.

Profile description:-

0 - 2 c.m. Dry 10YR5-3, moist 10YR4-3. Loam. Dry, very soft, weak fine subangular blocky. Laminated. Moderately water absorbent. No roots. Many small dark Calcium Carbonate concretions.

2 - 8 cm. Dry 10YR5-3, moist 10YR4-2. Loam. Dry, very soft, strong very fine crumb. Moderately water absorbent. No roots. Some small dark Calcium Carbonate concretions. Many soft white salt accumulations.

8 - 37 cm. Dry and moist 10YR4-2. Silty Clay Loam. Dry, soft, moderate very fine platy with many old vertical cracks infilled with material from above. Rapidly water absorbent. No roots. Few Calcium Carbonate concretions. Many soft white salt accumulations.

37 - 74 cm. As above with no Calcium Carbonate concretions, and abundant soft white salt accumulations and Gypsum crystals

74 - 131 cm. Dry and moist 10YR4-2. Silty Clay Loam. Dry, very hard, moderate medium angular blocky with many fine cracks and no pores. Rapidly water absorbent. No roots. Few dark Calcium Carbonate concretions. Many white salt accumulations in old cracks and root channels. Few shell fragments.

131-175 cm. Dry and moist 10YR4-2. Silty Clay, Dry, very hard, moderate medium angular blocky with many fine cracks and no pores. Moderately water absorbent. No roots. Common light grey Calcium Carbonate concretions. Few Gypsum crystals.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	PH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 8	70	15	15	3.38	8.12	8.25	2.2	0.35	6.2
8- 37	50	25	25	3.62	7.92	7.95	4.0	3.0	6.9
37- 74	42	26	32	3.84	8.75	9.03	36.0	32.0	38.0
74-131	30	20	50	7.60	8.12	8.74	19.0	11.2	28.8
131-175	35	22	43	13.2	7.98	9.12	13.5	9.7	18.3

Natrargidic Orthustent
Highly saline
Land Class 6.

Pit: DR359

Location: 328,000. 45,000 Date: 4.4.63.

Topography: Very slight slope to North-East.

Cultivation and Land Use: Nil.

Vegetation: Some *Acacia erhenbergiana* bushes in run-off channels, with sand accumulated around them.

Surface: Dry, firm, level, with no cracks. Much fine gravel. Many dark Calcium Carbonate concretions.

Profile description:-

0 - 2 cm. Dry 10YR6-4, moist 10YR4-4. Sand. Dry, loose, structureless, wind blown. Rapidly water absorbent. No roots. Many dark Calcium Carbonate concretions.

2 - 8 cm. Dry 10YR6-3, moist 10YR4-3, Clay Loam. Dry, soft, weak medium subangular blocky with few cracks and many pores. Moderately water absorbent. No roots. Some gravel. Some dark Calcium Carbonate concretions.

8 - 41 cm. Dry 10YR5-3, moist 10YR4-3. Clay Loam. Dry, soft, strong very fine angular blocky with many cracks and few pores. Some laminations. Moderately water absorbent. Few fine roots. Common light grey Calcium Carbonate concretions.

41 - 62 cm. Dry 10YR5-3, moist 10YR4-3. Silty Clay Loam. Dry, hard, strong medium prismatic with many cracks and no pores. Strongly and finely laminated Rapidly water absorbent. No roots. Much hard grey Calcium Carbonate in pans in old cracks. Much soft white salt, especially near the surface of this horizon.

62 - 119 cm. Dry 10YR5-3, moist 10YR4-3. Silty Clay Loam. Dry, hard, strong medium prismatic with many cracks and no pores. Strongly and coarsely laminated. Rapidly water absorbent. No roots. Much Calcium Carbonate in pans (Caliche) in old vertical cracks. Many soft white salt accumulations.

119- 158 cm. Dry 10YR5-2, moist 10YR4-2. Silty Clay Loam. Dry, hard, strong medium angular blocky with many cracks and no pores. Some laminations. Rapidly water absorbent. No roots. Abundant Caliche in cracks. Some soft white salt accumulations.

158 - 179 cm. Dry, 10YR6-3, moist 2.5Y4-3. Silt Loam. Dry, slightly hard, weak fine platy with few cracks and common pores. Weakly laminated. Rapidly water absorbent. No roots. Many thin Caliche layers in old cracks.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch. Na. Meq.per 100 gm. soil.
0- 8	65	10	25	3.2	8.62	8.98	0.62	0.25	4.1
8- 41	42	20	38	5.28	8.82	9.48	2.2	1.8	17.2
41- 62	30	42	28	7.00	8.59	8.73	40.8	44.5	37.5
62-119	15	42	43	5.81	8.00	8.62	19.0	19.4	46.6
119-158	40	27	33	8.85	7.75	8.57	13.6	10.4	31.6
158-179	45	35	20	7.40	7.85	8.59	8.2	18.0	17.5

Natrargidic Orthustent.

Highly saline. Land Class 6

Pit: DR394

Location: 295,000. 38,000. Date: 9.4.63.

Topography: Flat, with sandy mounds and dunes to the North and West.

Cultivation and Land Use: Nil.

Vegetation: *Acacia erhenbergiana* on sandy mounds. *Aerva javanica* in some shallow sand depressions.

Surface: Dry, firm, with some loose sand. Very many grey Calcium Carbonate concretions.

Profile description:

0 - 9 cm. Dry 10YR5-4, moist 10YR4-4. Clay Loam. Dry, slightly hard, weak medium subangular blocky with few cracks and many pores. Rapidly water absorbent. No roots. Common dark Calcium Carbonate concretions

9 - 34 cm. Dry 10YR4.5-3, moist 10YR3.5-3. Silty Clay Loam. Dry, slightly hard, strong fine subangular blocky with many cracks and few pores. Rapidl water absorbent. No roots. Common light grey Calcium Carbonate concretions.

34 - 53 cm. Dry 10YR5-4, moist 10YR4-3. Silt Loam. Dry, slightly hard, weak fine subangular blocky with few cracks and pores. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate concretions and white salt specks.

53 - 96 cm. Dry 10YR4-2, moist 10YR3-2. Silty Clay Loam. Dry, hard, moderate medium subangular blocky with many cracks and few pores. Some old cracks infilled with material from above. Rapidly water absorbent. No roots. Many light grey Calcium Carbonate concretions.

96 - 140 cm. Dry 10YR5-4, moist 10YR4-3. Silty Clay Loam. Dry, hard, structureles Compact, with no cracks or pores. Rapidly water absorbent. No roots. Many Gypsum crystals and light grey Calcium Carbonate concretions.

140 - 174.cm. Dry 10YR4.5-3, moist 10YR4-3. Silty Clay Loam. Dry, hard, moderate medium subangular blocky with many cracks and no pores. Rapidly water absorbent. No roots Many light grey Calcium Carbonate concretions. Very many Gypsum crystals.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon.	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq. per 100 gm. soil
	Sand	Silt	Clay	%	Soil Paste	1:5 Soil suspension			
0- 9	68	8	24	5.51	8.57	9.38	1.02	0.5	7.0
9- 34	40	21	39	7.09	8.52	9.26	6.5	3.6	20.8
34- 53	65	18	17	3.78	8.35	8.75	11.0	10.0	10.9
53- 96	60	21	19	3.13	8.48	8.65	36.0	26.2	19.0
96-140	25	16	49	4.32	8.32	8.76	14.0	13.1	37.4
140-174	53	18	29	4.61	8.61	8.80	30.8	38.2	20.8

Natrargidic Orthustent
Saline
Land Class 6.

C. Vertic Orthustent

Pit: DR311

Location:

Date: 26.3.63.

Topography: Flat, with some shallow watercourses nearby.

Cultivation and Land Use: Nil. (some grazing)

Vegetation: Many Acacia nilotica and Acacia seyal trees. Much Calotropis procera. Common Capparis decidua and Salvadora persica.

Surface: Dry, hard, with a thin layer of loose dust. Polygonal cracks, 1 cm. wide, partly infilled.

Profile description:

0 - 36 cm. Dry 10YR4-2, moist 10YR3-2.5. Silty Clay, Dry, hard, strong coarse subangular blocky with many cracks and few pores. Moderately water absorbent. Many fine roots. No salts.

36 - 59 cm. Moist 10YR3-2 with some 7.5YR4-4 mottles and black stains (Manganese?). Silty Clay Loam. Slightly moist, firm, structureless with few cracks and common pores. Moderately water absorbent. Many fine roots. No salts.

59 - 93 cm. Moist 2.5Y4-3 with no mottles and common black stains. Clay Loam. Slightly moist, friable, structureless with no cracks and common pores. Rapidly water absorbent. Common fine roots. No salts.

93 - 176 cm. Moist 2.5Y3.5-2. Silt Loam. Slightly moist, friable, structureless with no cracks and common pores. Rapidly water absorbent. Common fine roots. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil
0- 36	25	22	53	1.59	6.26	7.08	0.27	0.05	0.6
36- 59	47	15	38	1.51	7.68	7.91	0.35	0.04	0.3
59- 93	62	15	23	1.13	7.71	7.91	0.30	0	0.7
93-130	60	22	18	2.04	7.82	8.10	0.30	0.04	0.7
130-176	62	23	15	2.84	7.78	8.35	0.46	0.07	1.3

Vertic Orthustent
Non-saline
Land Class 1/2.

D. Natrargidic Vertic Orthustent.

Pit: DR243

Location: Date: 11.3.63.

Topography: Low silt hummocks and depressions.

Cultivation and Land Use: Nil.

Vegetation: Two *Tamarix nilotica* bushes and one *Calotropis procera* 100 yds. away. Otherwise nil.

Surface: Dry, firm, with a thin finely cracked cap in parts. Many light grey nodular Calcium Carbonate concretions.

Profile description:-

0 - 9 cm. Dry and moist 10YR4-2. Clay Loam. Dry, soft, strong fine subangular blocky with many fine cracks and pores. Remnants of old prismatic structures. Rapidly water absorbent. No roots. Many light grey nodular Calcium Carbonate concretions.

9 - 27 cm. Dry and moist 10YR4-2. Silty Clay. Dry, slightly hard, weak fine platy with few cracks and pores. Rapidly water absorbent. No roots. Common large Calcium Carbonate concretions. Many small white salt flecks (Gypsum?).

27 - 86 cm. Dry and moist 10YR3-2. Silty Clay. Dry, hard, strong medium angular blocky with many cracks and no pores. Many smeared surfaces (slickensides) at about 45° to the horizontal. Rapidly water absorbent. No roots. Many large and small grey Calcium Carbonate concretions.

86 - 131 cm. Dry and moist 10YR3-2. Silty Clay. Dry, hard, strong medium angular blocky. Main structure planes vertical and at 45° (not horizontal). Rapidly water absorbent. No roots. Many Calcium Carbonate concretions and thin Caliche (hard Calcium Carbonate) layers about ½ cm. thick, all at about 45°.

131 - 178cm. Dry and moist 10YR4-2 with faint 10YR4-3 mottles. Silty Clay. Dry, slightly hard, strong medium and fine angular blocky with structure planes as above. Common white Calcium Carbonate concretions. Many thin Caliche layers and white Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon.	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq. per 100 gm. soil
	Sand	Silt	Clay	%	Soil Paste	1:5 Soil suspension			
0- 9	35	17	48	3.47	8.26	8.91	26.0	16.8	33.6
9- 27	35	20	45	3.65	7.97	8.43	32.0	25.6	28.8
27- 60	20	25	55	4.02	7.86	8.44	24.0	18.1	28.3
60- 86	22	31	47	6.83	8.33	8.32	8.8	8.0	29.4
86-131	27	25	48	12.23	8.62	9.69	2.1	2.2	19.8
131-178	30	27	43	9.31	8.42	9.42	1.4	14.2	2.6

Natrargidic Vertic Orthustent.
Highly saline
Land Class 6.

E. Salorthid.

Pit: DR246

Location: 362,000. 159,000. Date: 11.3.63.

Topography: Flat.

Cultivation and Land Use: Nil.

Vegetation: None near the pit. Dense Tamarix scrub in the Kerma Basin starts 50 yds. North.

Surface: Patches of dry and moist sand, very soft. Pit in a moist patch.

Profile description:-

0 - 23 cm. Moist 10YR5-4. Sand. Moist, loose, structureless, wind-bedded desert sand. No visible salts.

23 - 69 cm. Dry 10YR6-4, moist 10YR4-4. Sand. Dry, loose, structureless desert sand. Rapidly water absorbent. No visible salts.

69 - 92 cm. Moist 10YR3-2. Clay. Moist, firm, structureless. Old vertical cracks up to 3 cm. wide infilled with sand. Moderately water absorbent. No roots. No salts.

92 - 140 cm. Moist 10YR3-2 with faint 10YR2-2 mottles. Clay. Moist, firm, structureless. Few cracks, infilled with sand, extending to the base of this horizon. Moderately water absorbent. No roots. Few black stains (Manganese?).

140 - 155cm. Moist 10YR3-2. Thin bands of Silt Loam and Silty Clay Loam. Very moist, friable to firm, structureless with no cracks. Moderately water absorbent. No roots. No salts.

155 - 170cm. Moist 10YR3-2 and 2.5Y3-2. Thin bands of Silty Clay Loam and Sand. Very moist, friable to firm, structureless with no cracks. Rapidly water absorbent. No roots. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon.	PH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Excha.Na. Meq.per 100 gm. soil
	Sand	Silt	Clay	%	Soil Paste	1:5 Soil suspension			
0- 23	92	5	3	1.46	7.37	7.41	100.8	6.4	2.30
23- 69	95	0	5	1.77	7.72	7.85	30.0	6.0	4.10
69- 92	40	22	38	1.17	7.81	7.98	7.6	4.4	8.60
92-140	35	27	38	1.65	7.65	7.99	4.5	4.6	11.20
140-170	80	10	10	0.40	7.68	8.15	3.4	1.7	5.10

Salorthid
Very highly saline
Land Class 6.

Pit: DR252

Location: 364,000. 158,000. Date: 12.3.63.

Topography: Flat. Sand dunes about 1 km. away to the West.

Cultivation and Land Use: Nil.

Vegetation: Nil.

Surface: Dry, soft. Much loose sand, slightly rippled in places. Many large light grey Calcium Carbonate concretions.

Profile description:-

0 - 2 cm. Dry 10YR5-3, moist 10YR4-2. Loamy Coarse Sand. Dry, very soft, structureless. Laminated. Rapidly water absorbent. No roots. Many large light grey Calcium Carbonate concretions.

2 - 26 cm. Dry and moist 10YR4-2. Silty Clay Loam. Dry, soft, moderate very fine crumb. Remnants of old prismatic structures with cracks infilled with material from above. Moderately water absorbent. No roots. Many white salt streaks (Gypsum?).

26 - 62 cm. Dry 10YR4-1, moist 10YR3-2. Silty Clay. Dry, slightly hard, strong very fine angular blocky with many cracks and no pores. Some wide vertical cracks. Rapidly water absorbent. No roots. Many white salt streaks and dull opaque gypsum crystals, some fibrous in thin horizontal pans up to 1 cm.thick. Common grey Calcium Carbonate concretions.

62 - 132 cm. Dry 10YR4-2, moist 10YR3.5-2. Silty Clay Loam. Dry, hard, moderate medium angular blocky. Compact, with few cracks and no pores. Rapidly water absorbent. No roots. Many white salt streaks and some crystals of Gypsum. No pans. Common grey Calcium Carbonate concretions and shiny Sodium Chloride stains on some ped faces.

132 - 184cm. Dry 10YR4-1.5, moist 10YR4-2. Silty Clay. Dry, very hard, strong medium angular blocky, with many cracks and no pores. Rapidly water absorbent. No roots. Many grey Calcium Carbonate concretions, and shiny Sodium Chloride stains on ped faces. Common soft shiny transparent Gypsum crystals.

Laboratory analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. meq.per litre	Exch.Na. Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 26	25	25	50	3.29	8.42	8.80	57.6	40.0	56.
26- 62	22	33	45	3.78	8.45	8.89	80.0	76.9	45.1
62-100	30	13	57	4.08	8.49	8.90	80.0	73.6	34.4
100-132	27	28	45	4.08	7.98	8.51	61.6	70.4	25.6
132-184	15	20	65	2.90	7.86	8.15	36.0	38.6	36.4

Salorthid.
Very highly saline.
Land Class 6.

Pit: DR312

Location: 343,000. 70,000 Date: 26.3.63.

Topography: Slightly undulating sandy plain.

Cultivation and Land Use: Nil.

Vegetation: Scatter Aerva javanica and small tussocks of Aristida sp.

Surface: Dry, soft, with much loose sand and common light grey Calcium Carbonate concretions.

Profile description :-

0 - 5 cm. Dry 10YR6-3, moist 10YR5-4. Sand. Dry, loose, structureless windblown sand. Rapidly water absorbent. No roots. Common light grey Calcium Carbonate concretions.

5 - 16 cm. Dry and moist 10YR4-2 with some 10YR4-4 mottles. Clay Loam. Dry, hard, moderate medium angular blocky with common cracks and no pores. Rapidly water absorbent. No roots. Many small white salt specks.

16 - 26 cm. Dry 2.5Y5-2, moist 2.5Y4-2 with common 10YR5-8 mottles. Loam. Dry, hard, weak medium subangular blocky with few cracks and no pores. Rapidly water absorbent. No roots. Common small white salt specks. Few Calcium Carbonate streaks.

26 - 110 cm. Dry 10YR7-3, moist 10YR6-3. Sand. Dry, very soft to loose, structureless with no cracks or pores. Rapidly water absorbent. No roots. Old root channels infilled with material from above and some Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na Meq.per litre	Exch.Na. Meq.per 100 gm. soil
0- 5	77	5	18	0.93	9.12	9.38	14.4	7.05	21.0
5- 16	42	20	38	2.90	8.67	9.02	81.6	62.0	37.0
16- 26	62	15	23	1.89	9.24	9.93	5.6	4.50	18.1
26-110	94	2	4	0.38	10.72	9.50	1.04	0.33	1.1

Salorthid
Very highly saline.
Land Class 6.

F. Psammustentic Orthustent.

Pit: DR182

Location: 368,000. 194,000 Date: 19.2.63.

Topography: Flat (near the edge of Kerma Basin).

Cultivation and Land Use: Nil.

Vegetation: Sparse vestigial grasses. Many low Bergia suffructiosa shrubs and Cotula kotschyi. Scattered Tamarix articulata.

Surface: Dry, hard, cracked into small blocks. No salts.

Profile description:-

0 - 7 cm. Dry 10YR4.5-2, moist 10YR3.5-2. Silty Clay Loam. Dry, slightly hard, strong medium subangular blocky to 5 cm., structureless and laminated beneath. Many cracks. R apidly water absorbent. Many fine roots. No salts.

7 - 21 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Loamy Fine Sand. Dry, soft, structureless with no cracks or pores. Rapidly water absorbent. Many fine roots. No salts.

21 - 78 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, loose, structureless. Rapidly water absorbent. Many fine roots. Some coarse desert sand and gravel layers.

78 - 92 cm. Moist 2.5Y4-2. Loamy Fine Sand. Moist, friable, structureless. Rapidly water absorbent. Common roots. No desert sand.

92 - 132 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, loose, structureless. Rapidly water absorbent. Common roots. Much desert sand.

132 - 175 cm. Moist 2.5Y4-2. Fine Sand. Very moist, loose, structureless. Rapidly water absorbent. Few roots. Little desert sand.

Laboratory Analyses:-

Depth cm	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil
0- 7	52	15	33	2.76	7.50	7.85	0.80	0.2	1.37
7- 21	77	13	10	0.75	8.65	9.30	1.60	0.6	8.45
21- 78	97	0	3	0.19	8.15	7.25	0.25	0.05	0.30
78- 92	95	2	3	0.27	7.75	7.35	0.24	0.1	0.07
92-132	100	Traces		Nil	8.81	8.10	0.16	0.04	0.13
132-175	100	Traces		0.19	8.45	7.10	0.23	0.03	0

Psammustentic Orthustent
Non-saline
Land Class 4

Pit: DR199

Location: 360,000. 185,000. Date: 22.2.63.

Topography: Flat top of a low ridge, with a shallow channel 200 yds. away

Cultivation and Land Use: Nil.

Vegetation: Nil. *Acacia erhenbergiana* bushes in the channel.

Surface: Dry, firm, sandy with common gravel and stones. Few Calcium Carbonate nodules.

Profile description:-

0 - 1 cm. Dry 10YR6-3, moist 10YR4-3. Loamy sand. Dry, soft, structureless, laminated wind blown crust. Rapidly water absorbent. No salts.

1 - 4 cm. Dry 10YR6-2, moist 10YR4-3. Silt Loam. Dry, soft, moderate medium subangular blocky. Rapidly water absorbent. Highly calcareous.

4 - 9 cm. Dry 10YR5-2, moist 10YR3-2. Silt Loam. Dry, soft, moderate medium subangular blocky with many fine cracks and no pores. Rapidly water absorbent. No roots. Common fine Calcium Carbonate streaks.

9 - 34 cm. Dry 10YR5-2, moist 10YR3-2. Silt Loam. Dry, soft, weak subangular blocky with few cracks and no pores. Rapidly water absorbent. No roots. Few fine Calcium Carbonate streaks.

34 - 115 cm. Dry 10YR6-3, moist 10YR5-2. Sand. Dry, loose, structureless. Rapidly water absorbent. Many old root channels infilled with Loamy sand. Little Calcium carbonate.

115 - 158cm. Dry 10YR5-2, moist 10YR3-2. Silt Loam. Dry, soft, weak medium subangular blocky with few cracks and no pores. Rapidly water absorbent. No roots. Few fine Calcium Carbonate streaks.

158 - 178cm. Dry 10YR6-3, moist 10YR5-2. Sand. Dry, loose, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts.

Laboratory Analyses:-

Depth Cm.	Soil Particles % Sand	Silt	Clay	Incorp. Carbon. %	pH Soil Paste	pH 1:5 Soil suspension	E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na Meq.per 100 gm. soil
0- 4	47	23	30	2.57	8.12	8.51	3.4	1.3	3.40
4- 9	77	10	13	2.94	8.93	9.83	0.84	0.6	18.2
9- 34	80	10	10	0.63	8.62	9.15	4.4	2.6	12.2
34-115	93	5	2	0.21	7.50	7.62	3.0	0.5	1.07
115-158	88	10	2	1.60	7.82	8.21	3.7	1.2	2.90
158-178	93	5	2	0.10	8.15	8.10	1.65	0.35	1.39

Psammustentic Orthustent.
Slightly saline.
Land Class 4.

Pit: DR207

Location: 365,000. 174,000. Date: 23.2.63.

Topography: Flat bottom of an annually flooded depression.

Cultivation and Land Use: Nil at the pit site. Sagia-grown wheat and other crops 100 yds.North. Some Lupins grown on residnal moisture round the edges of the depression.

Vegetation: Tamarix articulata bushes 5 to 10 yds. apart. Continuous sward of grass about 1 cm. high, dried up.

Surface: Dry, hard, level. Sharp-edged polygonal cracks up to 5 cm. wide. Peds up to 30 cm. across.

Profile description:-

0 - 15 cm. Dry 10YR2.5-2, moist 10YR2-2. Clay. Dry, hard, strong fine prismatic. Separate blocks 10 to 30 cm. across resting on the underlying sand layer. Moderately water absorbent. Many fine roots. No salts.

15 - 22 cm. Dry 10YR5-3, moist 10YR4-3. Loamy Sand. Dry, soft, structureless with no cracks or pores. Rapidly water absorbent. Many fine roots. No salts.

22 - 165cm. Dry 2.55-2, moist 2.5Y4-2. Sand. Dry to 50 cm., moist to 120 cm., wet below 120 cm. Structureless with no cracks or pores. Rapidly water absorbent. Many fine roots to 30 cm., many coarse Tamarix roots and no fine roots below 30 cm. Some old root channels infilled with Calcium Carbonate.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.N_a Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 15	40	2	58	1.03	6.92	7.43	0.38	0.1	1.10
15- 22	92	3	5	0.24	7.62	7.52	0.47	0.1	0.25
22- 60	97	3	0	0.29	8.10	7.85	0.25	0.06	0.29
60-110	100	Traces		0.54	8.53	8.35	0.34	0.06	0.29
110-165	100	Traces		0.49	8.45	8.44	0.40	0.06	0.29

Psammustentic Orthustent
Non-saline
Land Class 4.

Pit: DR310

Location: 364,000. 113,000. Date: 25.3.63.

Topography: Slightly undulating plain.

Cultivation and Land Use: Nil.

Vegetation: Scattered *Acacia erhenbergiana* bushes and *Aristida* sp.

Surface: Dry, firm, with much loose sand. Many small light grey Calcium Carbonate concretions.

Profile description:-

0 - 11 cm. Dry 10YR5-2, moist 10YR3-2 with few 7.5YR4-4 mottles. Silt Loam. Dry, soft, moderate fine platy with many fine cracks and common pores. Rapidly water absorbent. No roots. Some light grey Calcium Carbonate concretions.

11 - 64 cm. Dry 2.5Y5-2, moist 10YR3-2 with many 5YR4-6 mottles. Silt Loam. Dry, slightly hard, moderate medium subangular blocky with many fine cracks and common pores. Few fine roots (dead). Many small whitish Calcium Carbonate streaks.

64 - 114cm. Dry 2.5Y5-2, moist 10YR3-2 with many 5YR4-6 mottles. Very Fine Sandy Loam. Dry, slightly hard, weak medium subangular blocky with few fine cracks.and pores. Rapidly water absorbent. Rare fine roots. Many small whitish Calcium Carbonate streaks.

114 - 137 cm. Dry 2.5Y5-2, moist 2.5Y4-2 with no mottles. Loamy Fine Sand. Dry, very soft, structureless with no cracks or pores. Bedding planes visible. Some old infilled root channels. Rapidly water absorbent. No roots. Many small whitish Calcium Carbonate streaks.

137 - 175 cm. Dry 2.5Y5-2, moist 10YR3-2 with occasional 7.5YR4-4 mottles. Very Fine Sandy Loam. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. Many whitish streaks and few grey concretions of Calcium Carbonate.

175 - 183 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Fine Sand. Dry, very soft, structureless with no cracks or pores. Rapidly water absorbent. No roots. Few whitish Calcium Carbonate streaks.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 11	77	18	5	1.90	8.31	8.81	1.4	0.95	4.2
11- 64	85	10	5	2.34	8.38	8.84	2.3	1.40	5.9
64-114	90	7	3	2.83	8.15	8.82	2.8	1.80	6.2
114-137	97	3	0	0.43	8.28	8.62	0.57	0.37	1.3
137-175	87	10	3	2.64	8.32	8.96	0.40	0.23	2.9

Psammustentic Orthustent
Non-saline
Land Class 2/4.

Pit: DR330

Location: 351,000. 75,000. Date: 30.3.63.

Topography: Flat, with low sandy mounds around bushes.

Cultivation and Land Use: Nil.

Vegetation: Acacia erhenbergiana bushes 10 to 40 yds. apart. Scattered Calotropis procera.

Surface: Dry, soft, sandy, with much loose gravel and scattered stones. Many dark Calcium Carbonate concretions.

Profile description:-

0 - 4 cm. Dry 10YR6-3, moist 10YR4-3. Sand. Dry, loose, structureless. Rapidly water absorbent. Many dark Calcium Carbonate concretions.

4 - 29 cm. Dry 10YR4-1.5, moist 10YR4-2. Loam. Dry, soft, weak, medium platy with few fine cracks and pores. Rapidly water absorbent. Few fine roots. Common soft white Calcium Carbonate streaks.

29 - 75 cm. Dry 10YR5-4, moist 10YR4-3. Loamy Sand. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. Few fine roots. Common soft white Calcium Carbonate streaks.

75 - 130 cm. Dry 10YR6-3, moist 10YR5-4. Sand. Dry, soft, structureless with no cracks or pores. Rapidly water absorbent. No roots. Few Calcium Carbonate accumulations in old root channels.

130 - 142cm. Dry 10YR5-4, moist 10YR4-3. Loamy Sand. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. Abundant white Calcium Carbonate.

142 - 168cm. Dry 10YR6-3, moist 10YR5-4. Sand. Dry, soft, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon.	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil.
	Sand	Silt	Clay	%	Soil Paste	1:5 Soil suspension			
0- 4	82	5	13	4.35	8.55	8.75	0.31	0.04	0.3
4- 29	57	18	25	4.08	8.57	8.62	0.30	0.04	0.5
29- 75	80	5	15	5.25	8.61	8.83	0.26	0.06	0.3
75-130	90	2	8	1.13	8.38	8.62	0.25	0.06	0.45
130-142	77	10	13	20.7	8.72	8.85	0.27	0.09	0.8
142-168	87	5	8	0.74	8.52	8.61	0.32	0.08	0.25

Psammustentic Orthustent.
Non-saline
Land Class 2.

Pit: DR352

Location: 341,000. 52,000 Date: 2.4.63.

Topography: Flat.

Cultivation and Land Use: Nil.

Vegetation: Scattered *Acacia erhenbergiana* bushes with low sandy mounds around them.

Surface: Dry, soft, sandy with some gravel and many dark and light grey Calcium Carbonate concretions.

Profile description:-

0 - 8 cm. Dry 10YR5-4, moist 10YR4-3. Gravelly Sand. Dry, soft, structureless with few cracks and no pores. Rapidly water absorbent. No roots. Many Calcium Carbonate concretions.

8 - 35 cm. Dry 10YR5-4, moist 10YR4-3. Gravelly Loamy Sand. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. Common Calcium Carbonate concretions.

35 - 72 cm. Moist 10YR3.5-3. Fine Sandy Loam. Slightly moist, firm, structureless with few cracks and common pores. Some old cracks infilled with material from above. Rapidly water absorbent. No roots. Abundant white streaks and grey concretions of Calcium Carbonate.

72 - 182 cm. Moist 10YR3-2. Fine Sandy Loam. Moist, friable, structureless with no cracks and common pores. Rapidly water absorbent. No roots. Few white streaks and common grey concretions of Calcium Carbonate.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na Meq.per 100 gm. soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 8	87	3	10	2.32	7.78	8.64	4.0	1.7	4.2
8- 35	82	8	10	4.66	7.42	8.17	24.4	7.4	4.8
35- 72	70	7	23	8.70	7.65	8.39	36.0	25.6	9.4
72-120	70	7	23	3.78	8.05	8.70	18.0	15.2	16.3
120-182	70	7	23	2.00	8.72	9.32	5.0	4.3	18.3

Psammustentic Orthustent
Highly Saline
Land Class 6.

Pit: DR369

Location: 279,000. 38,000. Date: 6.4.63.

Topography: Flat.

Cultivation and Land Use: Nil.

Vegetation: Widely scattered *Panicum turgidum* and *Acacia ehrenbergiana*.

Surface: Dry, firm, level with some sand and scattered stones. Many grey Calcium Carbonate concretions.

Profile description:-

0 - 9 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Silt Loam. Dry, slightly hard, moderate fine subangular blocky with many fine cracks and few pores. Rapidly water absorbent. No roots. Common hard light grey Calcium Carbonate concretions.

9 - 89 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Loamy Fine Sand. Dry, soft, structureless with few vertical cracks and common pores. Rapidly water absorbent. Few old fine roots. Few soft white Calcium Carbonate concretions.

89 - 114 cm. Dry 2.5Y5-2, moist 2.5Y4-2. Very Fine Sandy Loam. Dry, slightly hard, structureless with no cracks and common pores. Rapidly water absorbent. No roots. Three separate, continuous horizontal Caliche layers, 1 to 5 cm. thick.

114 - 175 cm. Gravelly Sand. Dry, loose, structureless. Rapidly water absorbent. Much gravel with very shiny surfaces. No salts.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na. Meq.per 100 gm. soil.
	Sand	Silt	Clay		Soil Paste	1:5 Soil suspension			
0- 9	67	10	23	2.90	8.95	9.55	1.20	0.7	16.3
9- 50	85	2	13	4.70	7.85	8.66	5.00	3.1	7.7
50- 89	85	5	10	2.19	8.75	9.15	0.50	0.3	7.5
89-114	70	15	15	6.34	8.52	9.20	0.58	0.3	8.7
114-175	92	1	7	0.25	8.41	8.52	0.33	0.3	0.9

Psammustentic Orthustent.
Slightly saline.
Land Class 4.

G. Orthustentic Psammustent.

Pit: DR324

Location: 355,000. 87,000. Date: 28.3.63.

Topography: Slightly undulating gravelly plain.

Cultivation and Land Use: Nil.

Vegetation: Scattered small *Acacia erhenbergiana* bushes.

Surface: Dry, firm, sandy, level. Much fine gravel. Scattered stones. Many small dark Calcium Carbonate concretions.

Profile description:-

0 - 4 cm. Dry 10YR5-3, moist 10YR4-3. Sand. Dry, very soft, structureless. Laminated. Rapidly water absorbent. No roots. Many small dark Calcium Carbonate concretions.

4 - 30 cm. Dry and moist 10YR4-1.5. Loamy Sand. Dry, soft, structureless with no cracks and many pores (old root channels). Rapidly water absorbent. Few fine roots. Few white Calcium Carbonate streaks.

(Gradual Transition)

30 - 74 cm. Dry 10YR5-4, moist 10YR4-3. Loamy Sand. Dry, slightly hard, structureless with no cracks and many pores. Rapidly water absorbent. Few fine roots. No salts. Some gravel.

74 - 108 cm. Dry 10YR5-4, moist 10YR4-3. Loamy Sand. Dry, slightly hard, structureless with no cracks and few pores. Rapidly water absorbent. No roots. No salts. Common gravel, esp. in a band 10 cm. thick at the base of this horizon.

108 - 147cm. Dry 10YR5-4, moist 10YR4-3. Loamy Sand. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. Common gravel. Discontinuous iron pans and concretions about ½ cm. thick, generally surrounded by a lyer of soft white Calcium Carbonate.

147 - 181cm. Dry and moist 10YR6-3. Gravel and stones. Dry, slightly hard (cemented), very calcareous.

Laboratory Analyses:-

Depth cm	Soil Particles %			Incorp. Carbon. %	pH		E.C. Sat. Extr.	Sol.Na. Meq.per litre	Exch.Na Meq.per 100 gm soil
	Sand	Silt	Clay		Soil paste	1:5 Soil suspension			
0- 4	95	2	3	9.80	8.52	8.46	0.36	0.04	0.1
4- 30	82	8	10	1.57	8.65	8.89	0.54	0.11	1.1
30- 74	82	8	10	1.13	7.75	7.72	2.20	0.5	1.8
74-108	87	5	8	0.75	7.65	7.05	4.75	0.7	1.0
108-147	87	5	8	2.08	7.98	8.20	3.70	0.8	1.3

Orthustentic Psammustent
Non-saline
Land Class 4/6.

APPENDIX 2

Engineering Reconnaissance

Extensions to Sudan Survey Department Cross Sections

Kareima to Third Cataract - Left and Right Banks

C.S.	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
1 R.B.	80	24s	214.20				
				0	15.00	229.20	15 M ISO.Conc. post 1020
				0.173	15.98	230.18	
				0.426	17.42	231.62	
				0.616	18.28	232.48	
				0.907	19.22	233.42	
				1.141	20.00	234.20	20 M.ISO. Angle post 1/20 M
2 R.B.	88	24s	214.57				
				0	15.00	229.57	15 M ISO. Conc. post 901
				0.219	17.06	231.63	
				0.412	18.36	232.93	
				0.472	19.97	234.54	20 M.ISO. Angle post 2/20 M
3 R.B.	99	24s	214.84	0	15.00	229.84	15 M ISO. Cairn
				0.175	14.27	229.11	
				0.300	16.31	231.15	
				0.565	18.55	233.39	
				0.850	19.05	233.89	
				1.005	19.97	234.81	20 M.ISO. Angle post 3/20 M
4 R.B.	92	24s	215.34	0	15.00	230.34	15 M.ISO. Conc. post 669
				0.239	16.32	231.66	
				0.517	16.37	231.71	
				0.777	18.57	233.91	
				0.780	20.01	235.35	20 M.ISO. Angle post 4/20 M.
5 R.B.	76	24s	215.84	0	15.00	230.84	15 M.ISO. Conc. post 910
				0.304	15.29	231.13	
				0.603	15.47	231.31	
				0.939	16.17	232.01	
				1.317	17.07	232.91	
				1.660	17.22	233.06	
				1.970	19.17	235.01	
				2.097	20.00	235.84	20 M.ISO. Conc. post 5/20 M.

C.S.	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
6 R.B.	92	24s	216.16	0	15.00	231.16	15 M.ISO.Conc.post 643
				0.192	16.47	232.63	
				0.476	15.68	231.84	
				0.724	15.10	231.26	
				1.017	15.78	231.94	
				1.299	15.81	231.97	
				1.575	16.19	232.35	
				1.758	17.58	233.74	
				1.760	20.01	236.17	
7 R.B.	80	24s	216.48	0	15.00	231.48	15 M.ISO.Conc.post 668
				0.243	15.49	231.97	
				0.570	14.73	231.21	
				0.860	15.69	232.17	
				1.262	16.94	233.42	
				1.594	16.74	233.22	
				1.915	16.43	232.91	
				1.991	20.00	236.48	20 M.ISO. Angle post 7/20 M.
8 R.B.	92	24s	216.82	0	15.00	231.82	15 M.ISO.Conc.post 941
				0.300	14.10	230.92	
				0.799	14.96	231.78	
				1.296	16.03	232.85	
				1.570	17.02	233.84	
				1.862	17.53	234.35	
				2.338	18.59	235.41	
				2.706	19.54	236.36	
				3.007	20.01	236.83	20 M.ISO. Angle post 8/20 M.
9 R.B.	76	24s	217.14	0	15.00	232.14	15 M.ISO.Conc.post 1003
				0.318	16.13	233.27	
				0.700	17.84	234.98	
				1.097	21.22	238.36	
				1.292	17.12	234.26	
				1.596	15.27	232.41	
				1.978	16.66	233.80	
				2.356	17.22	234.36	
				2.782	17.95	235.09	
				3.191	18.72	235.86	
				3.520	19.96	237.10	20 M.ISO. Angle post 9/20 M.
10 R.B.	80	24s	217.46	0	10.00	227.46	10 M.ISO.Conc.post 972
				0.270	10.61	228.07	
				0.550	11.33	228.79	
				0.832	12.80	230.26	
				1.125	13.24	230.70	
				1.383	14.16	231.62	
				1.641	15.00	232.46	15 M.ISO. Angle post unnumbered

Cont'd.

C.S.	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
10 R.B. Cont'd.	80	24s	217.46	1.946	16.42	233.88	
				2.226	16.66	234.12	
				2.471	18.46	235.92	
				2.758	19.32	236.78	
				2.840	20.72	238.18	Top of local ridge
				3.008	19.37	236.83	
				3.195	20.54	238.00	20 M.ISO. Angle post 10/20 M.
11 R.B.	80	24s	217.78	0	15.00	232.78	15 M.ISO.Conc.post 665
				0.276	15.63	233.41	
				0.560	16.59	234.37	
				0.835	17.40	235.18	
				1.088	18.91	236.69	
				1.368	18.67	236.45	
				1.530	19.40	237.18	
				1.659	20.01	237.79	20 M.ISO. Angle post 11/20 M.
12 R.B.	80	24s	218.08	0	15.00	233.08	15 M.ISO. Conc.post 1041
				0.207	18.52	236.60	
				0.423	19.25	237.33	
				0.716	17.76	235.84	
				1.122	18.93	237.01	
				1.211	20.01	238.09	20 M.ISO. Angle post 12/20 M.
13 R.B.	85	23	218.40	0	15.00	233.40	15 M.ISO.Conc post 660
				0.068	19.02	237.42	
				0.072	19.98	238.38	20 M.ISO. Large triangular rock painted red.
14 R.B.	90	23	218.72	-	-	-	Section not located.
15 R.B.	90	23	219.04	-	-	-	Section not located.
16 R.B.	90	23	219.36	0	10.04	229.40	10 M.ISO. Angle post 1016
				0.215	14.99	234.35	15 M.ISO " " 1042
				0.300	15.29	234.65	
				0.553	16.49	235.85	
				0.789	18.66	238.02	
				0.996	20.01	239.37	20 M.ISO. Cairn

C.S.	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
17 R.B.	93	23	219.68	0	10.03	229.71	10 M.ISO. Angle post 1067
				0.058	13.19	232.87	Cairn.
				0.423	12.78	232.46	
				0.795	10.39	230.07	
				1.049	11.26	230.94	
				1.336	12.64	232.32	
				1.505	13.92	233.60	
				1.584	14.96	234.64	15 M.ISO. Angle post 1011
				1.640	18.95	238.63	Top of escarpment
				1.710	16.87	236.55	
				1.953	16.73	236.41	
				2.189	19.09	238.77	End of taken section Cairn.
18 R.B.	95	23	220.02	0	15.00	235.02	15 M.ISO.Conc.post 1007
				0.156	18.30	238.32	
				0.302	19.78	239.80	
				0.429	20.06	240.08	20 M.ISO. Cairn.
19 R.B.	100	23	220.34	0	15.00	235.34	15 M.ISO.Conc.post 1004
				0.096	18.21	238.55	
				0.168	20.01	240.35	20 M.ISO. Cairn
20 R.B.	96	23	220.66	0	15.00	235.66	15 M.ISO.Conc.post 1030
				0.085	18.21	238.87	
				0.138	14.71	235.37	
				0.367	17.28	237.94	
				0.395	20.00	240.66	20 M.ISO. Cairn
21 R.B.	96	23	220.98	0	15.00	235.98	15 M.ISO. Cairn
				0.137	15.29	236.27	
				0.347	18.48	239.46	
				0.509	19.13	240.11	
				0.627	-		
				0.669	19.98	240.96	20 M.ISO. Cairn
22 R.B.	101	23	221.30	0	15.00	236.30	15 M.ISO.Conc.post 1079
				0.034	16.61	237.91	
				0.068	14.52	235.82	
				0.134	18.71	240.01	
				0.192	20.00	241.30	20 M.ISO. Cairn

C.S.	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 R.B.	85	22	221.62	0	15.00	236.62	15 M.ISO.Conc.post 1078
				0.067	16.36	237.98	
				0.154	18.01	239.63	
				0.236	15.32	236.94	
				0.324	19.12	240.74	
				0.378	19.98	241.60	20 M.ISO. Cairn
56 R.B.	78	22	221.94	0	15.00	236.94	15 M.ISO.Conc.post 1099
				0.079	15.04	236.98	
				0.265	16.76	238.70	
				0.407	19.20	241.14	
				0.509	21.00	242.94	End of taken section Cairn
57 R.B.	77	22	222.26	0	15.00	237.26	15 M.ISO. Cairn
				0.258	15.14	237.40	
				0.425	17.81	240.07	
				0.585	20.01	242.27	20 M.ISO. Cairn
58 R.B.	75	22	222.58	0	15.00	237.58	15 M.ISO. Cairn
				0.045	17.88	240.46	
				0.099	20.00	242.58	20 M.ISO. Cairn
59 R.B.	75	22	222.90	0	15.00	237.90	15 M.ISO. Cairn
				0.082	18.75	241.65	
				0.131	19.99	242.89	20 M.ISO. Cairn
60 R.B.	72	22	223.22	0	15.00	238.22	15 M.ISO. Cairn
				0.024	18.98	242.20	
				0.035	20.21	243.43	20 M.ISO. Cairn
61 R.B.	78	22	223.54	0	15.00	238.54	15 M.ISO. Cairn
				0.094	17.61	241.15	
				0.175	19.99	243.53	20 M.ISO. Cairn
62 R.B.	75	22	223.86	0	15.00	238.86	15 M.ISO. Cairn
				0.057	17.28	241.14	
				0.207	19.08	242.94	
				0.353	17.26	241.12	
				0.507	17.88	241.74	
				0.674	19.52	243.38	End of taken section Cairn

C.S.	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
63 R.B.	75	22	224.18	0	15.00	239.18	15 M.ISO. Large Cairn
				0.248	15.14	239.32	
				0.499	16.53	240.71	
				0.889	15.91	240.09	
				1.255	16.02	240.20	
				1.533	16.72	240.90	
				1.716	18.86	243.04	
				1.809	20.02	244.20	20 M.ISO. Angle post 63/20 M.
64 R.B.	75	22	224.50	0	15.00	239.50	15 M.ISO. Cairn
				0.249	16.12	240.62	
				0.469	16.08	240.58	
				0.625	18.54	243.04	
				0.808	16.82	241.32	
				0.936	15.39	239.89	End of taken extension Cairn
65 R.B.	Section not extended area topographically unsuitable						
41 R.B.	67	21	226.57	0	10.00	236.57	10 M.ISO.Conc.post 1142
				0.124	13.20	239.77	
				0.204	14.97	241.54	15 M.ISO. Cairn
				0.256	20.00	246.57	20 M.ISO. Angle post 41/20 M.
42 R.B.	91	21	226.89	0	7.80	234.69	BM 30226 near Conc. post 754
				0.205	9.52	236.41	
				0.259	12.94	239.83	
				0.367	14.98	241.87	15 M.ISO. Cairn
				0.565	18.11	245.00	
				0.649	19.99	246.88	20 M.ISO. Angle post 42/20 M.
43 R.B.	91	21	227.21	0	10.00	237.21	10 M.ISO. Conc.post 784
				0.117	13.44	240.65	
				0.255	12.78	239.99	
				0.509	12.49	239.70	
				0.803	12.03	239.24	
				0.994	15.00	242.21	15 M.ISO. Cairn
				1.231	15.85	243.06	
				1.476	14.72	241.93	
				1.751	17.84	245.05	End of taken section Cairn
44 R.B.	91	21	227.53	0	9.36	236.89	Intermediate Conc. post 1138
				0.242	11.56	239.09	
				0.519	11.62	239.15	
				0.769	14.08	241.61	
				0.912	14.98	242.51	15 M.ISO. Cairn
				1.165	15.71	243.24	
				1.524	18.71	246.24	End of taken extension Cairn

C.S.	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
45 R.B.	91	21	227.85	0	10.00	237.85	10 M.ISO. Conc.post 1133
				0.076	14.10	241.95	
				0.185	15.01	242.86	15 M.ISO. Cairn
				0.266	18.79	246.64	
				0.333	22.16	250.01	
				0.350	24.76	252.61	End of taken extension Cairn
46 R.B. to 54 R.B. incl.		Sections not extended area topographically unsuitable					
33 R.B.		Section not extended area of sanddunes					
32 R.B.	21	19	232.01	0	15.00	247.01	15 M.ISO.Conc.post 1071
				0.300	15.84	247.85	
				0.510	17.28	249.29	
				0.707	18.88	250.89	
				0.811	19.98	251.99	20 M.ISO. Angle post 32/20 M.
31 R.B.		Section not extended area topographically unsuitable					
30 R.B.	21	19	232.65	0	15.00	247.65	15 M.ISO. Conc.post 1037
				0.255	15.89	248.54	
				0.511	17.32	249.97	
				0.634	20.00	252.65	20 M.ISO. Angle post 30/20 M.
29 R.B.	21	19	232.97	0	15.00	247.97	15 M.ISO.Conc.post 1023
				0.093	17.45	250.42	
				0.209	18.63	251.60	
				0.451	19.85	252.82	
				0.499	19.99	252.96	20 M.ISO.Angle post 29/20 M.
28 R.B.	21	19	233.29	0	15.00	248.29	15 M.ISO.Conc.post 1009
				0.220	16.25	249.54	
				0.466	16.81	250.10.	
				0.791	17.54	250.83	
				1.124	19.03	252.32	
				1.348	20.00	253.29	20 M.ISO. Angle post 28/20 M.
27 R.B.	21	19	233.61	0	15.00	248.61	15 M.ISO.Conc.post 1053
				0.192	16.49	250.10	
				0.354	17.82	251.43	
				0.420	20.01	253.62	20 M.ISO. Angle post 27/20 M.

C.S.	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 R.B.	20	19	233.93	0	15.00	248.93	15 M.ISO.Conc.post 1035
				0.249	16.97	250.90	
				0.480	18.67	252.60	
				0.789	20.04	253.97	20 M.ISO. Angle 26/20 M
25 R.B.	326	19	234.32	0	15.00	249.32	15 M.ISO.Conc.post 1088
				0.192	15.70	250.02	
				0.348	17.77	252.09	BM.30215 Near post 1036
				0.660	18.26	252.58	
				0.953	18.69	253.01	
				1.259	20.00	254.32	20 M.ISO.Angle post 25/20 M.
33 R.B.	21	18	234.89	0	15.00	249.89	15 M.ISO.Conc.post 1074
				0.207	16.79	251.68	
				0.373	19.98	254.87	20 M.ISO. Angle post 33/20 M.
34 R.B.	12	18	235.21	0	13.91	249.12	BM.30218 Near post 1034
				0.252	14.85	250.06	
				0.359	15.36	250.57	Remains of post 1058
				0.886	16.72	251.93	
				1.267	17.94	253.15	
				1.513	19.95	255.16	20 M.ISO. Angle post 34/20 M.
35 R.B.		Section not located					
36 R.B.	337	18	235.83	0	15.00	250.83	15 M.ISO.Conc.post 1090
				0.332	15.67	251.50	
				0.527	17.06	252.89	
				0.748	15.64	251.47	End of taken extension Angle post 36/T
37 R.B.	337	18	236.16	0	15.00	251.16	15 M.ISO.Conc.post 1096
				0.228	15.33	251.49	
				0.392	16.93	253.09	
				0.637	18.61	254.77	
				0.792	17.42	253.58	
				0.942	20.03	256.19	20 M.ISO. Angle post 37/20 M.
38 R.B.	318	18	236.49	0	15.00	251.49	15 M.ISO.Conc.post 1025
				0.260	16.89	253.38	
				0.552	17.07	253.56	
				0.676	19.97	256.46	20 M.ISO. Angle post 38/20 M.
39 R.B.	318	18	236.81	0	15.00	251.81	15 M.ISO. Cairn
				0.163	15.76	252.57	
				0.367	17.95	254.76	
				0.466	20.04	256.85	20 M.ISO. Angle post 39/20 M.

C.S.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Above Sea Level	Remarks
40 R.B.		Section not extended area topographically unsuitable					
66 67 R.B. 68		Sections not extended area topographically unsuitable					
88 L.B.	272	24s	214.67	0	15.00	229.67	15 M.ISO.Conc.post 907
				0.153	16.43	231.10	
				0.392	19.18	233.85	
				0.655	19.98	234.65	20 M.ISO. Angle post 88/20 M.
87 L.B.	269	24s	214.99	0	15.00	229.99	15 M.ISO.Conc.post 896
				0.228	15.76	230.75	
				0.541	15.24	230.23	
				0.833	18.61	233.60	
				1.152	16.56	231.55	
				1.384	17.31	232.30	
				1.750	20.01	235.00	20 M.ISO. Angle post 87/20 M.
86 L.B.	271	24s	215.31	0	15.00	230.31	15 M.ISO.Conc.post 900
				0.102	18.65	233.96	
				0.152	19.98	235.29	20 M.ISO. Two Cairns
85 L.B.	265	24s	215.63	0	15.00	230.63	15 M.ISO.Conc.post 869
				0.280	15.81	231.44	
				0.614	18.11	233.74	
				0.858	17.52	233.15	
				1.138	16.84	232.47	
				1.382	16.60	232.23	
				1.702	17.04	232.67	
				1.952	16.05	231.68	
				2.204	15.84	231.47	
				2.452	15.74	231.37	
				2.723	15.78	231.41	
				2.987	15.76	231.39	
				3.262	19.99	235.62	20 M.ISO. Angle post 85/20 M.
84 L.B.	260	24s	215.95	0	15.00	230.95	15 M.ISO. Cairn
				0.060	15.29	231.24	
				0.317	16.40	232.35	
				0.557	15.76	231.71	
				0.756	18.81	234.76	
				0.998	18.55	234.50	
				1.198	19.99	235.94	20 M.ISO. Angle post 84/20 M.

C.S.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remakrs
83 L.B,	260	24s	216.27	0	15.00	231.27	15 M.ISO.Conc.post 881
				0.218	14.68	230.95	
				0.441	14.61	230.88	
				0.683	16.44	232.71	
				0.922	17.03	233.30	
				1.170	18.35	234.62	
				1.397	19.27	235.54	
				1.532	20.01	236.28	20 M.ISO. Angle post 83/20 M.
82 L.B.	260	24s	216.59	0	15.00	231.59	15 M.ISO.Conc.post 875
				0.225	16.96	233.55	
				0.389	18.27	234.86	
				0.565	18.05	234.64	
				0.735	18.55	235.14	
				0.957	17.80	234.39	
				1.196	17.68	234.27	
				1.429	18.79	235.38	
				1.751	18.32	234.91	
				2.002	18.27	234.86	
				2.302	19.98	236.57	20 M.ISO. Angle post 82/20 M.
81 L.B.	260	24s	216.91	0	15.00	231.91	15 M.ISO.Conc.post 882
				0.015	17.12	234.03	
				0.193	20.00	236.91	20 M.ISO. Angle post 81/20 M.
80 L.B.	260	24s	217.23	0	15.00	232.23	15 M.ISO. Cairn
				0.153	16.34	233.57	
				0.392	16.19	233.42	
				0.638	19.39	236.62	
				0.875	20.03	237.26	20 M.ISO. Angle post 80/20 M.
79 L.B.	260	24s	217.55	0	15.00	232.55	15 M.ISO. Cairn
				0.161	14.87	232.42	
				0.352	18.73	236.28	
				0.440	19.99	237.54	20 M.ISO. Angle post 79/20 M.
78 L.B.	260	24s	217.87	0	15.00	232.87	15 M.ISO. Cairn
				0.144	16.77	234.64	
				0.294	19.33	237.20	
				0.348	20.00	237.87	20 M.ISO. Angle post 78/20 M.
77 L.B.	260	23	218.19	0	15.00	233.19	15 M.ISO Cairn
				0.126	16.39	234.58	
				0.276	18.48	236.67	
				0.558	19.53	237.72	
				0.623	19.98	238.17	20 M.ISO. Angle post 77/20 M.

C.S.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres		Remarks
					Above NMWL	Above Sea Level	
76 L.B.	260	23	218.51	0	10.00	228.51	10 M.ISO.Conc.post 888
				0.280	11.36	229.87	
				0.608	12.18	230.69	
				0.857	12.03	230.54	
				1.094	10.57	229.08	
				1.404	10.29	228.80	
				1.706	10.43	228.94	
				2.207	10.89	229.40	
				2.297	12.55	231.06	
				2.355	15.00	233.51	15 M.ISO. Two earth cones
				2.442	17.72	236.23	
				2.664	16.32	234.83	
				2.921	18.04	236.55	
				3.231	17.77	236.28	
				3.471	18.83	237.34	
				3.654	19.98	238.49	20 M.ISO. Angle post 76/20 M.
75 L.B.	265	23	219.21	0	15.00	234.21	15 M.ISO. Conc.post 926
				0.025	15.63	234.84	
				0.114	16.35	235.56	
				0.213	14.49	233.70	
				0.417	14.04	233.25	
				0.523	14.76	233.97	
				0.626	14.06	233.27	
				0.724	14.04	233.25	
				0.853	14.07	233.28	
				0.971	13.20	232.41	
				1.239	13.29	232.50	
				1.450	14.68	233.89	End of taken extension Sand/gravel cone
74 L.B.	252½	23	219.54	0	15.00	234.54	15 M.ISO.Conc.post 956
				0.032	17.32	236.86	
				0.223	16.25	235.79	
				0.371	18.09	237.63	
				0.457	19.71	239.25	End of taken extension Sand/gravel cone
73 L.B.	258	23	219.84	0	15.00	234.84	15 M.ISO.Conc.post 917
				0.140	17.37	237.21	
				0.280	17.48	237.32	
				0.455	18.65	238.49	
				0.702	21.01	240.85	End of taken extension Sand/gravel Cone
72 L.B.	252	23	220.17	0	15.00	235.17	15 M.ISO.Conc.post 915
				0.200	15.17	235.34	
				0.399	16.67	236.84	
				0.648	19.16	239.33	
				0.775	21.06	234.23	End of taken extension Sand/gravel cone

C.S.	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
71 L.B.	279	23	220.50	0	15.00	235.50	15 M.ISO.Conc.post 914
				0.220	16.45	236.95	
				0.330	19.92	240.42	End of taken extension Sand/gravel cone
70 L.B.	278	23	220.82	0	15.00	235.82	15 M.ISO.Conc.post 982
				0.174	14.65	235.47	
				0.423	16.99	237.81	
				0.586	15.46	236.28	End of taken extension Sand/gravel cone
69 to 62 incl.		Sections not extended area topographically unsuitable					
61 L.B.	255	22	223.60	0	15.00	238.60	15 M.ISO.Conc.post 948
				0.160	17.37	240.97	
				0.288	19.17	242.77	
				0.321	20.05	243.65	20 M.ISO. Angle post 61/20 M.
60 L.B.	248	22	223.99	0	15.00	238.99	15 M.ISO. Cairn
				0.050	12.29	236.28	
				0.256	13.25	237.27	
				0.331	14.85	238.84	
				0.413	18.73	242.72	
				0.584	18.55	242.54	
				0.694	19.95	243.94	20 M.ISO. Angle post 60/20 M.
59 L.B.	253	22	224.30	0	10.00	234.30	10 M.ISO.Conc.post 852
				0.304	7.33	231.63	
				0.621	8.78	233.08	
				0.839	9.50	233.80	
				1.093	11.61	235.91	
				1.290	15.00	239.30	15 M.ISO. Cairn
				1.395	19.18	243.48	
				1.409	20.03	244.33	20 M.ISO. Angle post 59/20 M.
58 L.B.	256	22	224.60	0	8.24	232.84	BM.20135 near Conc. post 849
				0.128	8.29	232.89	
				0.337	10.34	234.94	
				0.491	12.80	237.40	
				0.560	15.02	239.62	15 M.ISO. Cairn
				0.614	20.00	244.60	20 M.ISO. Angle post 58/20 M.
57 & 56		Section not extended area topographically unsuitable					

C.S.	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.	263	21	225.29	0	15.00	240.92	15 M.ISO.Conc.post 840
				0.116	17.44	243.36	
				0.181	19.99	245.91	20 M.ISO. Angle post 55/20 M.
54 L.B.	222	21	225.61	0	15.00	240.61	15 M.ISO.Conc.post 965
				0.186	15.17	240.78	
				0.458	15.38	240.99	
				0.704	15.87	241.48	
				1.014	15.83	241.44	
				1.274	16.66	242.27	
				1.588	18.96	244.57	
				1.828	19.98	245.59	20 M.ISO. Angle post 54/20 M.
53 L.B.	222	21	225.93	0	15.00	240.93	15 M.ISO.Conc.post 953
				0.173	15.56	241.49	
				0.401	17.17	243.10	
				0.548	18.49	244.42	
				0.609	20.01	245.94	20 M.ISO. Angle post 53/20 M.
				0.638	20.42	246.35	Top of local rise
				0.805	17.23	243.16	
				1.199	17.48	243.41	
				1.424	18.45	244.38	
				1.753	18.17	244.10	
				2.076	17.26	243.19	
				2.562	17.92	243.85	
				2.994	17.64	243.57	
				3.451	18.32	244.25	
				3.770	19.18	245.11	
				3.847	19.98	245.91	20 M.ISO. Angle post 53/20 M.
51 L.B.	271	21	226.57	0	15.00		15 M.ISO.Conc.post 883
				0.217	15.37		
				0.475	15.89		
				0.726	16.13		
				0.968	16.81		
				1.204	17.40	243.97	
				1.477	17.50	244.07	
				1.685	18.73	245.30	
				1.724	19.99	246.56	20 M.ISO. Angle Post 51/20 M.
				1.760	20.13	246.70	
				1.951	18.68	245.25	
				2.252	17.75	244.32	
				2.512	18.47	245.04	
				2.837	17.60	244.17	
				3.147	16.39	242.96	
				3.460	16.76	243.33	
				3.712	16.72	243.29	
				4.031	17.92	244.49	
				4.307	18.77	245.34	
				4.666	20.03	246.60	20 M.ISO. Angle post 51/20 M.

C.S.	Line Deg. Mag.	Map Sheet No.	MNWL Metres A.S.L.	Distance Km.	Grd. Level Metres Above NMWL	Grd. Level Metres Above Sea Level	Remarks
50 L.B.	271	21	226.89	0	15.00	241.89	15 M.ISO.Conc.post 908
				0.238	15.61	242.50	
				0.591	16.40	243.29	
				0.930	14.81	241.70	
				1.248	15.57	242.46	
				1.584	16.15	243.03	
				1.872	18.15	245.04	
				1.953	20.01	246.90	
				1.024	21.46	248.35	Top of local ridge
				1.293	19.06	245.95	
				1.587	19.51	246.40	
				1.727	20.00	246.89	20 M. ISO. Angle 50/20 M
49 L.B.	271	21	227.21	0	15.00	242.21	15 M.ISO.Conc.post 898
				0.210	15.68	242.89	
				0.476	15.73	242.94	
				0.828	14.78	241.99	
				1.165	15.63	242.84	
				1.508	16.41	243.62	
				1.803	18.08	245.29	
				1.983	20.01	247.22	20 M.ISO. Angle post 49/20 M.
48 L.B.	272	21	227.53	0	15.00	242.53	15 M.ISO.Conc.post 858
				0.221	15.89	243.42	
				0.449	16.96	244.49	
				0.798	16.60	244.13	
				1.106	16.84	244.37	
				1.400	17.14	244.67	
				1.750	15.66	243.19	
				2.088	15.66	243.19	
				2.430	16.07	243.60	
				2.727	16.94	244.47	
				3.139	18.77	246.30	
				3.345	20.00	247.53	20 M.ISO. Angle post 48/20 M.
47 L.B.	271	21	227.85	0	15.00	242.85	15 M.ISO.Conc.post 857
				0.299	14.94	242.79	
				0.717	15.26	243.11	
				1.074	15.68	243.53	
				1.476	16.44	244.29	
				1.839	18.08	245.93	
				2.113	20.00	247.85	20 M.ISO. Angle post 47/20 M.
46 L.B.	271	21	228.17	0	15.00	243.17	15 M.ISO.Conc.post 973
				0.283	15.63	243.80	
				0.601	15.51	243.68	
				0.933	15.31	243.48	
				1.317	15.54	243.71	
				1.652	16.13	244.30	
				2.048	15.36	243.53	
				2.497	16.22	244.39	
				2.882	16.87	245.04	

Cont'd.

C.S.	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
46 L.B. Cont'd.	271	21	228.17	3.215	15.99	244.16	
				3.525	15.52	243.69	
				3.833	16.01	244.18	
				4.069	16.99	245.16	
				4.345	17.36	245.53	
				4.689	17.38	245.55	
				4.993	17.37	245.54	
				5.326	18.78	246.95	
				5.602	19.16	247.33	
				5.935	19.31	247.48	
				6.157	20.03	248.20	20 M.ISO. Angle post 46/20 M.
45 L.B.	246	21	228.49	0	15.00	243.49	15 M.ISO.Conc.post 933
				0.371	15.05	243.54	
				0.716	15.69	244.18	
				1.140	15.42	243.91	
				1.429	14.21	242.70	
				1.795	15.14	243.63	
				2.300	14.93	243.42	
				2.861	16.71	245.20	
				3.399	15.86	244.35	
				4.000	14.27	242.76	
				4.593	15.18	243.67	
				5.119	15.00	243.49	
				5.698	14.75	243.24	
				6.132	15.67	244.16	
				6.566	15.94	244.43	
				7.025	15.96	244.45	
				7.468	15.13	243.62	
				7.904	14.77	243.26	
				8.372	15.68	244.17	
				8.725	15.80	244.29	
				9.132	16.47	244.96	
				9.509	18.04	246.53	
				9.793	17.70	246.19	
				10.008	16.37	244.86	
				10.342	15.11	243.60	
				10.580	14.95	243.44	
				10.839	15.40	243.89	
				11.076	15.84	244.33	
				11.314	16.04	244.53	
				11.511	17.46	245.95	
				11.626	20.04	248.53	20 M.ISO. Angle post 45/20 M.
44 L.B.	246	20	228.81	0	15.00	243.81	15 M.ISO. Conc.post 864
				0.373	16.48	245.29	
				0.614	16.63	245.44	
				1.120	15.69	244.50	
				1.857	17.18	245.99	
				2.547	18.35	247.16	
				3.112	18.59	247.40	
				3.341	20.01	248.82	20 M.ISO. Angle post 44/20 M.

C.S.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Above Sea Level	Remarks
43 L.B.	246	20	229.13	0	15.00	244.13	15 M.ISO.Conc.post 897
				0.338	15.37	244.50	
				0.810	15.91	245.04	
				1.280	17.70	246.83	
				1.459	19.91	249.04	20 M.ISO. Angle post 43/20 M.
42 L.B.	246	20	229.45	0	15.00	244.45	15 M.ISO.Conc.post 991
				0.548	17.24	246.69	
				1.160	19.08	248.53	
				1.665	19.82	249.27	
				1.713	19.99	249.44	20 M.ISO. Angle post 42/20 M.
41 L.B.	246	20	229.77	0	15.00	244.77	15 M.ISO.Conc.post 997
				0.508	17.14	246.91	
				0.843	18.86	248.63	
				0.937	20.01	249.78	20 M.ISO. Angle post 41/20 M.
40 L.B.	186	20	230.09	0	15.00	245.09	15 M.ISO.Conc.post 902
				0.347	15.40	245.49	
				0.725	17.17	247.26	
				0.956	19.53	249.62	
				1.225	19.71	249.80	
				1.397	20.00	250.09	20 M.ISO. Angle post 40/20 M.
39 L.B.	186	20	230.41	0	15.00	245.41	15 M.ISO.Conc.post 949
				0.311	15.57	245.98	
				0.587	16.56	246.97	
				0.849	18.45	248.86	
				1.022	20.00	250.41	20 M.ISO. Angle post 39/20 M.
38 L.B.	197	20	230.73	0	15.00	245.73	15 M.ISO. Conc.post 828
				0.323	15.91	246.64	
				0.585	17.42	248.15	
				0.635	18.35	249.08	
				0.912	19.30	250.03	
				1.021	20.00	250.73	20 M.ISO. Angle post 38/20 M.
37 L.B.	235	20	231.05	0	15.00	246.05	15 M.ISO.Conc.post 976
				0.331	16.12	247.17	
				0.667	17.19	248.24	
				1.050	19.34	250.39	
				1.276	19.99	251.04	20 M.ISO. Angle post 37/20 M.
36 L.B.		Section not extended area topographically unsuitable					

C.S.	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
35 L.B.	216	19	231.69	0	15.00	246.69	15 M.ISO.Conc.post 999
				0.298	16.62	248.31	
				0.596	17.30	248.99	
				0.887	17.05	248.74	
				1.124	17.11	248.80	End of taken extension Angle post 35/T
34 L.B.		Section not extended area topographically unsuitable					
33 L.B.	202	19	232.33	0	15.00	247.33	15 M.ISO.Conc.post 892
				0.124	15.39	247.72	
				0.347	17.17	249.50	
				0.548	18.92	251.25	
				0.667	19.71	252.04	End of taken extension Angle post 33/T
32 L.B.	207	19	232.65	0	15.00	247.65	15 M.ISO.Conc.post 856
				0.283	16.40	249.05	
				0.710	17.99	250.64	
				1.047	18.44	251.09	
				1.438	19.83	252.53	
				1.505	19.99	252.64	20 M.ISO. Angle post 32/20 M.
31 L.B.	198	19	232.97	0	15.00	247.97	15 M.ISO.Conc.post 904
				0.288	16.67	249.64	
				0.664	17.76	250.73	
				0.920	18.49	251.46	
				1.292	20.00	252.97	20 M.ISO. Angle post 31/20 M.
30 L.B.		Section not extended area topographically unsuitable					
29 L.B.	195	19	233.61	0	15.00	248.61	15 M.ISO.Conc.post 966
				0.323	16.47	250.08	
				0.584	16.63	250.24	
				0.835	19.31	252.92	
				1.223	19.18	252.79	
				1.572	19.36	252.97	
				1.911	20.02	253.63	20 M.ISO. Angle post 29/20 M.
28 L.B.	188	19	233.93	0	15.00	248.93	15 M.ISO.Conc.post 863
				0.114	17.12	251.05	
				0.247	19.82	253.75	
				0.400	16.94	250.87	
				0.744	16.17	250.10	
				0.912	17.04	250.97	
				1.226	17.15	251.08	
				1.510	16.99	250.92	
				1.726	17.25	251.18	
				1.835	18.06	251.99	
				1.962	18.12	252.05	
				2.083	17.92	251.85	
				2.405	19.54	253.47	
				2.454	20.01	253.94	20 M.ISO.Angle post 28/20 M.

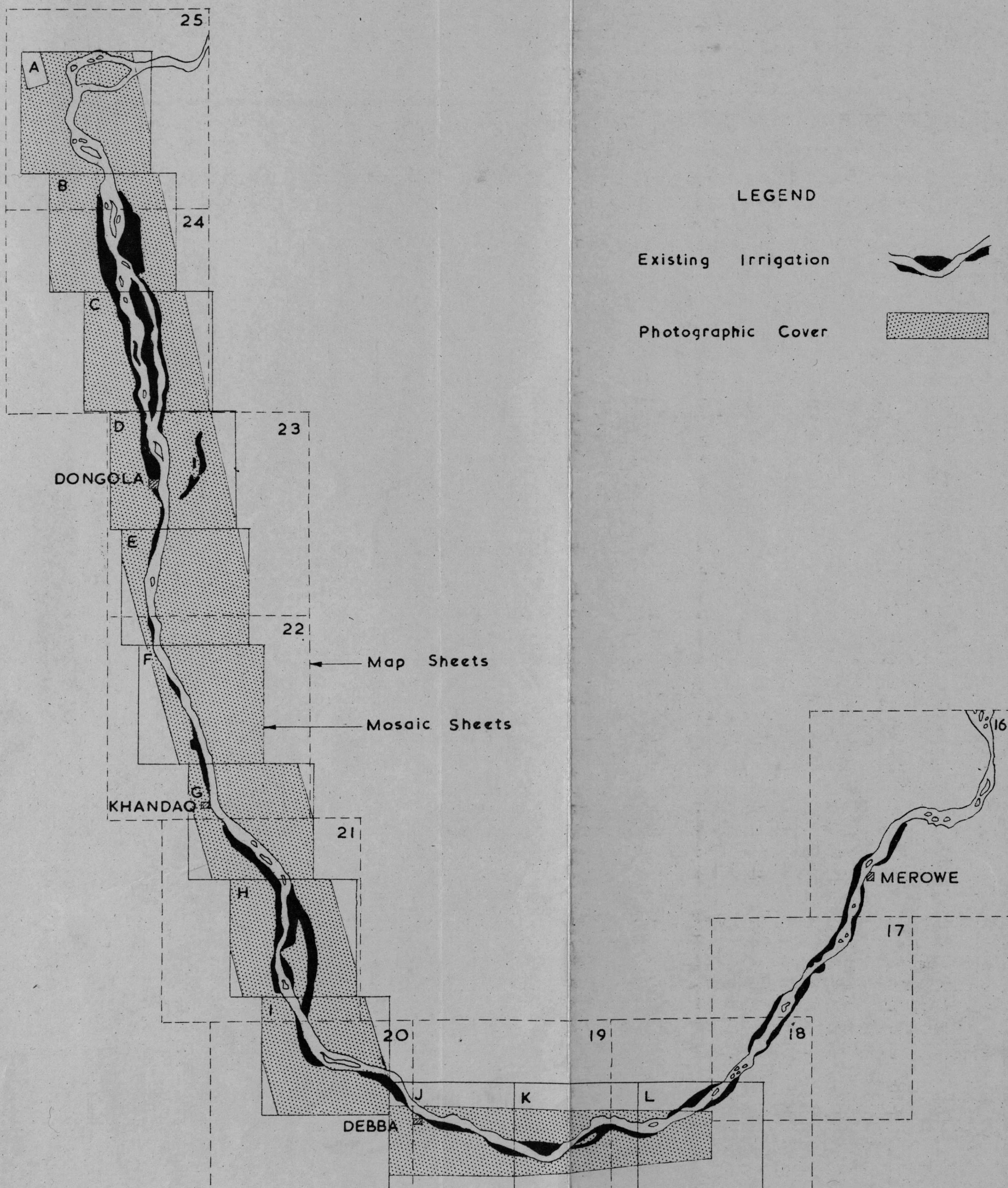
C.S.	Line Deg. Mag.	Map Sheet No.	NMWL Metres A.S.L.	Distance Km.	Grd.Level Metres Above NMWL	Grd.Level Metres Above Sea Level	Remarks
27 L.B.	150	19	234.25	0	15.00	249.25	15 M.ISO.Conc.post 967
				0.184	18.52	252.77	
				0.503	18.53	252.78	
				0.701	17.10	251.35	
				0.857	16.93	251.18	
				1.134	17.50	251.75	End of taken extension Angle post 27/T
26 L.B.		Section not extended area topographically unsuitable					
25 L.B.	140	18	235.21	0	15.00	250.21	15 M.ISO.Conc.post 920
				0.403	15.77	250.98	
				0.838	15.92	251.13	
				1.191	18.14	253.35	
				1.519	18.47	253.68	
				1.915	19.67	254.88	
				2.159	20.02	255.23	20 M.ISO.Angle post 25/20 M.
24 L.B.	190	18	235.53	0	15.00	250.53	15 M.ISO.Conc.post 906
				0.220	15.20	250.73	
				0.545	15.78	251.31	
				0.782	17.21	252.74	
				1.006	18.73	254.26	
				1.161	18.40	253.93	
				1.468	18.56	254.09	
				1.785	19.73	255.26	
				1.832	20.02	255.55	20 M.ISO. Angle post 24/20 M.
23 L.B. to 16 L.B. incl.		Sections not extended area topographically unsuitable					
12 L.B.	126	18	238.09	0	15.00	253.09	15 M.ISO.Conc.post 670
				0.192	16.97	255.06	
				0.465	18.65	256.74	
				0.636	20.02	258.11	20 M.ISO. Angle post 15/20 M.
14 L.B.		Section not extended area topographically unsuitable					
13 L.B.	-	18	238.73	0	15.00	253.73	15 M.ISO.Conc.post 604
				0.137	17.83	256.56	
				0.384	19.41	258.14	
				0.554	20.01	258.74	20 M.ISO. Angle post 13/20 M.
12 L.B.		Section not extended area topographically unsuitable					

C.S.	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
11	133	17s	239.37	0	15.00	254.37	15 M.ISO.Conc.post 598
				0.199	16.02	255.39	
				0.472	17.08	256.45	
				0.700	17.28	256.65	
				0.917	20.02	259.36	20 M.ISO. Angle post 11/20 M.
10 L.B.	126	17s	239.69	0	15.00	254.69	15 M.ISO.Conc.post 597
				0.408	17.26	256.95	
				0.698	19.41	259.10	
				0.891	20.00	259.69	20 M.ISO. Angle post 10/20 M.
9 L.B.	133	17s	240.01	0	15.00	255.01	15 M.ISO.Conc.post 657
				0.154	17.91	257.92	
				0.496	18.54	258.55	
				0.762	20.02	260.03	20 M.ISO. Angle post 9/20 M.
8 L.B.	133	17s	240.33	0	15.00	255.33	15 M.ISO.Conc.post 633
				0.053	16.96	257.29	
				0.427	18.11	258.44	
				0.735	20.00	260.33	20 M.ISO. Angle post 8/20 M.
7 L.B.	133	17s	240.65	0	15.00	255.65	15 M.ISO.Conc.post 613
				0.155	16.52	257.17	
				0.418	17.58	258.23	
				0.629	17.59	258.24	
				0.910	18.35	259.00	
				1.147	19.99	260.64	20 M.ISO. Angle post 7/20
6 L.B.	110	17s	240.97	0	15.00	255.97	15 M.ISO.Conc.post 606
				0.275	16.42	257.39	
				0.567	17.63	258.60	
				0.883	20.00	260.97	20 M.ISO. Angle post 6/20 M.
5 L.B.	115	17s	241.29	0	15.00	256.29	15 M.ISO.Conc.post 592
				0.193	16.96	258.25	
				0.507	18.93	260.22	
				0.604	19.99	261.28	20 M.ISO. Angle post 5/20 M.
4 L.B.	132	17s	241.61	0	15.00	256.61	15 M.ISO.Conc.post 630
				0.435	15.91	257.52	
				1.028	17.77	259.38	
				1.576	19.97	261.58	20 M.ISO. Angle post 4/20 M.

C.S.	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
3 L.B.	132	17s	241.96	0	15.00	256.96	15 M.ISO.Conc.post 625
				0.411	16.73	258.69	
				0.799	17.93	259.89	
				1.045	20.03	261.99	20 M.ISO. Angle post 3/20 M.
2 L.B.	132	17s	242.25	0	15.00	257.25	15 M.ISO.Conc.post 608
				0.344	15.33	257.58	
				0.723	16.72	258.97	
				1.141	18.02	260.27	
				1.467	19.19	261.44	
				1.666	20.01	262.26	20 M.ISO. Angle post 2/20 M.
1 L.B.		Section not extended area topographically unsuitable					

Figure 7

EXISTING IRRIGATION
MAP AND PHOTOGRAPHIC COVER



Scale: 1:1,000,000

SIR M.MACDONALD & PARTNERS

Date: August 1963