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ROSEIRES SOIL SURVEY

REPORT No. 11

THE WHITE NILE
EAST BANK MELUT TO RABAK
EXPLORATORY SOILS AND ENGINEERING SURVEY

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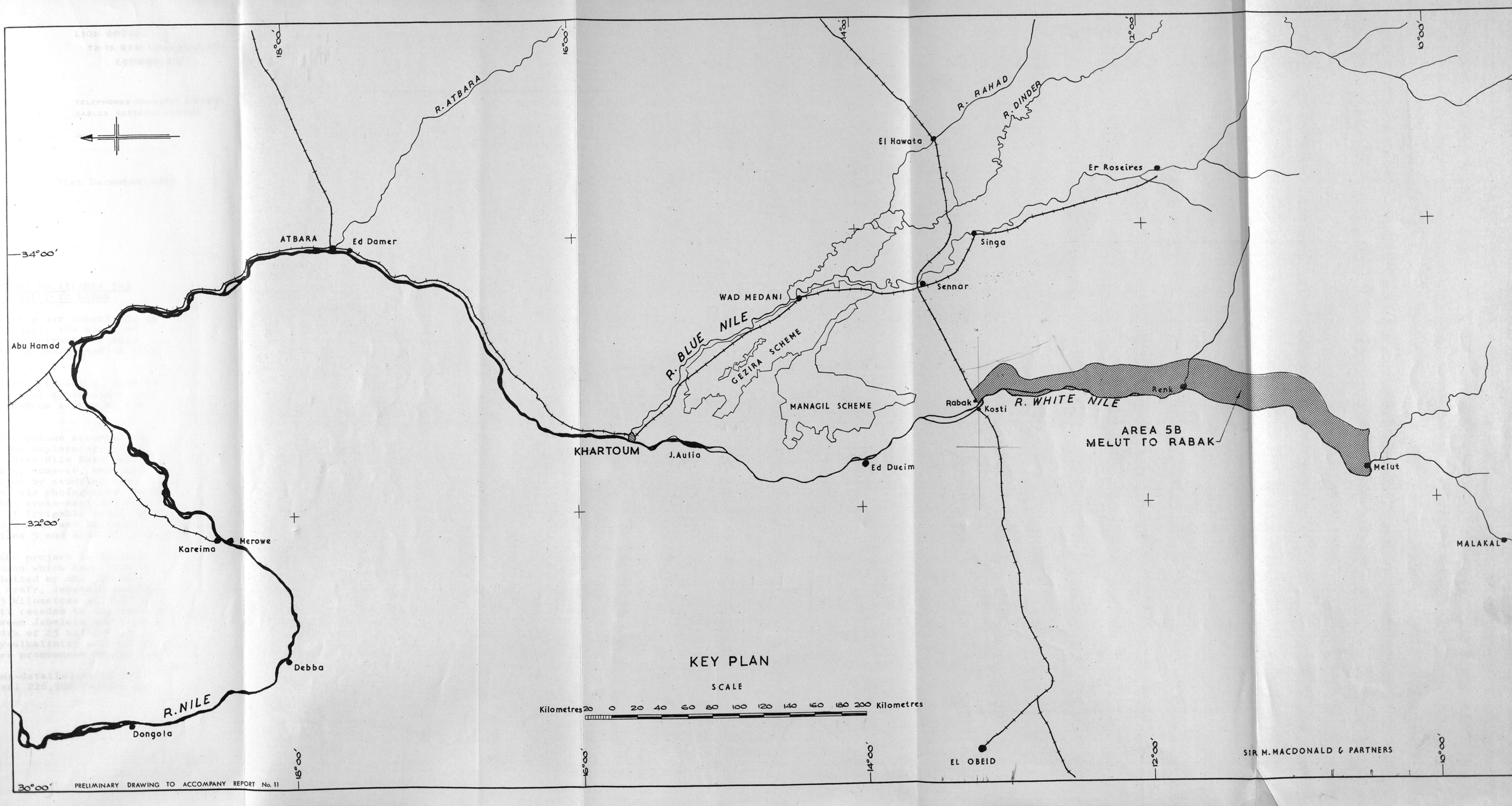
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Sir M. MacDonald & Partners
CONSULTING ENGINEERS

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Your ref..... Our ref..... Date .....

31st December, 1965.

H.E. The Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
REPUBLIC OF THE SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY REPORT NO.11(AREA 5b)
WHITE NILE EAST BANK, MELUT TO RABAK

We have pleasure in submitting our Report No. 11 for the Roseires Soil Survey Project, the study of which was entrusted to us by the Contract for Soil Survey of Irrigable Lands in the Sudan signed on 27th September, 1962.

Because of unforeseen hazards (flooding, lack of road access and security risks), our Exploratory Soil Survey was confined to the Rabak-Renk sector of the project area.

The report, which is in one volume accompanied by an album of maps, contains the exploratory soils and engineering survey of the White Nile East Bank between Renk and Rabak. We have, however, made an appraisal of the Renk-Melut lands by studying all existing data, including recent air photographs, photo-mosaics, maps, Survey Department cross-sections and the report on "The Estimation of Irrigable Areas in the Sudan" (1951-3) by Sir Alexander Gibb and Partners. These are described in Appendices 5 and 6 of the report.

The eastern boundary of the project is defined mostly by the 20 metre isopotamon which here lies on a well defined escarpment delimited by the 390 and 405 metre contours. At Jebel Nyefr, Jebelein and Renk this high ground lies within 5 kilometres of the river but between these localities it recedes to the eastward to form embayments which, between Jebelein and Geigar, attain in places a maximum width of 25 kilometres. These is a widespread salinity-alkalinity problem in these lands, which becomes less pronounced in the south.

Lands recommended for semi-detailed soils and land classification survey total 226,500 feddans in three blocks as follows :-

(i) Rabak South Area (20,000 feddans). These lands are well placed for development as they are adjacent to the railway line and the towns of Rabak and Kosti. These lands could be grouped with the block in Area 5a, north of Rabak, for development as one irrigation unit. The crops grown could be more diversified than those on the Gezira lands because of the wide range of soil textures.

(ii) Jebelein Area (51,000 feddans). These clay lands lie to the east of the existing irrigation development and extend from El Hideib southwards to Jebelein. Because of the high clay content, low salinity and moderate alkalinity most of the land would be suitable for a long-staple cotton rotation.

(iii) Geigar Area (155,500 feddans). About half of these lands should be suitable for a long-staple cotton rotation. The pattern of development will become apparent following the semi-detailed soil and land classification survey.

The outcome of the office studies of the area from Renk to Melut is as follows :-

Renk to Gelhak South of Renk, the escarpment (20 metre isopotamon) swings away south-eastwards and then parallels the White Nile at a distance of about 30 kilometres to the vicinity of Jebel Jogdeid where it turns eastwards towards the foot of the Ingessana Hills. Between Renk and Gelhak there is a block of land up to 25 kilometres wide and easily commandable by pump from the White Nile. The total area is about 380,000 feddans. Limited data show that the soils are, in general, of sandier texture than in the Gezira and that the total salt content and extractable sodium content is low. Because of low clay content these lands are probably not suited for long-staple cotton production but in view of the low salinity and moderate alkalinity they should be regarded as potentially suitable for field crops other than long-staple cotton. It would appear that an Exploratory Soil Survey should be carried out in this area when the opportunity occurs.

Gelhak to Melut This part of the project area forms a vast lowland plain below the 20 metre isopotamon. The present sustained high-level of the White Nile, which has caused extensive flooding in all the khors from Jebel Achmed Agha southwards to Melut, limits the project area to a few islands of high ground. It would therefore appear that the only areas available for development are those in the vicinity of Melut, already defined by Sir Alexander Gibb and Partners. This area totals 70,000 feddans, of which Melut Pump Scheme serves an area of 10,000 feddans. The semi-detailed soil survey for the remainder should be completed before further development.

In conclusion, therefore, we recommend the following areas for further investigation :-

Rabak to Renk	226,500 feddans for Semi-detailed Soil Survey

When opportunity occurs the following areas might also be studied :-

Renk to Gelhak	380,000 feddans for Exploratory Soil Survey
Gelhak to Melut	60,000 feddans for Semi-detailed Soil Survey

The soil studies have been carried out by Hunting Technical Services Limited, London.

We should like to record our appreciation for the assistance we have received during the course of our survey from officials of many Ministries in the Sudan Government, with special reference to the Ministry of Agriculture, the Ministry of Irrigation and Hydro-electric Power and the Sudan Survey Department.

We are, Excellency,

Your obedient servants,

SIR M. MACDONALD & PARTNERS.

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Dr. A. Kronenburg of the Khartoum Ethnological Museum for his advice concerning population distribution.

* Now professor in geography at Dar-es-Salaam University.

CHAPTER I

SUMMARY

1.1 The area covered by the Exploratory Soils and Engineering Survey is situated on the east bank of the White Nile between Rabak and Renk and has a length of approximately 160 kilometres. The eastern survey boundary roughly coincides with either the 20 metre isopotamon or a 25 kilometre distance from the river, whichever is the nearer. The outcome of this study is recorded in the report.

1.2 Due to high river levels which occurred during the field season which made the roads south of Renk impassable, combined with the uncertain security situation, the study of the area from Renk to Melut was restricted to an appraisal of the aerial photography, maps and published reports. The results of this study are recorded in Appendices 5 and 6.

1.3 Human settlement between Renk and Rabak is mainly along the river bank where cotton is grown. Also, a number of villages are located on the sandy ridges and adjacent to the large blocks of dura which extend east of the area; inland roads connect these villages with the main road which runs parallel to the river.

1.4 The area between Renk and Rabak is essentially an alluvial clay plain which was presumably deposited in the period from Upper Pleistocene to Recent; also originating from this era are a number of other physiographic features such as the "debbats" (a string of low, isolated mounds along the river), the sand dune area near Rabak and the sandy ridges. From west to east the following sequence can be distinguished in the clay plain, viz:-

a) Dark grey clay seasonally flooded ("toich")

b) Dark grey clay above the level of annual flooding.

c) Brown clay.

Evidence of older geological periods exist in three forms: the gently undulating Nubian sandstone outcrops in the north (Upper Cretaceous), the steep pinnacle-like "jebels" and the low marble ridges around Nyefr; the latter two belong to the Basement Complex.

The solid geology of the area extending from Rabak to Renk comprises both Basement Complex (Pre Mesozoic) and Umm Ruwaba Series (from Tertiary to Early Quaternary) but practically all of this is covered by young unconsolidated deposits.

1.5 Climatological data for the area from Renk to Rabak is provided by the meteorological stations at Kosti and Renk and a rainfall station at El Jebelein. These show the usual pattern of a more equable climate in the south; Renk has lowersummer and higher winter temperatures than Kosti, higher rainfall, higher humidity and lower evaporation; the average thirty year mean rainfall figures are: Kosti 406 mm, El Jebelein 417 mm and Renk 526 mm.

1. 6 The vegetational classification is based on Harrison and Jackson's "Ecological Classification of the Vegetation of the Sudan".

The northern part of the Renk to Rabak area, as far South as El Jebelein, is dominantly Acacia mellifera thornland; below this Acacia seyal is found in increasing numbers but is not completely dominant. The presence of Acacia mellifera makes it necessary to classify large areas as transitional; towards the south however Acacia seyal again becomes dominant thus giving the area a banded appearance. Acacia Senegal is dominant on lighter textured soils.

1.7 Apart from grazing and wood cutting which are widely practiced activities in the area between Renk and Rabak, the following types of agricultural land use occur:

a) Cultivation of rainfed dura; this is mostly on the higher grounds near the northwestern survey boundary.

b) Groundnuts on the sandy ridges

c) Rainfed dukhn in the Rabak sand dune area.

d) Scattered "shaduf" and "seluka" cultivation on riverain land south of El Goda.

e) Irrigated cotton along the river.

The average total area annually planted with cotton between Renk and Rabak is 27,393 feddans. The overall average yields in five

consecutive seasons (1960-65) amount to 3.5, 4.1, 5.0, 4.2 and 2.7 kantars per feddan respectively; the overall average for 5 seasons is therefore 3.9 kantars per feddan.

All pump schemes between Renk and Rabak are privately owned; the majority of the schemes fall in the size class of 100 to 500 feddans. Everywhere in the area a three course rotation is practised, cotton-dura-fallow.

1.8 The following soil survey methods have been employed:-

a) Aerial photographs have been used for field location and delineation of soil boundaries.

b) Due to restricted accessibility most field observations had to be made along previously cleared traverses; included in this group of approximately west-east running traverses are two sample lines in which pedological variations were studied in greater detail. The overall density was approximately 1 observation per 2,000 feddans.

c) The ultimate objective of the survey was the compilation of two separate maps, a soil map and a land suitability map.

1.9 (a) "Land suitability" as used in this report should be interpreted as suitability for investigation at semi-detailed level.

(b) The land suitability map has been derived entirely from the soil map, i.e. soil mapping units consistently correspond with specific land suitability units.

(c) The land suitability map consists of only three units:

1. Land recommended for further investigation.
2. Land unsuitable for further investigation.
3. Pump schemes and seasonally flooded land.

(d) The following limitations have been used on the assessment of the suitability:

1. Topographic limitations.

Sloping or undulating topography.

Elevation above the general level of the clay plain.

Micro relief of the surface.

2. Soils limitations.

Soil depth.

Clay percentage.

Alkalinity.

Absence of cracks.

1.10 The soils have been classified according to the U.S.D.A. 7th Approximation. Since diagnostic characteristics are in general only weakly expressed, it is believed that all soils of the area come into the order of Entisols; distinction of soil types is on a subgroup level or otherwise by phases.

a) Very dark grey clays (Grumaquertic Orthustents).

Extensive deposits of very dark grey clay deominate the area; profiles of the very dark grey clays consist of a coarsely structured and weakly cracked toplayer overlaying a compact subsoil. In places a very uneven microrelief had developed on the surface of these clays. Low permeability and high alkalinity are two unfavourable features of the Grumaquertic Orthustents.

A decrease of overall alkalinity is noticeable towards the south of the area; on account of this factor two alkalinity phases were introduced corresponding with higher and lower overall E.S.P. levels.

b) Brown clays (Grumustertic Orthustents).

In an easterly direction the very dark grey clays give way to the brown clays which occupy slightly higher ground. Like the very dark grey clays, the brown clays have a cracked zone underlain by a hard compact subsoil; on the whole cracks are better developed in the brown clay than in the very dark grey clay.

From alkalinity point of view the brown clays compare favourably with the previous group and uneven surfaces do not seem to occur amongst this soil type.

c) Soils of sandy ridges, sand dunes and conglomerate outcrops; these soil types occupy comparatively small parts of the area and moreover they are all unsuitable for further investigation.

1.11 From the whole group of soil types shown on the map, two are

recommended for further investigation.

a) The very dark grey clays, (Grumaquertic Orthustents), phase with lower overall alkalinity.

b) The brown clays (Grumustertic Orthustents).

The total area of these two soil types between Renk and Rabak is 172,000 feddans; this means approximately one quarter of the area is suitable for further investigation.

1.12 In addition, from examination of the field and laboratory data, an interpretation of the land quality to standards similar to those used in Roseires Areas 1 and 5a showed that an additional 54,500 feddans of land in the Rebek Jebelein sector might have favourable development possibilities and should also be covered by semi-detailed soil and land classification survey.

1.13 The lands recommended for semi-detailed soil survey and land suitability classification in the area between Renk and Rabak are as follows:

Area No.	Locality	Map Sheet No.	Area (Feddans)
1.	Rabak South Area	1	20,000
2.	Jebelein Area	2	51,000
3.	Tayba, Geigar and Renk North Area	2 & 3	155,500
		Total Area	226,500

1.14 Preliminary layouts for canalization of the areas recommended for semi-detailed soil survey have been prepared for five pump schemes for a gross area of 165,500 feddans. The remaining areas recommended for semi-detailed soil survey can best be irrigated by extension from existing pump schemes (61,000 feddans).

1.15. An office study of the area between Renk and Gelhak indicates that an exploratory soil survey should be carried out in this area totalling some 380,000 feddans.

1.16 The areas in the vicinity of Melut which were defined by Sir Alexander Gibb and Partners in their report "Estimation of Irrigable Areas in the Sudan 1951-3" and not already incorporated in the Melut Pump Scheme should be covered by semi-detailed soil survey prior to further development. The remainder of the area between Gelhak and Melut is subject to flooding at times of high river level.

CHAPTER 2

THE ENVIRONMENT

2.1 Location and general description of the area

2.1.1 Definition of the area

The survey area is situated along the east bank of the White Nile between Rabak and Renk having a length of approximately 160 km.

The northern and southern limits of area are formed by the Kosti-Sennar railway, and a West-East line drawn through Renk; the eastern survey boundary approximates with either the 20 m. isopotamon or a 25 km distance from the river, whichever is the nearest. The pump schemes adjacent to the river constitute the Western boundary of the survey region.

The area lies between latitudes 11°45'N. and 13°10'N. and longitudes 32°45'E. and 32°55'E.; the area forms part of both the Kosti District (administrative headquarters in Kosti; part of Blue Nile Province) and the Northern Renk District (administrative headquarters in Renk; part of Upper Nile Province). The town of El Jebelein occupies a position in the middle of the area.

2.1.2 Human settlement

The major urban centres (Rabak, El Jebelein, Geigar, Renk) are situated along the river bank where cotton is grown. Also a number of small villages (e.g. Sagaya and Nyefr; occur near the eastern survey boundary on the transition between dark grey and brown clay; the inhabitants grow rainfed dura on the brown clay and graze their herds on the shrub covered dark grey clay. Furthermore, human settlement is found on the sandy ridges (e.g. Abu Delor and Abu Shalaya) where groundnut cultivation is practised; the villages of the second and third group depend on hafirs for their water supply. Three abandoned village sites were encountered in area; all three are located on small, isolated and treeless mounds which rise a few metres

above the general level of the clay plain. Owing to these features the mounds can be seen on the aerial photographs.

These sites have a grass cover conspicuously different from the surrounding clay plain. Their surface is littered with pottery shards and a lesser amount of hand transported stones; pottery shards also occur in the subsoil (see profile descriptions No. 8056 and 8095). A sample of shards from site No. 8056 has been submitted to the Antiquities Service in Khartoum for dating. The calcareous coatings which cover the objects of this site suggest that they must have been buried for a considerable length of time.

At the sites No. 8066 and 8095 which are both well away from the river, silted up old hafirs were found.

2.1.3 Population

The population of the area is predominantly of Arabic extraction although an increasing number of Nilotic people are evident towards the South; Dinka villages occur on the Abu Shalaya ridge.

An isolated community of Fellata (= migrants from West Africa) is found in the village Makharda, North of El Hideib; their livelihood is a rather unusual one as they grow rice on the "toich" land along the river. The rice crop which is of rather poor quality, is harvested in December before the cotton picking starts. Nomads with their herds and flocks are regularly seen in the area; by local usage they are referred to as "Fariq Arab".

2.1.4 Communications

Kosti and Rabak are on the Sudan Railway system; moreover both towns are connected with Khartoum by road; motor traffic passing the Kosti railway bridge is restricted to vehicles not exceeding 6.2 feet in width or 3 tons weight. Government steamers from Kosti call at Jebelein and Renk on their way South. During part of the year there is an air service between Khartoum and Rabak twice a week.

A graded earth road running parallel to the east bank of the river constitutes the major means of communication for motor traffic in the area; a number of branches connect the inland villages

with the main road. Some of the inland branches originate from land survey traces, which came into regular use as roads after they were cut.

Apart from a small number of inland roads, access to the area is difficult; this is due to:

1. The main road runs through the irrigated pump schemes and therefore is isolated from the hinterland by waterlogged soil.
2. The greater part of land survey traces as shown on the topographic map have become obliterated by vegetation, which prevents them from being located in the field.

2.2 Physiography

2.2.1 Geological history

The 1:1,000,000 geological map (sheet 55, Khartoum), shows that the survey region includes parts of both the Basement Complex and the Umm Ruwaba Series; a small island of the Nubian Series also occurs in the area. These facts account for most of the geomorphologic features of the region, but they have little bearing on the nature of the superficial flat clay deposits, which actually constitute the parent material of the major soils in the area.

As several of the more conspicuous features in the landscape between Rabak and Renk are associated with the older geological periods, it seems worthwhile to give a brief outline of the area's geological history as far as is known from the literature.

(a) Earliest periods

The formation of the Basement Complex goes back to the Pre Cambrian era and seems to have continued throughout the better part of the Palaeozoic; the Basement Complex is the substructure on which all Mesozoic and younger sedimentation has taken place. This platform has been produced by the erosion of a complex old land surface which included both igneous and sedimentary rocks, mostly folded and metamorphosed. The pinnacle-like, steep inselbergs near El Jebelein, Jebel Kodi, Jebel Nyefr and the subdued, gently sloping marble outcrop South of Jebel Nyefr all constitute irregularities in the dominantly

horizontal Basement platform; everywhere else in the stretch between El Jebelein and Rabak the Basement Complex is buried under more recent, unconsolidated deposits.

(b) The Mesozoic

A long period of mainly continental deposition commenced in the Upper Palaeozoic and continued all through the Mesozoic until the Upper Cretaceous; the predominant sediments are horizontal to gently dipping sandstones, siltstones and mud stones which in general are poor in fossils and contain only few other deposits.

Relevant to the northern part of the surveyed region are the Nubian Series which belong to the Upper Cretaceous; essentially they consist of silicified sandstone and conglomerate beds.

One such a Nubian sandstone outcrop occurs near Rabak. This outcrop is part of a ridge which in a south-eastern direction extends as far as the village Vanoga. The undulating ridge consists of both red sands as well as red clays which are rich in ferruginous grit; in fact the Rabak-Vanoga ridge is partly overblown with sand and has a dune like topography. It would appear therefore that both sandstone weathering and dune-formation have contributed to the present shape and composition of it.

It is suggested that the Qoz Girgaf outcrop (conglomerate) might be another feature originating from the Nubian Series.

(c) Tertiary and Early Quaternary

A major geologic event since the deposition of the Nubian Series is the uplift of the region's eastern margin and the simultaneous formation of a North-South running syncline; this tectonic depression is the present central plain of Egypt and the Sudan through which the Nile flows. In a later stage of the Tertiary the valley of the White Nile and its tributaries sunk to great depths so that an extensive and deep trough resulted; in a subsequent process of aggradation the trough became infilled with a thick layer of unconsolidated sediments: the Umm Ruwaba Series. It is sometimes assumed that for a long time the White Nile must have had the character of a lake, originally without any northern outlet towards the main Nile. The Umm Ruwaba Series

constitute the deeper substratum of the survey area between El Jebelein and Renk; this fact however has little local consequence as the Umm Ruwaba Series are everywhere overlain by more recent deposits.

(d) Upper Pleistocene to Recent

During this era the clay of the plains and the Kordofan sands were deposited.

(i) The clays are the exposed alluvial beds which overly most of the Basement Complex and all of the Umm Ruwaba Series in the investigated region; the two dominant soil types of the area. - the dark grey and brown clays, - have developed in these deposits. Although not many details seem to be known about these clays, their alluvial origin is generally agreed upon.

(ii) The Kordofan sands are the stabilised quartz sand dunes ("qoz") which occupy an extensive area in the Sudan. Of the two kinds of sediments, - the clays and the Kordofan sand dunes, - this latter group is thought to be the older one.

2.2.2 The Landscape

Apart from the already mentioned jebels the most prominent physiographic features are:

(a) The clay plains.
(b) The debbats.
(c) Conglomerate outcrops and gravel beds.
(d) The ridges.

(a) The Clay Plains

The clay plain dominantly has a flat topography and slopes downwards to the Nile bed with so small a gradient as to be unnoticeable in the field. A number of khors (natural drainage channels) constitute insignificant depressions in the terrain; two of the major khors are old subsidiary Nile channels. Only in a few places have the intermittent streams developed a shallow but distinct meanderbelt (unit G on the physiographic map).

Although preponderantly flat, some slopes do occur in the clay plains e.g. the transition from very dark grey to brown clay, which is usually marked by a small but distinct rise in the level of the plain.

Another slight break in the relief of the clay plain can be observed on several places along the main road through the area; this road regularly follows a gentle undulation in the plains surface and runs across several low mounds on which most of the pump scheme villages are built. From West to East the following sequence can be distinguished in the clay plain viz:

(i) Dark grey clay seasonally flooded ("toich") or dissected by a braiding river pattern.

(ii) Dark grey clay above level of annual flooding.

(iii) Brown clay.

(b) The debbats

A considerable number of 2-3m high isolated mounds are found a short distance from the river; most of them have a roundish shape and diameters varying between 10 and 30m.

These hummocks, - or "debbat" in Arabic, - are nearly all present on former sites of inhabitation and occur at irregular intervals along the river bank. In one such "debbat" near El Jebelein buried pottery shards and other artifacts were found.

Most of the mounds consist of brown sand rich in calcareous concretions, a few however have dark coloured clay loam profiles. Only a very few hummocks of this kind occur further away from the Nile; one such an isolated "debbat" was found in trace CS 12 at a distance of 21 km from the river. Hand transported rock fragments, pottery shards and a silted up hafir are evidence of former human settlement on this "debbat". It is believed however that these inland mounds differ in origin from the ones along the river; hence they have been shown with separate symbols on the physiographic map. The origin of the mainly sandy,, isolated mounds along the Nile bank is not known; from Andrew it is understood that the debbats are presumably of Pleistocene age.

Note: In Arabic the word "debbat" (plural:"debaba") refers specifically to small isolated mounds. The term "qoz" is applied to both sand dunes of the Kordofan type and narrow elongated ridges as will be described under (i).

(c) Conglomerate and gravel beds

(i) Conglomerate outcrops

These are found at several places in the northern survey area between Rabak and El Jebelein; one of them is the Rabak-Vanoga ridge. Another large outcrop of cemented quartz gravel is "Qoz Girgaf", about 12.5 km South of Vanoga along the road.

This is an undulating body of superficially weathered quartz conglomerate rising several metres above the clay plain. The outcrop protrudes rather abruptly above the terrain with a West facing scarp and a dissected, much gentler back-slope to the East. The conglomerate consists of well rounded quartz gravel and includes a fair quantity of pea iron concretions. These components are held together by a brownish red to brown, very hard cement which must contain a high percentage of iron oxide; a thin weathered top layer of this conglomerate bed is excavated for building purposes. Another, smaller outcrop of this kind occurs along the Northern foot of the major jebel near El Jebelein; it is too small however to be shown on the physiographic map. Both "Qoz Girgaf" and the Rabak-Vanoga ridge which has been described previously, are thought to be outcrops of Nubian sandstone (unit B on physiographic map).

(ii) Gravel beds

Also in the northern area gravel beds are found covered by a layer of soil with a thickness of at least 100 cm. In contradistinction to group (c) (i) it seems quite certain that here the soil is not genetically related to the underlying gravel-bed. Apart from anything else, an in situ soil would have had a far higher gravel content. These soil-covered gravel beds are recognisable by a distinctive vegetation. Locally these deposits may have a slightly higher elevation than the clay plain, but only occasionally they assume the shape of a distinct ridge. One buried gravel area forms a narrow strip running from Jebel Kodi in the direction of Jebel Nyefr; this strip is on a level with the clay plain and has a clearly differing vegetation pattern.

An indication for the geological age of the gravel beds is given by Andrew. He reports the occurrence in the White Nile plain of sand and gravel banks to which he ascribes Pleistocene age.

Almost certainly the gravel beds and conglomerate outcrops must be the source of iron stained covers of quartz gravel which are found quite frequently on top of the dark grey clay, especially between Rabak and El Jebelein. South of El Jebelein the gravel covers decrease both in density and average particle size and beyond Geigar practically no more gravel is found; furthermore it was observed that no quartz gravel of any significance occurs on the brown clays.

This is in accordance with the theory that the superficial gravel covers in the northern survey area originate from gravel sources such as "Qoz Girgaf". The area south of El Jebelein is too far removed from these sources and the brown clays are mostly at too high a level, so that in both cases gravitional transport (by off streaming water) becomes impossible.

(d) The ridges

Four distinct ridges were found in the survey area:

1. A ridge from the jebels near El Jebelein in N.E. direction.
2. The Abu Delor ridge.
3. The Abu Shalaya ridge.
4. The Rom ridge.

Unlike the gravel beds, the occurrence of these ridges is not confined to the region North of El Jebelein but extends from a place near El Jebelein to Renk. The ridges extend over distances of several kilometres and are 2.5 - 5 m above the surrounding clay plain to which they fall with very gentle slopes. The soils of the ridges have high sand percentages and reddish colours; textures range from very sandy clay to loamy coarse sand.

Regarding the origin of the sandy ridges Andrew has suggested two different explanations viz. the ridges being Kordofan sand dunes which were spread flat by rain wash; alternatively the ridges should be considered Pleistocene sand outcrops, protruding through the exposed clay cover. According to a more recent concept the ridges are thought to be old lake shores. In a study of the White Nile, Berry describes two distinct river terraces each of which corresponds with past water

levels of the river. According to this author the two terraces must have been formed under lacustrine conditions and therefore it is quite likely that the sandy ridges represent fossil lake shores. This concept involves the temporary transformation of a flowing river into a still water lake and requires a blocking of the White Nile; such a ponding may have been brought about either by a high flooding of the Blue Nile or by the deposition of a sediment bar, vast enough to temporarily check the flow of the White Nile.

Note: Not included in the above group is the low, gently sloping ridge South of Jebel Nyefr because of its entirely different (Pre Mesozoic) origin.

This ridge is a subdued outcrop of marble overlain by a thin veneer of conglomerate (see description of site No. 7046). In the near future the marble will be quarried to supply raw material for the Rabak cement factory (under construction). The marble ridge is shown as unit F on the physiographic map.

2.3 Climate

2.3.1 General

The climate of the area is typical of those parts of the Sudan having a summer rainy season. For approximately seven months of the year northerly winds are the dominating factor producing low humidity, drought and high temperatures, reaching a maximum prior to the onset of the rains. The wind then veers round to the south and the 'harif' or rainy season brings high humidity and lower temperatures for five months. After the rains the temperature increases and the dry season begins.

The region is served by two meteorological stations at Kosti and Renk, and a rainfall station at El Jebelein. A further rainfall station has been set up at Geigar but is not yet recording results.

2.3.2 Temperature

The monthly averages of the mean daily maximum and mean daily minimum temperature at Kosti and Renk are shown in figures 1 and 2. As would be expected due to its more southerly longitude Renk shows the more equable climate with lower summer and higher winter temperatures than Kosti. Both stations have their hottest month in April, but the

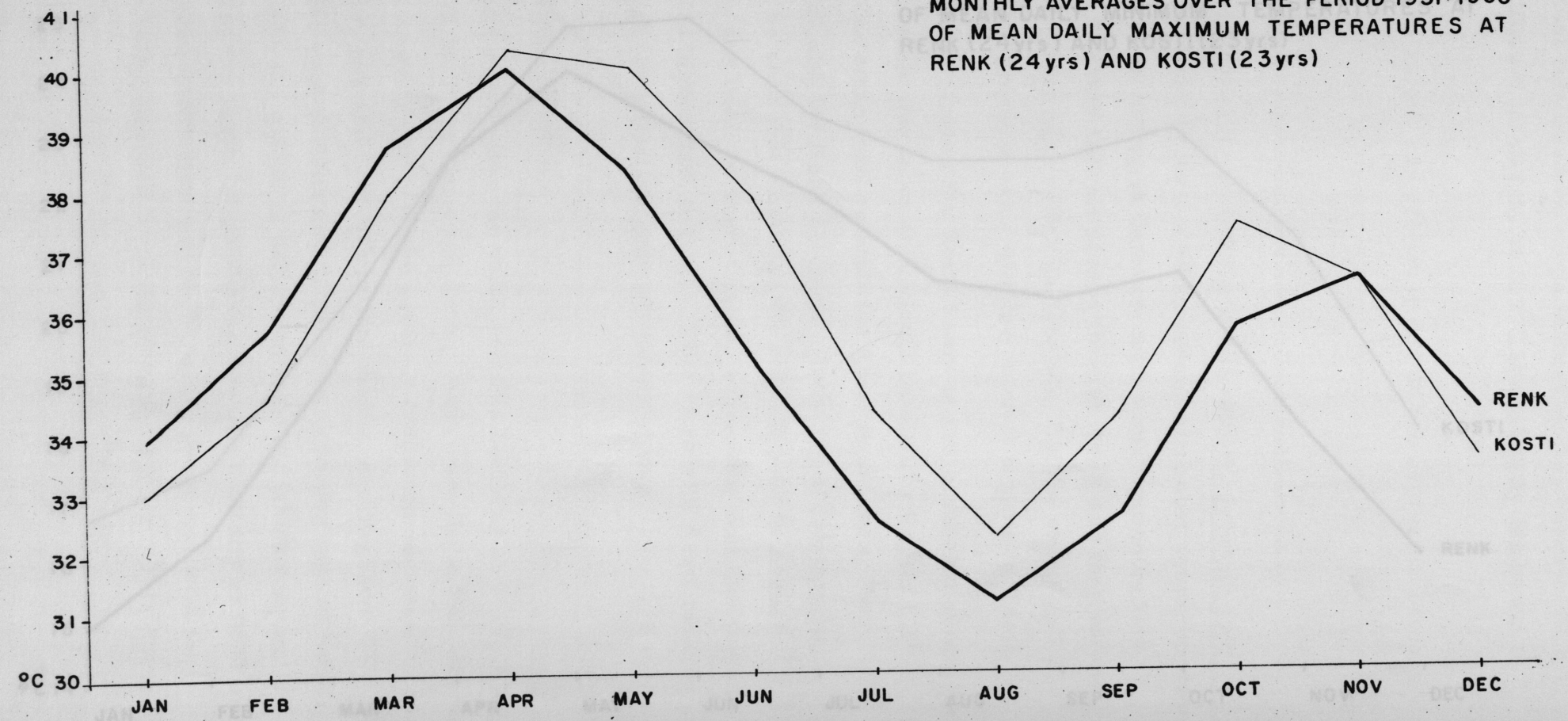
MONTHLY AVERAGES OVER THE PERIOD 1931-1960
OF MEAN DAILY MAXIMUM TEMPERATURES AT
RENK (24 yrs) AND KOSTI (23 yrs)
41
40
39
38
37
36
35
34
33
32
31
°C 30
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
RENK
KOSTI

Fig. 1

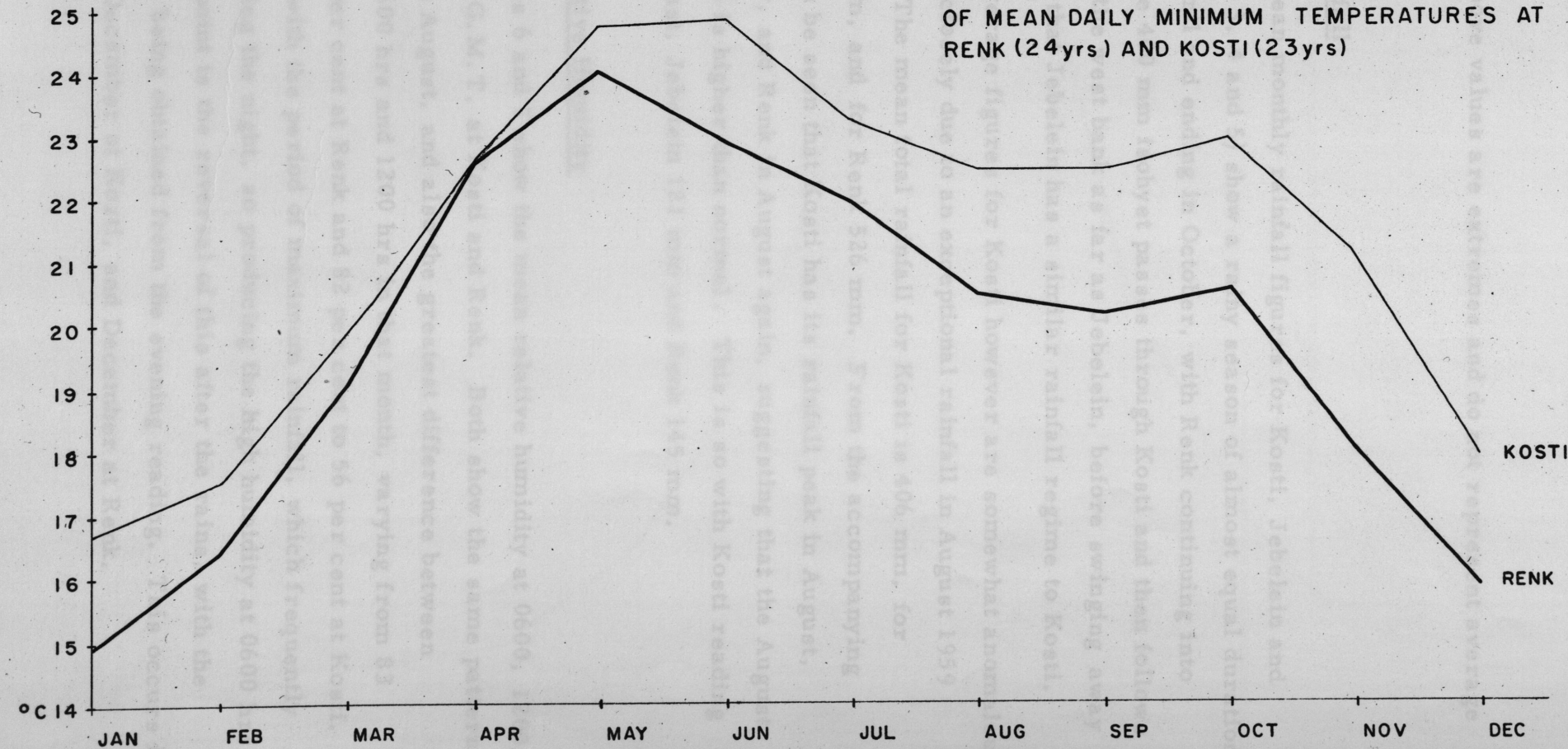
MONTHLY AVERAGES OVER THE PERIOD 1931-1960
OF MEAN DAILY MINIMUM TEMPERATURES AT
RENK (24yrs) AND KOSTI (23yrs)
25
24
23
22
21
20
19
18
17
16
15
°C 14
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
KOSTI
RENK

Fig.2

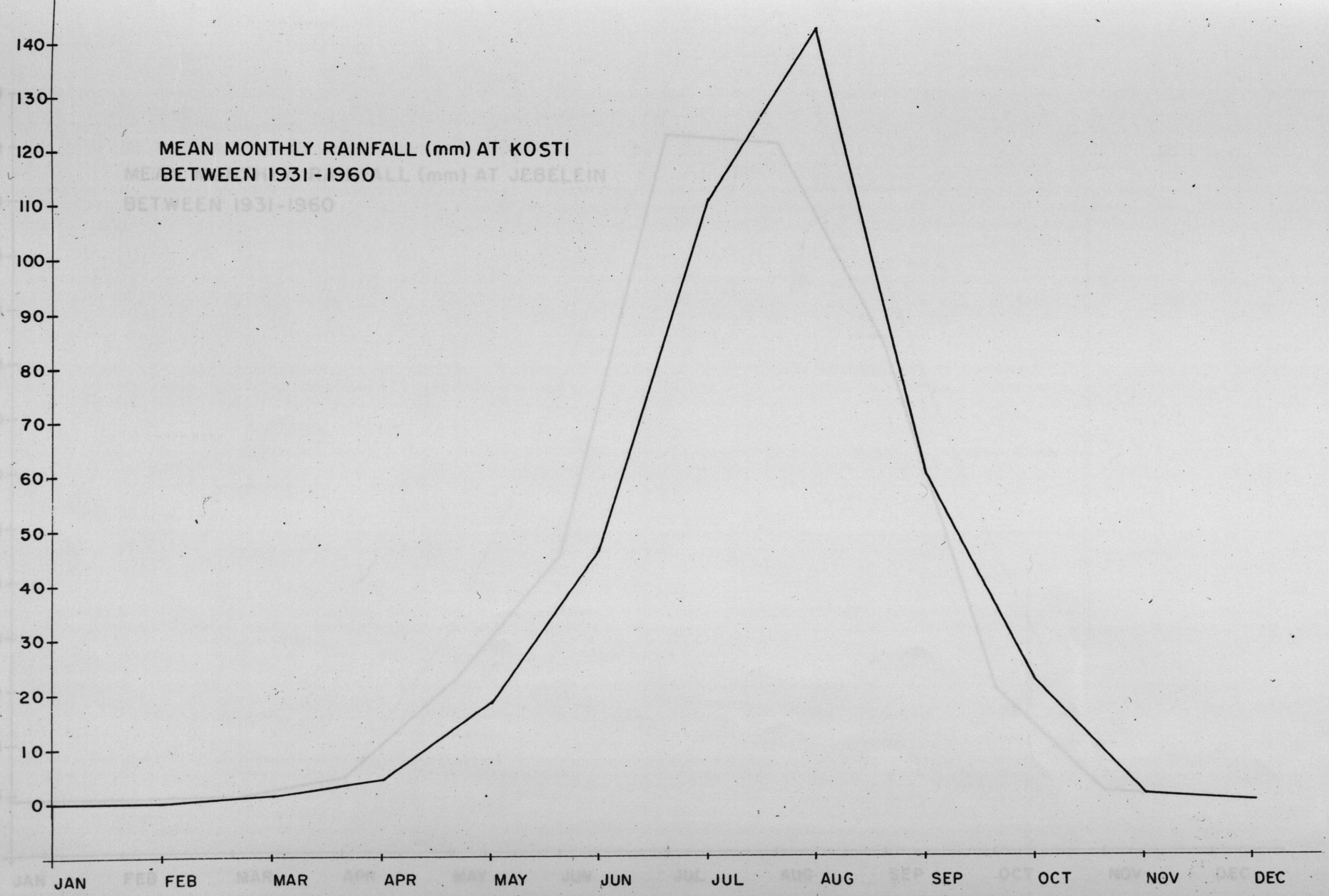
MEAN MONTHLY RAINFALL (mm) AT KOSTI
BETWEEN 1931-1960
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 3

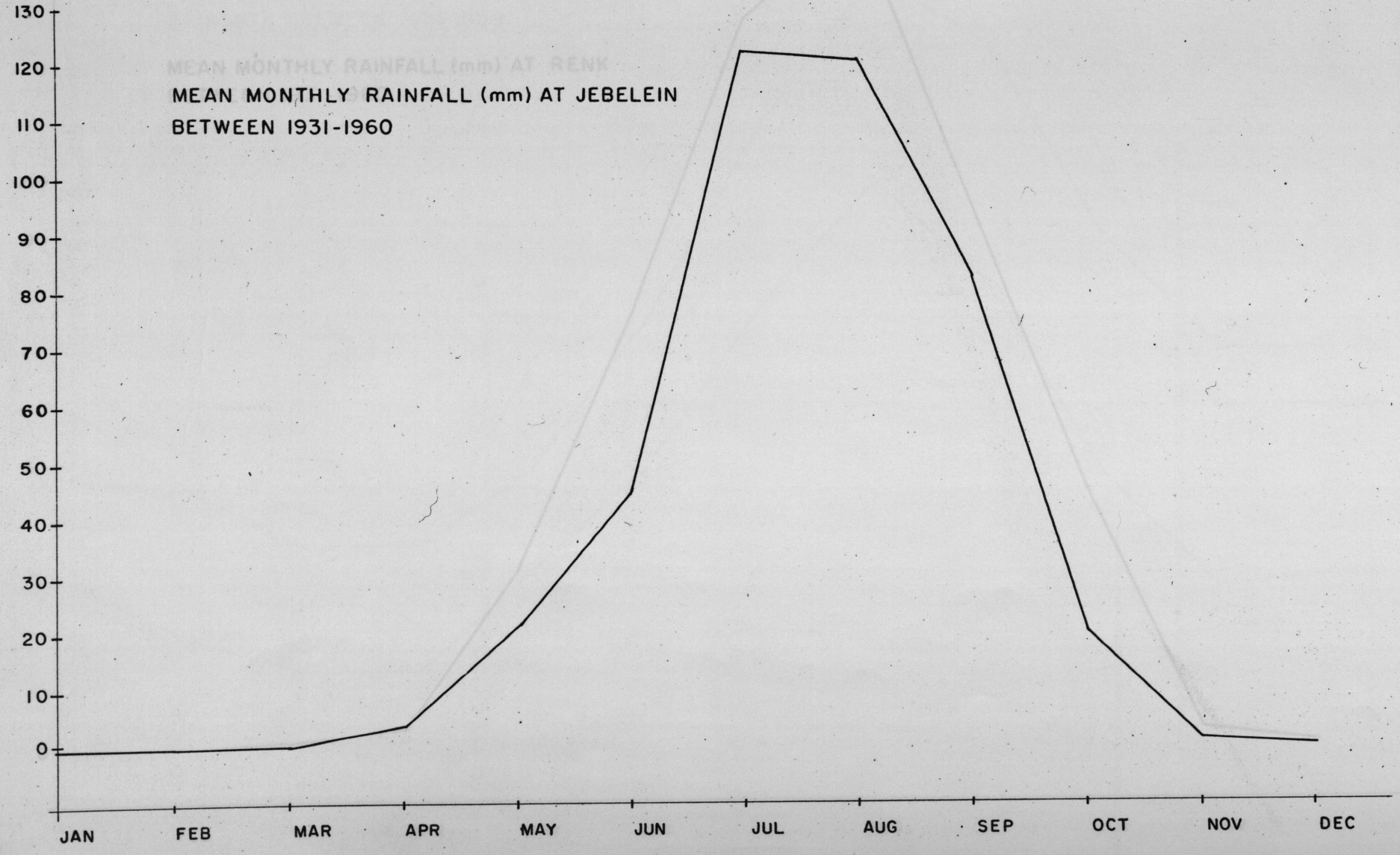
MEAN MONTHLY RAINFALL (mm) AT JEBELEIN
BETWEEN 1931-1960
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig.4

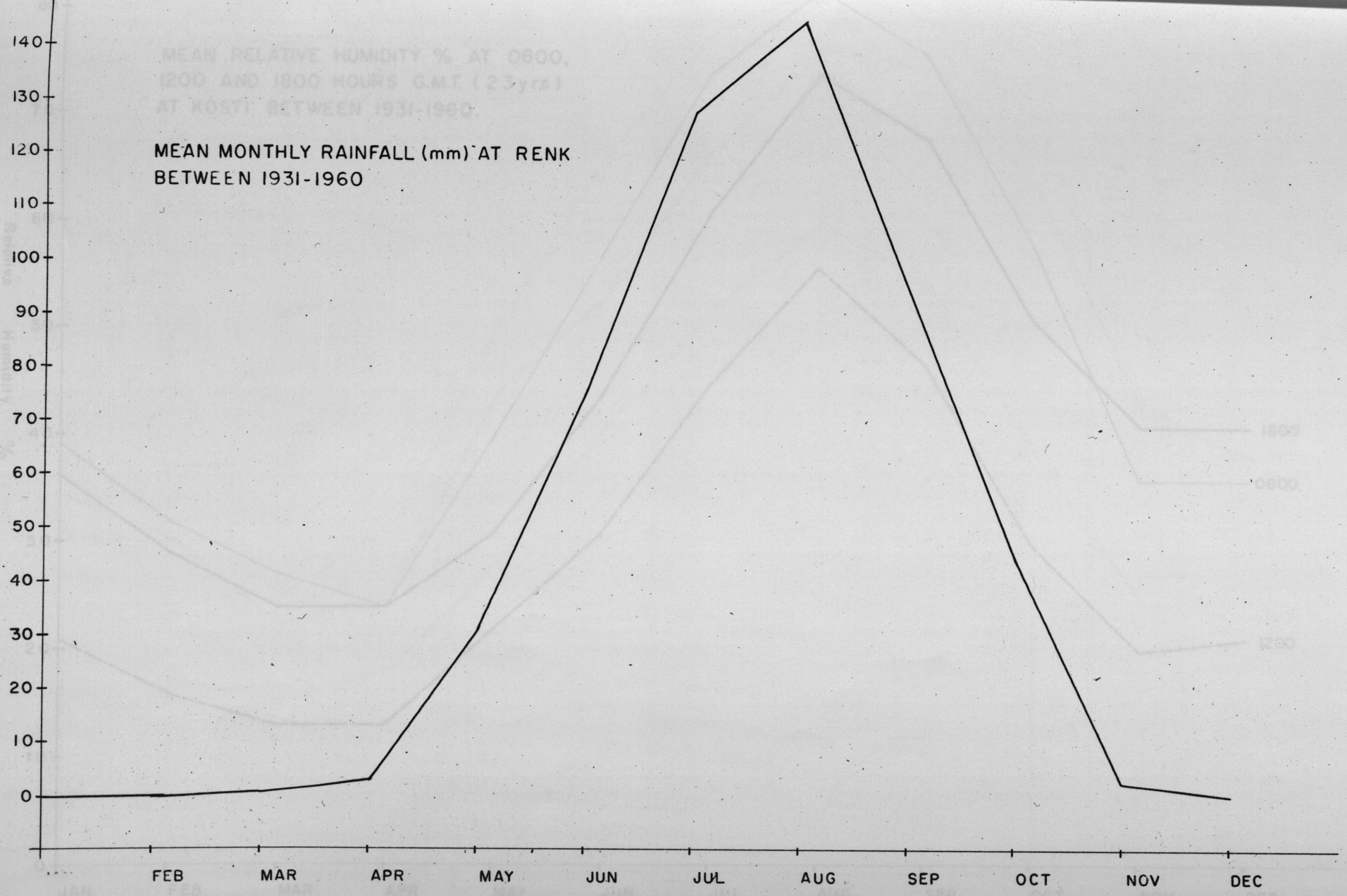
MEAN MONTHLY RAINFALL (mm) AT RENK
BETWEEN 1931-1960
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 5

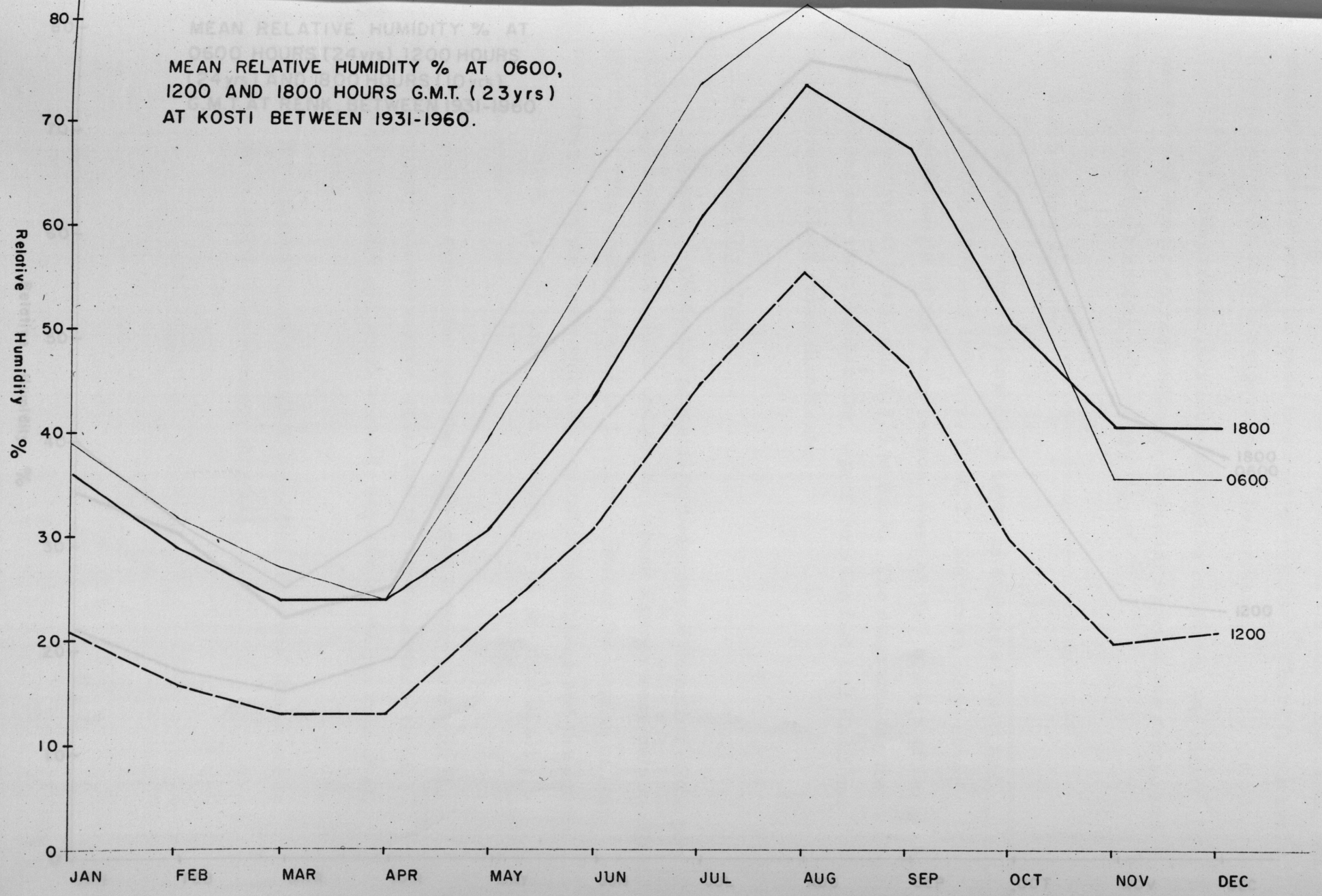
MEAN RELATIVE HUMIDITY % AT 0600, 1200 AND 1800 HOURS G.M.T. (23yrs) AT KOSTI BETWEEN 1931-1960.
Relative Humidity %
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1800
0600
1200

Fig. 6

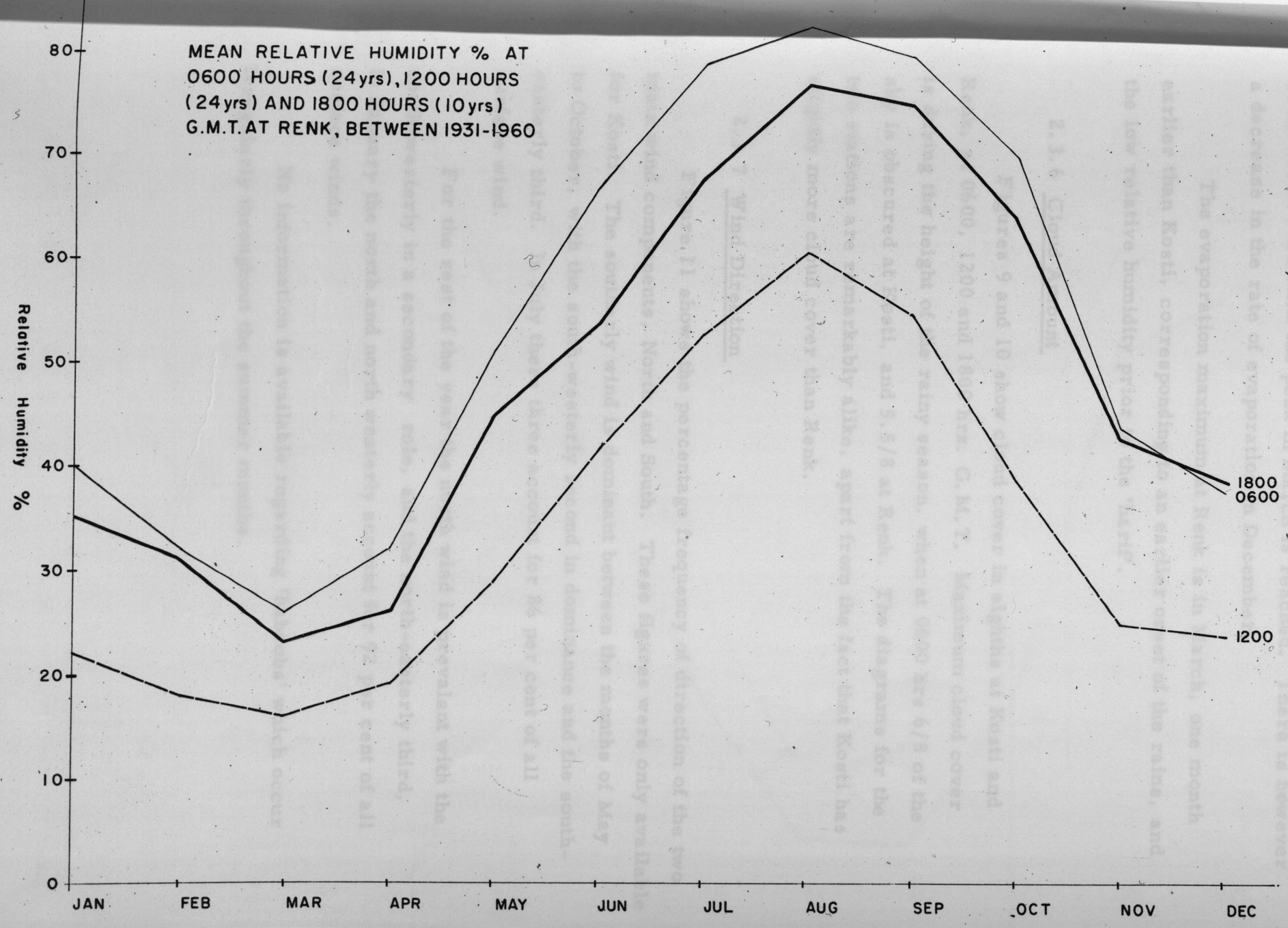
MEAN RELATIVE HUMIDITY % AT
0600 HOURS (24 yrs), 1200 HOURS
(24 yrs) AND 1800 HOURS (10 yrs)
G.M.T. AT RENK, BETWEEN 1931-1960
Relative Humidity %
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1800
0600
1200

Fig. 7

2.3.5 Evaporation

Figure 8 shows the daily evaporation (Piche) in mm for Kosti and Renk. As expected the trough occurs roughly at the period of maximum rainfall and the two peaks occur in accordance with the periods of maximum temperature, in the case of Kosti. Renk does not show a peak to correspond with the temperature maximum at the end of the rains, but continues to rise until the peak in March is reached. There is however a decrease in the rate of evaporation in December.

The evaporation maximum at Renk is in March, one month earlier than Kosti, corresponding to an earlier onset of the rains, and the low relative humidity prior to the 'harif'.

2.3.6 Cloud Amount

Figures 9 and 10 show cloud cover in eighths at Kosti and Renk, at 0600, 1200 and 1800 hrs. G.M.T. Maximum cloud cover is during the height of the rainy season, when at 0600 hrs 6/8 of the sky is obscured at Kosti, and 5.5/8 at Renk. The diagrams for the two stations are remarkably alike, apart from the fact that Kosti has slightly more cloud cover than Renk.

2.3.7 Wind Direction

Figure 11 shows the percentage frequency of direction of the two main wind components, North and South. These figures were only available for Kosti. The southerly wind is dominant between the months of May to October, with the south-westerly second in dominance and the south-easterly third. In July these three account for 86 per cent of all surface wind.

For the rest of the year the north wind is prevalent with the north-westerly in a secondary role, and the north-easterly third, In January the north and north westerly account for 92 per cent of all surface winds.

No information is available regarding 'haboobs' which occur irregularly throughout the summer months.

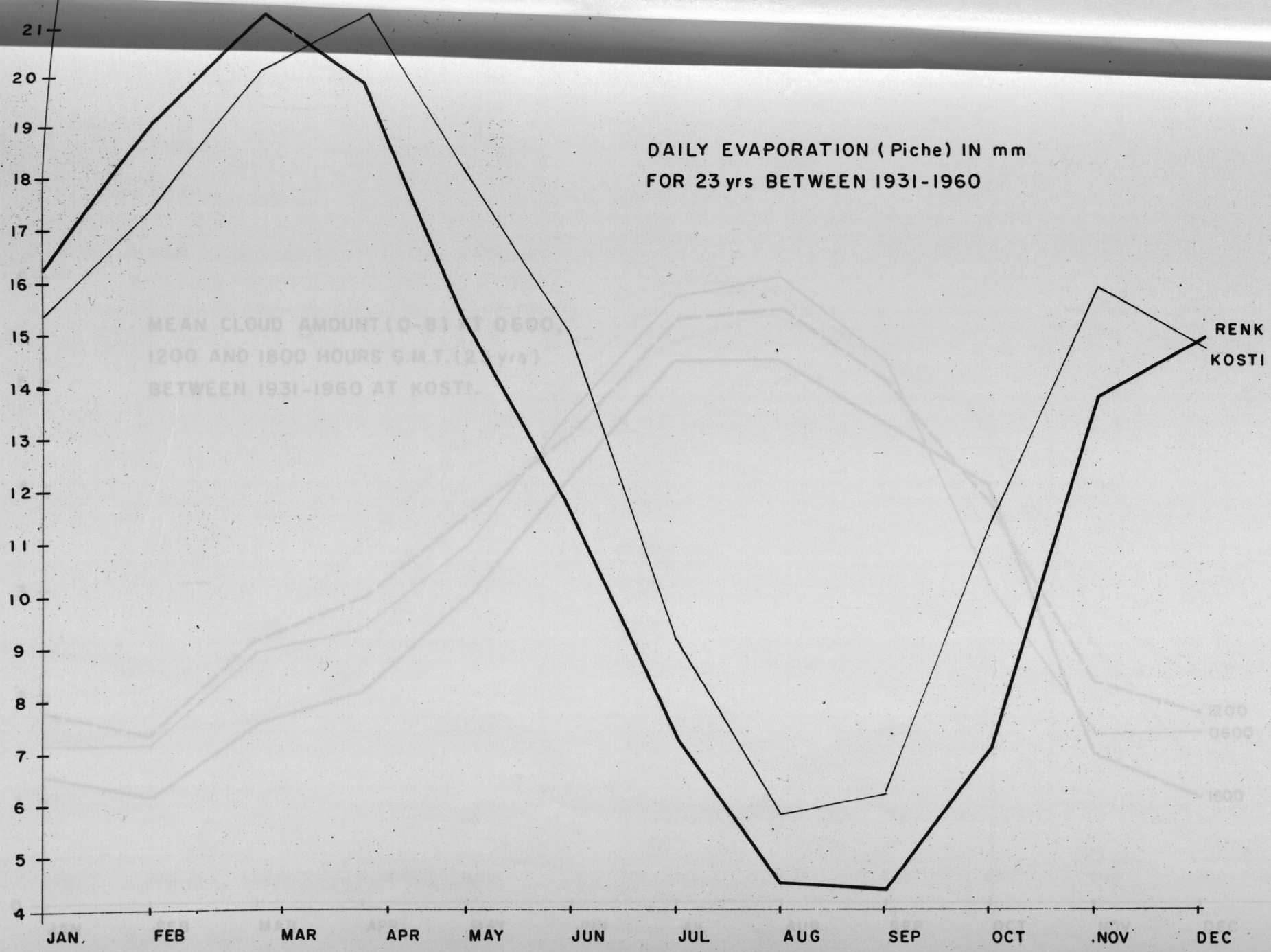
DAILY EVAPORATION (Piche) IN mm
FOR 23 yrs BETWEEN 1931-1960
RENK
KOSTI
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
JAN.
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Fig. 8

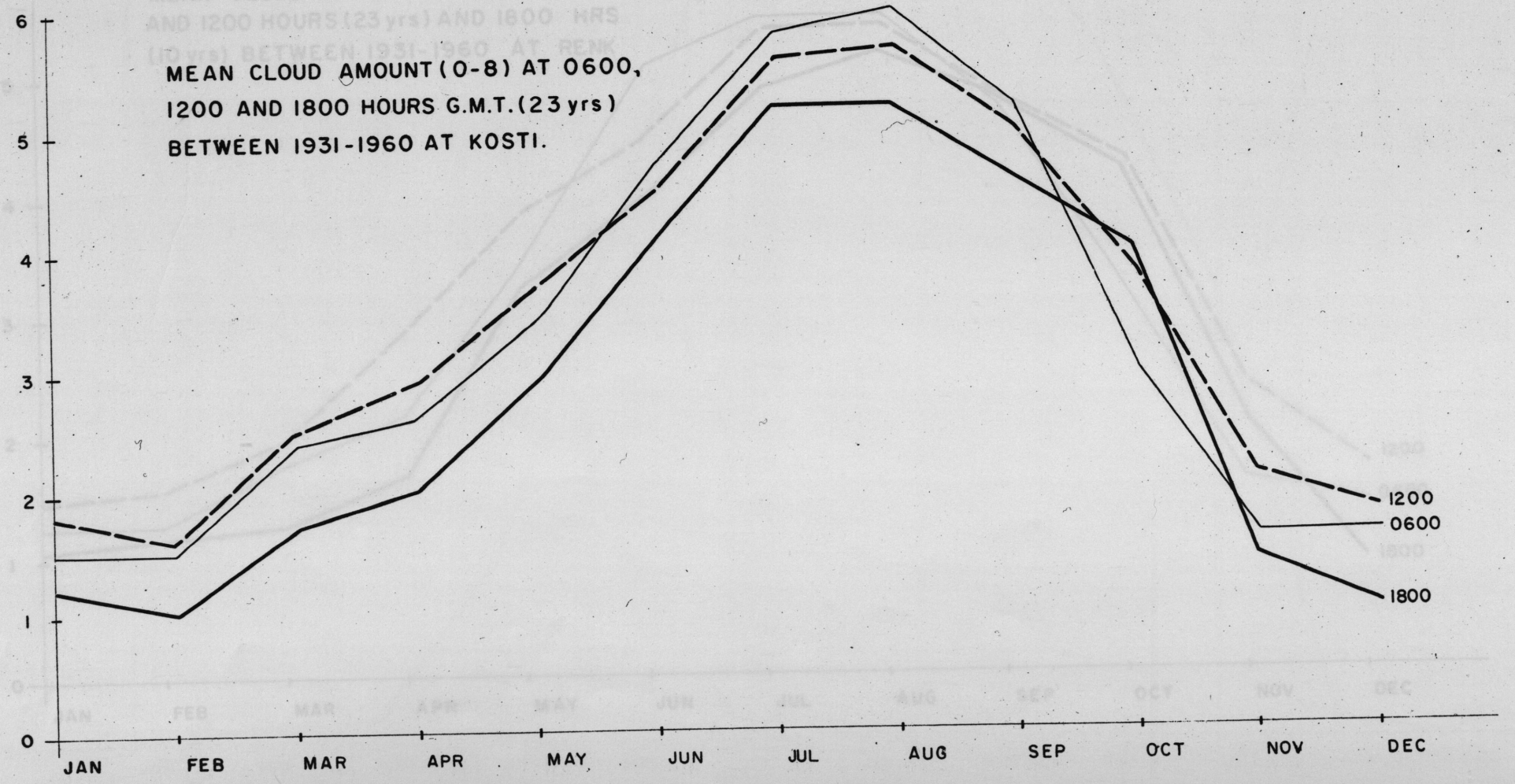
MEAN CLOUD AMOUNT (0-8) AT 0600, 1200 AND 1800 HOURS G.M.T. (23 yrs) BETWEEN 1931-1960 AT KOSTI.
6
5
4
3
2
1
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1200
0600
1800

Fig. 9

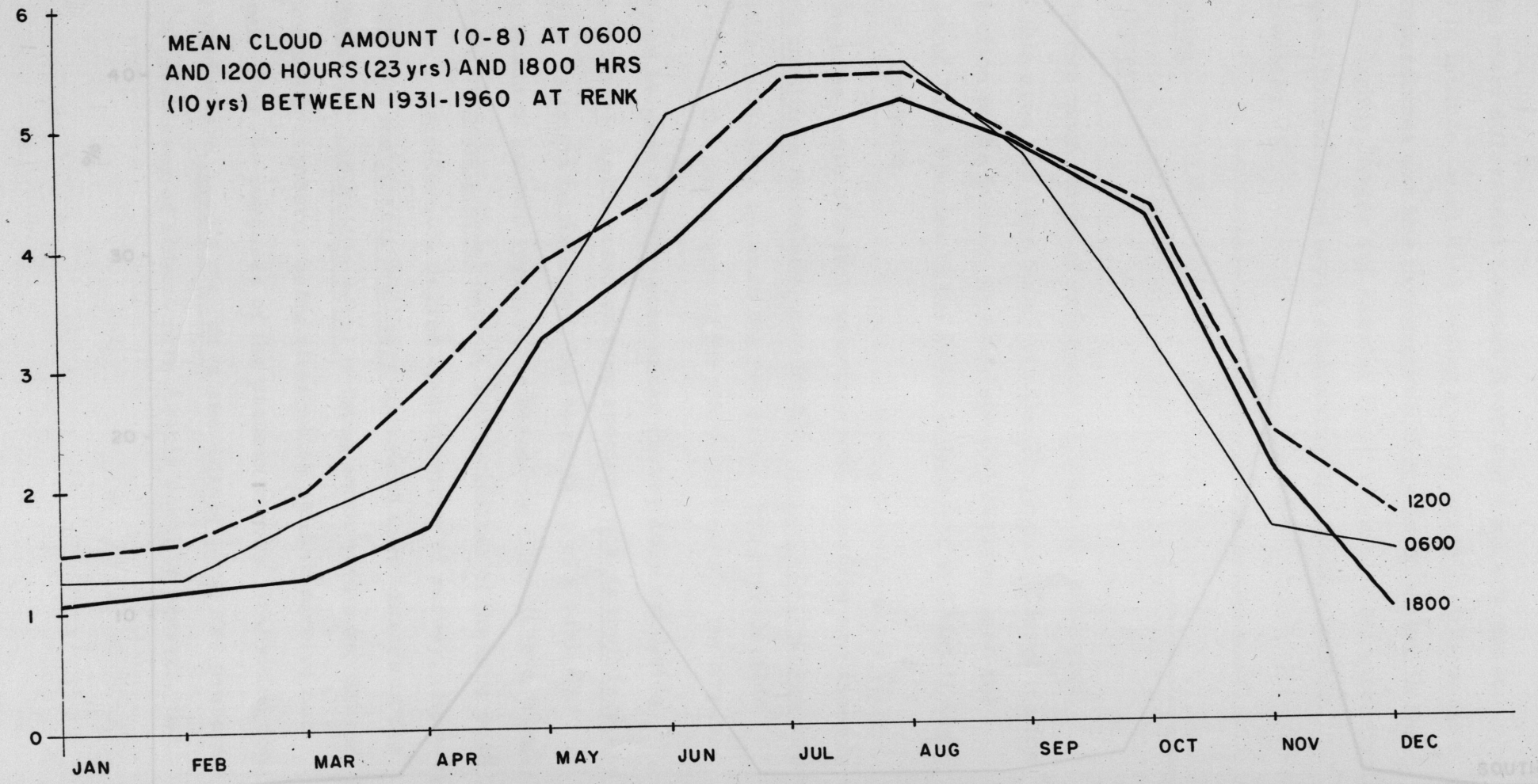
MEAN CLOUD AMOUNT (0-8) AT 0600
AND 1200 HOURS (23 yrs) AND 1800 HRS
(10 yrs) BETWEEN 1931-1960 AT RENK
6
5
4
3
2
1
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1200
0600
1800

Fig. 10

MEAN MONTHLY PERCENTAGE FREQUENCY OF THE DIRECTION OF THE TWO MAIN SURFACE WIND CONPONENTS, 1951 — 1960 AT KOSTI

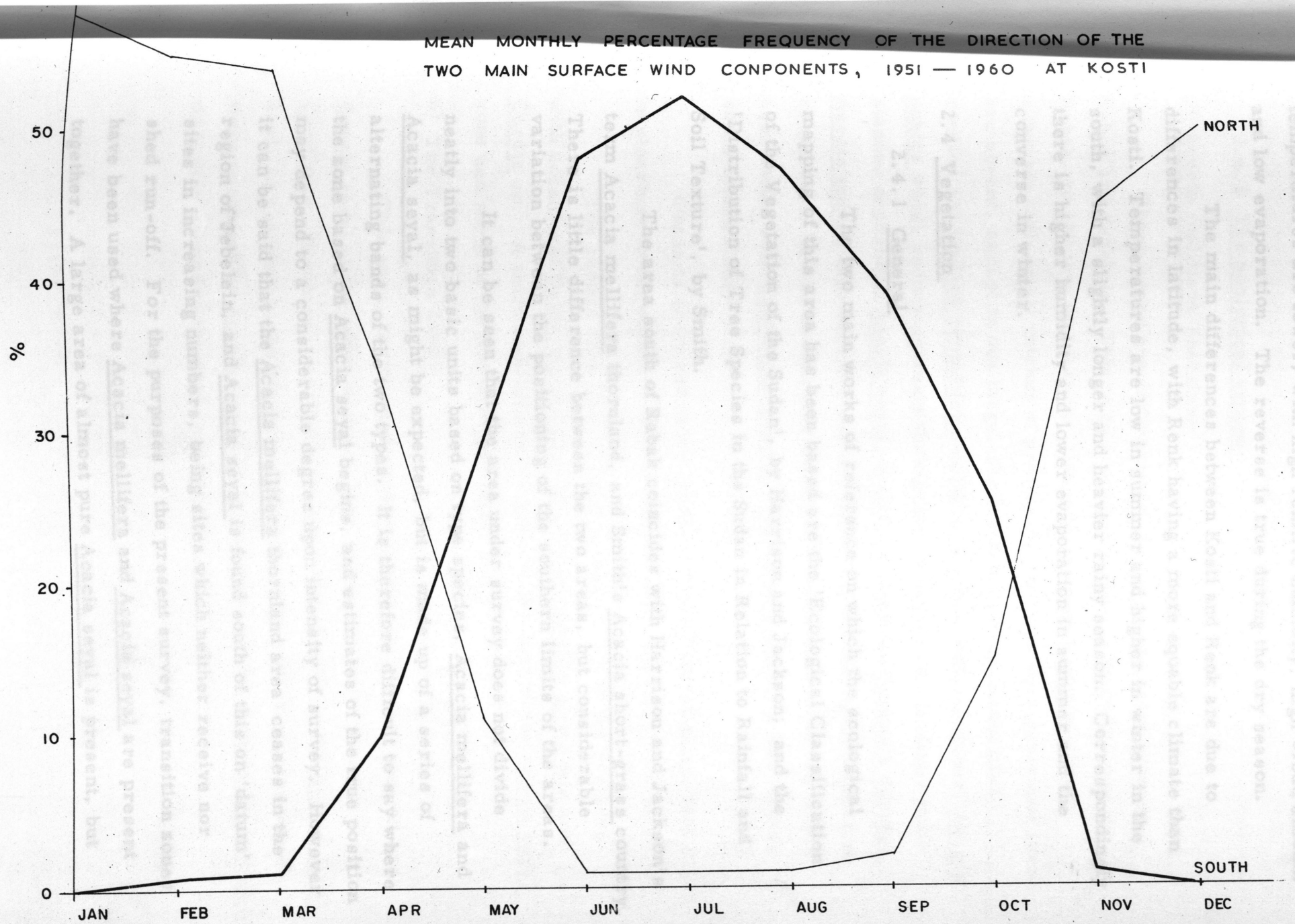

Fig.11

2.3.8 Conclusions

The inter-relationship of the climatological data can be clearly seen from the accompanying diagrams. During the rainy season temperatures are lower, with high relative humidity, high cloud amount and low evaporation. The reverse is true during the dry season.

The main differences between Kosti and Renk are due to differences in latitude, with Renk having a more equable climate than Kosti. Temperatures are low in summer and higher in winter in the south, with a slightly longer and heavier rainy season. Correspondingly there is higher humidity and lower evaporation in summer and the converse in winter.

2.4 Vegetation

2.4.1 General

The two main works of reference on which the ecological mapping of this area has been based are the 'Ecological Classification of the Vegetation of the Sudan', by Harrison and Jackson; and the 'Distribution of Tree Species in the Sudan in Relation to Rainfall and Soil Texture', by Smith.

The area south of Rabak coincides with Harrison and Jackson's term Acacia mellifera thornland, and Smith's Acacia short-grass country. There is little difference between the two areas, but considerable variation between the positioning of the southern limits of the areas.

It can be seen that the area under survey does not divide neatly into two basic units based on type species, Acacia mellifera and Acacia seyal, as might be expected, but is made up of a series of alternating bands of the two types. It is therefore difficult to say where the zone based on Acacia seyal begins, and estimates of the true position may depend to a considerable degree upon intensity of survey. However it can be said that the Acacia mellifera thornland area ceases in the region of Jebelein, and Acacia seyal is found south of this on 'datum' sites in increasing numbers, being sites which neither receive nor shed run-off. For the purposes of the present survey, transition zones have been used where Acacia mellifera and Acacia seyal are present together. A large area of almost pure Acacia seyal is present, but

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superseded by more Acacia mellifera further south. Whether this area can be regarded as the northernmost limit of Acacia seyal country will depend on the thickness of the succeeding belt of Acacia mellifera further south and this was not determined.

2.4.2 The ecological groups

a) Acacia mellifera Thornland

Three areas are distinguished, the main one being between Rabak and Jebelein. This is in a rainfall regime of from 406 mm at Rabak, to 417 mm at Jebelein. Dense thickets of Acacia mellifera alternate with small patches of grassland, but large open grassland areas are absent, except in one large, shallow depression. Associated species are Cadaba rotundifolia which is abundant and ubiquitous, Acacia nubica which occurs sparsely throughout but sometimes in dense pure stands, occasional Acacia seyal, Acacia senegal and Capparis decidua. Acacia nubica also occurs close to settlements and on disused areas of cultivation. It will re-colonise worked-out land and is often found in association with Calotropis procera. Boscia senegalensis was seen in some depressions.

Grass is short and small patches of many varieties are found in clearings in the scrub.

The second area East of Renk is less pure than the northern with occasional Dalbergia melanoxylon, Dichrostachys glomerata and Cordia sp. A third smaller area is found to the east of the Acacia seyal zone and north of the Abu Shalaya ridge.

b) The Transition Zone

This area, having predominant Acacia mellifera at one end and Acacia seyal at the other seems to have a type species in the form of Cordia sp. It comes in south of Jebelein and dies away in the Acacia seyal area, to reappear in the southern transition zone. Other species noted were occasionally Acacia fistula in depressional areas, Acacia drepanolobium on higher ground to the east, and Salvadora persica.

c) Acacia seyal Woodland

Acacia seyal is dominant in this area, in some parts to the exclusion of other species, with the exception of Cadaba rotundifolia, which is as abundant here as in previous areas. In the literature the area is variously described as Acacia Seyal-Balanites savannah and Acacia tallgrass country. In fact Balanites aegyptiaca occurs infrequently and the grass is of the same species and stature as in previous areas, though large open grassland plains are more plentiful. Acacia drepanolobium occurs on higher ground in the north-east, Acacia senegal on lighter textured soils and Acacia nubica on previously cultivated areas. Balanites aegyptiaca is more in evidence in the south,and Acacia fistula shows a slight increase with rainfall.

d) Well drained Areas with Acacia senegal as Type Species

These areas are usually lighter textured within the top horizon, and often rise a few metres above the level of the clay plains, so that there is greater water availabi lity without waterlogging. Five such areas are shown on the map, and other areas of similar drainage conditions exist, which are given over to fairly intensive cultivation, and are dealt with in the corresponding section.

A great variety of tree species is present besides Acacia senegal, many of which are exotic to this area. Balanites aegyptiaca is fairly abundant and the other common types are all represented. Others include Maerua sp. Azadirachta indica, Grewia sp. Calotropis procera, Sclerocarya birrea, Combretum hartmannianum and Combretum aculeatum. Of the grass species, Schoenefeldia gracilis is often more prominent than in other areas.

e) The Open Grassland Areas

With one exception all these areas occur within the first zone of transition between Acacia mellifera and Acacia seyal. The exception is a large shallow depression within the Acacia mellifera area, and has a fairly uniform vegetation of Sorghum sp. (addar) and Cymbopogon nervatus principally. The other areas are situated on higher ground towards the eastern boundary. If elevation above the surrounding plain is the explanation of these grasslands, their location within the northern transition zone is due to this slight rise in plain level being more extensive and better developed than in other areas.

No one grass is dominant to the exclusion of others in any area, and patterns produced by adjacent patches of different grasses are quite complex.

The dominant species are Cymbopogon nervatus, Sorghum purpureo-sericeum, Cymbopogon giganteum, Rottboellia exalta, Sehima ischaemoides, Aristida sp., Schoenefeldia gracilis and other Sorghum sp. Dominant herbs are Fagonia cretica and Ocimum basilicum. Sorghum sp. (addar) is more prominent on water-receiving sites than on these plains.

Note: In Arabic open grass country is referred to as "sagaya".

2.4.3 Arabic Vernacular Names of Plants Identified

Grasses

Addar	-	Sorghum sp.
Ancuge	-	"
Anis	-	" purpureo-sericeum
Ansora	-	Cymbopogon giganteum
Abu Asabi	-	Dactylotenium aegyptium
Umm Belila	-	Rottboellia exaltata
Binnu	-	Eragrostis sp.
Danab el Kadis	-	Aristida hordaecea
" " Kalib	-	" "
Difra	-	Schoenefeldia gracilis
Dumbalab	-	Sehima ischaemoides
Umm Gardul	-	Sporobolus sp.
Abu Gigra	-	Brachiaria brigantha
Gaw	-	Aristida adscensionis
Hamra	-	Hyparrhenia sp.
Abu Harba	-	Beckeropsis nubica
Haskaneit	-	Andropogon sp.
Abu Liseig	-	Setaria verticillata
Likh	-	Sporobolus helveolus
Mahareib	-	Cymbopogon proximus
Mamlehar	-	Dinebra retroflexa
Mara Hamra	-	Setaria pallida
Umm Meleiha	-	Dinebra retroflexa

Moreira	-	Cymbopogon nervatus
Mustehi	-	Chloris virgata
Nal	-	Cymbopogon nervatus
Nailum	-	Andropogon sp.
Rabash	-	Sehima ischaemoides
Umm Rejo	-	Hyparrhenia sp.
Abu Sabiba	-	Schoenefeldia gracilis
Umm Sheiko	-	Andropogon gayanus
Simeima	-	Aristida plumosa
Wiwi	-	Pennisetum mollissimum

Herbs

Umm Barru	-	Abutilon pannosum
Umm Jiru	-	Celosia argentea
Umm Rehan	-	Ocimum basilicum
Runta	-	Chrozophora plicata
Seid	-	Cyperus spp.
Umm Shok	-	Fagonia cretica
Tabr	-	Ipomoea cordofona

Shrubs and Trees

Arak	-	Salvadora persica
Babanus	-	Dalbergia melanoxylon
Gedeim	-	Grewia spp.
Habil	-	Combretum hartmannianum
Hashab	-	Acacia senegal
Heglig	-	Balanites aegyptiaca
Inderab, Anderab	-	Cordia spp.
Kadad	-	Dichrostachys glomerata
Kitr	-	Acacia mellifera
Kurmut	-	Cadaba rotundifolia
Lalob	-	Balanites aegyptiaca
Laot	-	Acacia nubica
Leyum	-	Sclerocarya birrea
Mukheit	-	Boscia senegalensis
Nabak	-	Ziziphus spp.
Neem	-	Azadirachta indica
Shaiheit	-	Combretum aculeatum

Shau	-	Salvadora persica
Sofar	-	Acacia drepanolobium
Surreh	-	Maerua spp.
Talh	-	Acacia seyal
Talh Abiad	-	Acacia fistula
Tundub	-	Capparis decidua

2.5 Land Use

2.5.1 Non agricultural land use

Forms of non agricultural land use are gravel digging (Qoz Girgaf), firewood cutting in the extensive scrubland areas and charcoal burning which is mainly concentrated in the Acacia seyal woodland, as "talh" seems to lend itself best to the making of charcoal. Finally, the marble ridge is a potential source of raw material for the Rabak cement factory.

2.5.2 Grazing

Both nomads and settled villagers graze their animals (mainly goats, sheep and to a much lesser extent also cattle) in the vast expanses of grass and scrub which cover the area; the river bank, irrigation channels and hafirs serve as watering places for livestock.

Large herds of cattle were seen grazing in the strip of land between Jebel Nyefr and Jebel Kodi; this is possibly due to a greater palatability of the grasses associated with "well drained areas typified by Acacia senegal".

Grazing is also practised in the "toich" land during the periods that these areas are not flooded.

2.5.3 Crop production

a) Dura

The cultivation of rainfed dura (Sorghum vulgare Pers.) is found mainly on the higher grounds along the eastern edge of the area, where inland roads and hafirs have enabled settlement. Although at present most of the dura is grown on brown clay, it is not known whether this soil type has been deliberately chosen. Vast blocks of dura fields occur just outside the eastern survey boundary between Rabak and El Jebelein; the fields coming within this boundary are more dispersed.

Two Mechanised Crop Production Schemes occur not far outside the surveyed area:

The Umm Delwis Sagaya Scheme approximately 45 km East of Geigar and the Qoz Rom Sagaya Scheme approximately 20 km East of Renk.

The table below shows the overall average dura yields of the Qoz Rom Sagaya Scheme for 4 successive seasons; the averages were calculated from figures given by the Inspector of Agriculture for the Northern Renk District.

Table 1: Dura Yields of Qoz Rom Sagaya Scheme

Season	Yield in sacks per feddan	Total area in feddans
60/61	1.7	6,650
61/62	3.0	9,670
62/63	1.7	10,990
63/64	2.9	12,390

1 sack dura (Feterita) = 73 kg.

b) Groundnuts

Groundnuts are grown on 3 out of the 4 sandy ridges occurring in area 5B. The soil of the ridges is well suited to this particular crop as the nuts can be easily lifted; moreover these soils combine free drainage with a fairly good waterholding capacity. Crop yield data which appear to be rough estimates rather than accurate figures, were made available by the Inspector of Agriculture for the Northern Renk District. The approximate values shown in the table refer presumably to the Abu Shalaya and Rom ridges.

Table 2: Approximate Groundnut yields N. Renk District

Season	Yield in kantars per feddan	Total area in feddans
57/58	4	1,500
58/59	3	2,500
59/60	4	3,000
60/61	10	3,500
61/62	5	8,000
62/63	5	4,125

1 kantar = 44.9 kg.

c) Miscellaneous crops

A number of minor agricultural activities will be dealt with in this section.

The cultivation of rice on "toich" land by a small Fellata community near El Hideib has been mentioned already in the population chapter.

Rainfed dukhn (bullrush millet, Pennisetum typhoideum) is grown in the small Rabak sand dune area.

Scattered shaduf and seluka cultivation (vegetable gardens) was observed on riverine land South of El Goda; as a result of the exceptionally high river level during the season 1964-65, all riverine cultivation which was noticed in operation during January was brought to an end by the subsequent inundation of the land.

d) Cotton Pump Schemes

i) Scheme sizes and yields

There are 47 cotton pump schemes in the area between Renk and Rabak all of which are privately owned.

All cotton yield figures mentioned in this section were supplied by the Inspectors of Agriculture of the Kosti and Northern Renk Districts.

Table 3 gives overall cotton yields for the whole of area; it also shows the total annual area under cotton.

Table 3: Area and Average Yield of Cotton on 47 Pump Schemes

Season	Overall cotton yield in kantars per feddan	Total area under cotton in feddans
59/60	3.5	26,016
60/61	4.1	26,846
61/62	5.0	27,676
62/63	4.2	29,048
63/64	2.7	27,381

The comparatively low average yield for the season 63/64 seems to be due partly to unfavourable distribution of the rainfall and partly to pests. On the Goda scheme (5,000 feddans) a serious attack of black arm (Xanthomonas malvacearum) reduced the 1964 crop yield from an expected 4 to 0.8 kantar per feddan; the low 1964

harvest of a scheme as large as Goda has considerably depressed the overall average for that year.

Table 4 shows the size distribution of the pump schemes between Rabak and Renk; frequently sizes are average ones as the area under cotton varies from year to year for many of the schemes.

Table 4: Size distribution of Private Pump Schemes

Size in feddans	Number of schemes	Frequency percentage
less than 100	7	14.9
100 - 499	29	61.7
500 - 999	7	14.9
more than 1,000	4	8.5
Total	47	100

A list of names, sizes and crop yields of the individual pump schemes in the area is included, (Appendix 3). A number of very small schemes were excluded.

Table 5 has been compiled from this list; it shows the distribution of crop yield levels during the past 5 seasons and illustrates the point that nearly one third of all individual crop yields fall between 4 and 5.9 kantars per feddan.

Table 5: Frequency occurrence of cotton yield levels in 5 seasons

Yield in kantars per feddan	Frequency of occurrence	Frequency percentage
0 - 1.9	29	10.6
2 - 3.9	116	42.3
4 - 5.9	86	31.4
6 - 7.9	40	14.6
8 - 9.9	3	1.1
Total	274	100

ii) Rotation

The pump schemes in the area practise a three course rotation: cotton - dura - fallow; practically all the cotton (variety: X 1730 Lambert) is processed in the Rabak ginning factory. Only dura is grown as the second crop although occasionally small plots with vegetables, lubia (Dolichos lablab) and groundnuts can be observed.

iii) Pesticides and fertiliser.

The spraying of pesticides by aircraft is common practice in the area. 100 kg of ammonium sulphate per feddan seems to be the standard quantity of fertiliser used on the pump schemes.

iv) Water consumption.

Although a licence is required to establish a new pump scheme, there is no restriction regarding water consumption. Depending on the rainfall, irrigation takes place 10 to 12 times per season. On the Nyefr pump scheme it was reported that per watering a quantity of 400 cubic m per feddan is applied.

v) Mapping of the pump schemes.

Aerial photographs with the corresponding mosaic have been used for the mapping of the pump schemes; as they are fairly recent, it is unlikely that there is a significant discrepancy between the map and the field layout. As far as possible, "toich" land, sandy mounds, uncultivated patches and abandoned plots have been excluded from the actual pump schemes.

From interviews it was learned that several licensees have abandoned the less suitable parts of their areas. Both in the field and on the aerial photographs it is difficult to distinguish between fallow and abandoned cotton land; it is therefore quite possible that some abandoned areas have been shown as actual pump schemes on the map.

Irregularity of the surface relief and high sand percentage of the soil were given as reasons for the abandoned land.

vi) Tenure system.

The tenant is entitled to the entire dura crop. The profits of the cotton crop are shared between licensee (56-58 per cent) and tenant (44 - 42 per cent). With some exceptions, all production costs, - from land preparation to storage in Port Sudan, - are shared on the same basis.

The following expenses are entirely met by the licensee:

4% state levy on cotton.
Land rent of LS 1 per feddan.
Heavy equipment.
Fuel for pumps.
Main canal maintenance.

CHAPTER 3

SOIL SURVEY METHODS

3.1 Aerial photography

The 1:25,000 vertical aerial photographs, flown during the early sixties, - served a threefold purpose:

a. The compilation of a 1:50,000 photomosaic; this mosaic, - compiled by the Sudan Land Survey Department, - has been used as a field base map.

b. Location in the field. Starting points of traces can be marked very accurately on the prints wherever they intersect with an irrigation canal; thus the traces can be located with considerable precision. Due to the absence of any conspicuous features and the density of the vegetation, orientation outside the traces is virtually impossible.

c. The delineation of boundaries on the soil map. For this purpose 560 prints were analysed stereoscopically. Although the landscape is monotonous, there are a number of physiographic and vegetational features which can be delineated on the photographs. The boundaries of the physiographic, land use and vegetation maps were largely obtained by aerial photo interpretation; the same applies to the miscellaneous land types of the soil map. In so far as a soil mapping unit could be correlated with a specific geomorphologic or vegetational element, soil boundaries also were delineated with the aid of aerial photographs.

During the field work it was noticed that a sudden change in vegetation (in type, density or patterns) quite frequently has a pedological significance; e. g.

(i) In dark grey clay areas a rather abrupt increase in scrub density was regularly observed in association with a rough surface topography; this enables the tentative delineation of such areas.

(ii) An abrupt change from scrub or woodland to open grass country with scattered dura fields quite often marks the transition from dark grey to brown clay. In the southernmost part of the area however the transition from dark grey to brown clay was not indicated by any vegetational changes; here the boundary was almost invariably determined by field mapping.

(iii) A very characteristic vegetation pattern is shown by the low conglomerate area "Qoz Girgaf" and the marble outcrop near the village Nyefr; it is a "banded" pattern consisting of stripes of bare soil and narrow bands of vegetation running more or less parallel to each other.

3.2 Field Survey Procedure

3.2.1 Location of the observation sites

Initially all obviously unsuitable areas were eliminated by photo interpretation; this group comprises most of the miscellaneous land types of the soil map.

To meet the contractual requirement of one observation per 2,500 feddans, a 10.5 sq. km grid was marked out on the mosaics, one site to be investigated within each square of the grid; the original aim was to select the site within each square in such a manner as to cover a specific landform or vegetation pattern.

This procedure however had to be adapted to the field conditions as the density of the vegetation which prevailed in many places, rendered compass navigation impossible; the general lack of land marks and inland roads added to this difficulty. Only north of El Jebelein could part of the field work be done along inland roads.

The solution to this problem was the use of cut traverses at right angles to the river, which could offer proper access to the featureless and frequently quite dense scrubland. In general these traverses were 5 km apart, observations were made along them at an interval of 2.5 km.

3.2.2 Sample lines

For a more detailed investigation of any pedological changes occurring in a succession from the river, two sample lines were established in appropriate parts of the area. In both the transition in clay type (from dark grey to brown) plus associated phenomena could be studied.

In the sample lines, observations were made at an average interval of 1.5 km. About one third of the sample line observations were pits so as to ensure a more thorough inspection of the profiles.

3.2.3 Overall density of observation

In a total surveyed area of 501,000 feddans 35 pits plus 219 bores (= 254 sites) were investigated; hence the overall density of observation, including sample lines, equals 1 observation per 1,972 feddans.

3.2.4 Samples for chemical analysis

From each bore site a "fixed depth sample" was taken; the word "fixed depth sample" as it is used in this report, means a 0 to 90 cm bulk sample of soil. From every pit, such a sample and a number of natural horizon samples were collected. Basically the number of natural horizon samples is determined by the pedological horizons distinguishable; in several pits however the natural horizons were split into a number of sub layers with a thickness of 30 cm at most. This method of sampling ("detailed sampling") enables a better study of chemical values in relation to depth.

All results of the chemical analyses are given in Appendix 2.

The soil classification of individual bore sites is shown in the last column of the fixed depth sample sheets. The soil classification of pits is not indicated on the natural horizon sample sheets, but can be found under the corresponding site number on the fixed depth sample sheets since both natural horizon and fixed depth samples have been collected from every soil pit.

It can be seen that sometimes there is a difference in classification between the individual site and the mapping unit in which this site is included. This is due to either impurities in the mapping unit or the pedological classification of sites within miscellaneous land types. The following examples may serve to illustrate these points:

a) A number of observations have been made in "debbats" which are mostly too small to be delineated on the 1:100,000 map and therefore the classification of such a debbat site and the mapping unit in which it is included, will differ.

b) A few sites are located in miscellaneous land types which are defined in terms of geomorphology or land use, whereas classification of the soil profiles in these areas is generally on a pedological basis. Here again sites and mapping unit differ in classification.

c) On the analysis sheets, sites included in mapping unit B 2.1 have been classified taxonomically. This unit is an association of very dark grey (B 1.2) and brown clays (B 1.3). Therefore the individual sites classified as either Grumaquertic or Grumustertic Orthustents differ in designation from the association to which they belong.

3.2.5 Permeability tests

For a detailed description of the procedure, reference is made to previous reports. Due to hidden cracks some of the results are not reliable, but the overall impression is one of very low permeability. The average permeability of the dark grey clay (17 tests) amounts to 0.004 m/day.

The results of 22 tests are listed in Appendix 4.

3.3 Chemical Analyses of Samples

The following is a list of the chemical determinations carried out by Agricultural Services (Sudan) Ltd.

3.3.1 Fixed depth samples

E.C. in mmhos/cm.
Saturation percentage.
Mechanical analysis, into sand, silt and clay (International system).
Soluble sodium in meq/100 gms of soil.
Total extractable sodium in meq/100 gms of soil.
Total number of fixed depths samples = 253.

3.3.2 Natural horizon samples

pH of a 1:5 suspension.
pH of the soil paste.
E.C. in mmhos/cm.
Saturation percentage.
Mechanical analysis into, coarse sand, fine sand, silt and clay.
(International system).

Soluble sodium in meq/100 gms of soil.

Total extractable sodium in meq/100 gms of soil.

Cation exchange capacity in meq/100 gms of soil.

Total number of natural horizon samples = 109.

3.3.3 Methods of Chemical Analyses

The following is a description of the methods used in making the above determinations.

a. Mechanical Analysis: Bouyoucos Hydrometer Method

40 grams of soil were soaked with 250 mls of water and 11 mls of 10 per cent sodium hexametaphosphate solution overnight, and dispersed next morning in an electric stirrer for 10 minutes. The whole was then transferred to a 1 litre measuring cylinder, shaken, and readings taken after 4 minutes, 2 hours, and 7 hours, in order to estimate percentages of sand, silt and clay respectively. With every reading the temperature is recorded and corrections made for temperatures and dispersing agent content. The readings are also corrected for soil moisture content, when required, by performing separate moisture determinations.

b. pH

Potentiometric determinations using a glass electrode on the soil paste or 1:5 suspension were carried out.

c. Electrical Conductivity

Calculated by using a Solubridge on the saturation extract.

d. Soluble Sodium in the Saturation Extract

A sample of the appropriately diluted saturation extract is analysed on the flame-photometer.

e. Total Extractable Sodium

12.5 grams of soil were soaked in 50 ml of normal ammonium chloride for 1 hour. The solution was then decanted off, and the soil placed in a filter and washed repeatedly with Normal ammonium chloride, the filtrate being collected in the flask holding the original decanted liquid. This was continued until 250 mls of filtrate were collected.

The filtrate (5 mls) was diluted 20 times, and sodium estimated on the flame-photometer, against a standard containing 10 p. p. m. of sodium in ammonium chloride. The reading gives the sum of soluble plus exchangeable sodium, i. e. total extractable sodium. To obtain the exchangeable sodium figure, the previously estimated soluble sodium in the saturation extract, must be subtracted.

f. Saturation Percentage

That is: the moisture percentage of a saturated soil paste, expressed on a dry-weight basis.

$$\text{i. e. } \frac{\text{Weight of paste - weight of oven-dry soil}}{\text{Weight of oven-dry soil}} \times 100$$

g. Cation Exchange Capacity

The clay is converted into a sodium clay using sodium acetate. Soluble salts are washed out with 95 per cent alcohol, and sodium is then released using ammonium acetate. It is estimated on the flame-photometer (ref. U.S.D.A. Handbook No. 60).

3.4 Map Compilation

3.4.1 The soil map

Observation sites and relevant photo interpretation boundaries were transferred freehand from the aerial photographs (scale 1:25,000) to the photo mosaic (scale 1:50,000); a transparency of the soil map obtained in this manner was photographically reduced to a scale of 1:100,000 and all information from this reduction was transferred to the corresponding 1:100,000 topographic sheets.

In order to facilitate the transfer operation the scale of the reduced soil map has been slightly corrected so as to fit more accurately the corresponding topographic sheets.

Minor cartographic errors in this procedure are caused by the following factors:

a. The actual scale of the aerial photographs differs substantially from the supposed value of 1:25,000. It was found that the average scale of the prints is approximately 1:26,700.

b. There are many instances where two adjoining runs are displaced in respect to each other and as a consequence, topographic features are distorted or dislocated on the photomosaic.

c. Differences in shape and scale between the 1:100,000 reduction of the mosaic and the topographic sheets..

3.4.2 The Land Suitability Map

The word "land suitability" as used in this report means the suitability of the land for further investigation at semi detailed level. The legend of the land suitability map consists of three units:

1. Land recommended for further investigation.
2. " unsuitable " " "
3. Pump schemes and seasonally flooded riverine land.

For obvious reasons very little field work was done in unit No. 3. The criteria used for the distinction between the groups 1 and 2 will be discussed at a later stage.

The land suitability map is entirely derived from the soil map; this means that each boundary of the land suitability map must coincide with a boundary of the soil map and each unit of land suitability map must consistently correspond with the same soil mapping units.

CHAPTER 4

THE SOILS AND THEIR SUITABILITY FOR FURTHER INVESTIGATION

4.1 A brief review of the soils

a) The very dark grey clays

Extensive deposits of very dark grey clay dominate the area. Their profiles consist of a coarsely structured and weakly cracked top layer which overlies a compact and impermeable subsoil. In places a very uneven microrelief has developed on the surface of these clays. Low permeability and high alkali are two unfavourable features of the dark grey clays. A decrease in overall alkali content is noticeable towards the south of the area. On account of this factor, two alkali phases were introduced, which are related to a higher and a lower overall E.S.P. level.

b) The brown clays

Moving in eastern direction slightly higher ground is encountered and the very dark grey clay gives way to the next important soil type: the brown clays.

Like the very dark grey clays, they have a cracked zone underlain by a hard and compact subsoil. On the whole, cracks are better developed in the brown clay than in the very dark grey clay; yet it is considered that the formation of cracks in the brown clay is not sufficiently intensive to classify them as Vertisols.

From an alkalinity point of view these clays compare very favourably with the previous group and uneven surfaces do not seem to occur amongst this soil type.

In certain areas characterised by contrasting vegetation and slightly elevated relief the brown clays have a platy or compact top layer, which is similar to an incipient surface crust. Underlying pebble beds are sometimes found beneath this soil type within a depth of 1.50 m. Cracking is poorly developed in profiles of this kind.

c) Soils of sandy ridges, sand dunes and conglomerate outcrops

Little profile development can be seen in the soils of the four sandy ridges occurring in the area. The profiles have reddish colours

and sandy textures. Sand percentages are 65 or more. A similar profile morphology was found in the Rabak sand dunes; here however a zone with maximum coloration (B-horizon) is observable and this may be indicative of some active soil forming process.

No obvious profile development is visible in the conglomerate derived soils; they are found on top of the marble ridge and in the Nubian sandstone outcrops. The soils derived from Nubian sandstone are reddish in colour with clay loam to clay texture. Sometimes they contain appreciable amounts of quartz gravel and pea iron.

4.2 Suitability criteria

There are two sets of conditions which may render a soil unsuitable for further investigation. Wherever these factors are absent or only operative to a restricted extent, the area has been recommended as suitable.

The following limitations are involved in the assessment of suitability:

a. Topographic limitations.

i) Sloping or undulating topography.

ii) Elevation above the general level of the clay plain.

iii) Uneven microrelief of the surface.

b. Soil limitations

i) Shallow soil depth.

ii) Clay percentage.

A clay percentage below 40 in the 0-90 zone is considered to be unacceptable. It was noted that where natural horizons were sampled there was frequently an increase in the clay content of the second horizon over the upper horizon in the top metre. Therefore a clay percentage of just under 40 in a 0-90 cm bulk sample could well mean a clay percentage of below 35 in the top half metre which by the land classification adopted for semi-detailed surveys would entail downgrading. In addition it was noted that such soils were avoided by pump schemes owners due to their lack of cracking capacity, moreover it is thought that the yield potential is probably adversely affected by poor physical conditions.

iii) Alkali content (Exchangeable Sodium percentage)

Land with a preponderance of observations having an E. S. P. value greater than 20 in the top 90 cm is considered unsuitable.

A general slight increase of E.S. P. with depth was found in the natural horizon samples so that a 0-90 cm depth sample with

an E.S.P. of above 20 would have an upper zone (0-45 cm) E.S.P. considerably in excess of 15 which is the accepted limit for better class land. In addition to this it so happens that few sites occur with E.S.P.'s approximating to 20 in the 0-90 cm zone, they are either well above or well below. Therefore this value is a useful naturally occurring standard.

It must be remembered that as this is a reconnaissance investigation the importance of the limits chosen is considerably less than their overall frequency occurrence. Each site is not being mapped individually but as a member of a group.

iv) Absence of cracks.

The entire absence of cracks in a clay profile is believed to be a limiting factor. In clays with an otherwise poorly developed structure, cracks must play a significant role in the moisture supply of the subsoil. A certain minimum degree of cracking is therefore considered to be a necessity.

4.3 Individual soil types

A. Miscellaneous land types

The units of this group are self explanatory and are excluded from further investigation for obvious reasons such as cotton cultivation (A1), seasonal flooding (A3 and A4) and unsuitable topography (A2, A5 and A6). These are listed in the legend. Mapping unit A2 (the low sandy mounds or "debbats") is interesting from a pedological point of view.

Although it is assumed that not all the "debbats" have the same origin, at least a number of them have profiles similar to site No.8056 (see Appendix), but the artifacts may not always be present. If the calcium carbonate nodules have been formed in situ, and the morphology of the profiles makes this very likely, it can be safely assumed that at least 5 per cent of the sand consists of easily weatherable minerals. If this is so, the 8056 site can be classified as an Orthic Psammustent; the indurated calcareous subsoil on the other hand is suggestive of a transitional position towards the order of Aridisols.

Presumably due to differences in origin and partly also as a result of human interference, debbat profiles vary considerably and hence no generally applicable classification can be given for the soils of the debbats.

B. Soils

B1 Entisols

B1.1 = ORTHIC ORTHUSTENTS ON (GRAVELLY) SANDY CLAY LOAM TO (GRAVELLY) CLAY.

a) Morphology and geographical distribution.

The B1.1 soils are supposed to originate from weathered conglomerate beds; like the solid conglomerate deposits they have a reddish colour and frequently contain abundant quartz gravel and pea iron. Their texture is normally lighter than clay; and cracks if present at all, are very small in size.

This soil type is found on the two undulating Nubian sandstone outcrops in the North of the area and on the marble ridge near Nyefr; in this latter case the soil has developed on a thin veneer of conglomerate that overlies the marble (see pit description No. 7046)

b) Classification.

In the absence of any visible sign of profile development and the clay percentage regularly falling below 40 the B1.1 soils have been classified as Orthic Orthustents.

c) Suitability.

Relief and elevation, texture and the absence of any sizable cracks all make the B1.1 soils wholly unsuitable for further investigation.

B1.2 GRUMAQUERTIC ORTHUSTENTS ON CLAY.

a) Morphology and geographical distribution.

In mapping unit B1.2 three phases have been distinguished. These three phases differ in alkalinity or surface microrelief but not in profile morphology.

The Grumaquertic Orthustents or very dark grey clays occupy by far the greatest part of the area. They are deposits of the White Nile flood plain which extends in places far beyond the survey limits.

The description of profile No. 8050 (see appendix) is representative for all three phases of the Grumaquertic Orthustents.

i) Structure and consistency of top soil.

A hard, coarse angular blocky or sometimes vaguely prismatic

structure dissected by vertical cracks; to a very limited extent the cracks are infilled with fine granular aggregates. The self mulching process and subsequent sloughing of granular peds into the cracks is only operative to a restricted degree.

ii) Cracking.

The major cracks, varying in width between 3 and 10 mm, seldom extend to a depth of more than 50 cm. Thus they occur in the angular blocky top horizon and continue into the upper part of the massive subsoil. In comparison with Blue Nile profiles the cracking development of the Grumaquertic Orthustents is rather poor.

Although the significance of the cracks is not yet fully understood, it is known that the moisture supply of the subsoil depends on them and therefore the degree of cracking must have a bearing on crop productivity. At present it is believed that both the shallow root depth (top 7.5 cm on average) and the low moisture content of the subsoil are the results of poor cracking.

iii) Soil colour.

Commonly at least the first 100 cm of the profiles have wet colours varying from 10YR 4/1 (dark grey) to 5Y 3/1 (very dark grey). For the clays to be "grumaquertic", the chroma of the top 30 cm may not exceed 1.5.

It is normal to find a very gradual change towards olive grey between 100 and 150 cm. A number of profiles with olive grey (5y 5/2 to 4/2) colours all the way from the surface, but otherwise completely identical in morphology, have been included in the Grumaquertic Orthustents.

iv) Subsoil.

At a depth of more than 35 cm the soil is normally very slightly moist, very firm, massive and impermeable; vertical cracks may extend to somewhat greater depth (50 cm) but no other signs of structure are present.

With a low permeability and a low, level topography the very dark grey clays are bound to be very poorly drained. They must be waterlogged during the entire rainy season and presumably even for some time afterwards.

It is not known however whether the dark colour of this soil type may be attributed to poor drainage or constitutes an inherent characteristic of the parent material. Similarly it is impossible to tell whether the lighter colour of the brown clays is associated with the slightly better drainage conditions which seem to prevail there. In a great many of the clay profiles strong brown (7.5 YR 5/6) mottles are found in the olive grey subsoil below a depth of more than 150 cm.

Soft and hard calcareous particles, - usually not larger than 5 mm, - are found in nearly all profiles, they are small, partly weathered fragments of calcareous material of which the origin is unknown.

Gypsum is present in a limited number of profiles and in general its occurrence is confined to a layer below more than 140 cm. It is found either in minute white crystals or in thin yellowish flakes with an average size of 2 mm.

A subsoil totally different from the usual type occurs in the northern part of the area along the Khor Agwal sample line. It has a dark yellowish brown colour and abounds in gypsum, calcareous nodules and reddish mottles.

v) Texture.

The dominant texture is clay throughout the whole of the profile. In many observations very thin inclusions of very pale brown (10YR 7/3) sand occur. It is believed that these sand grains have entered the profiles via cracks, although the sandy inclusions occur far beneath the lower limit of present cracking.

Although profiles with and without sandy inclusions constitute a highly irregular pattern, more sandy inclusions are found near the river than elsewhere.

The distribution of clay percentages in the top 90 cm is shown in the table below:-

Distribution of clay percentages in Grumaquertic Orthustents

Clay %	Frequency	Frequency percentage
less than 40	9	4.3
40 - 49	40	21.0
50 - 59	79	41.6
60 - 69	53	27.8
70 or more	10	5.3
	191	100.0

An increase of clay percentage with depth can be seen in most profiles for which horizon samples are available. It is not known whether this is due to eluviation or original deposition.

vi) Chemical properties.

Alkalinity.

At reconnaissance level the overall alkali content should be considered rather than the E.S.P. values of individual sites. Applying this principle to the area it is found that the overall E.S.P. shows a tendency to decrease in a southerly direction. Accordingly two alkali phases were established.

Bl.2 a - alkali phase with 96 per cent of observations having E.S.P. values of more than 20 in the top 90 cm.

Bl.2 b - alkali phase with only 67 per cent of observations having E.S.P. values of more than 20 in the top 90 cm.

Understandably the transition from the one phase to the other is a gradual one, not marked by any conspicuous features in the terrain. Because of its gradual nature the boundary between the two alkali phases (5 km South of El Goda) can only be shown by a straight line on the soil map.

Associated with this alkali trend are three concurrent phenomena:

- an increase of annual rainfall from Jebelein to Renk of over 100 mm.
- the appearance of an Acacia seyal woodland zone about half way between ElGoda and Tayba.

- a smoother microrelief coinciding with the appearance of the Acacia seyal woodland zone. Some areas with rough surface topography do occur here (mapping unit B1.2 c) but these are isolated patches in a dominantly smooth terrain.

For all profiles E.S.P. values increase with depth. In a number of cases however this trend is reversed and below an average depth of 100 cm the alkalinity decreases after an initial rise.

pH values, free lime status and salinity.

Seventy eight per cent of all pH paste values lie between 8.00 and 9.00. In all samples pH 1:5 suspension is slightly higher than the corresponding pH paste value. Extreme values in pH paste (less than 8.00 or more than 9.00) can be associated with corresponding low and high E.S.P. figures.

Practically all the dark grey clays effervesce with 10 per cent HCl aq; an appreciable quantity of free and soluble calcium carbonate must therefore be present in the Grumaquertic Orthustents.

A substantial difference in overall salinity exists between the two alkali phases. In phase 1.2 a (overall high alkali) 14.5 per cent of the observations have E.C. values of more than 4 mmhos/cm. For phase 1.2 b (overall lower alkali) the corresponding figure is only 1.5 per cent, which is a negligible amount.

Correlation between C.E.C. and clay percentage

Calculation of E.S.P. values in fixed depth samples is based on the assumption that in a montmorillonitic clay 1 gram of clay fraction has a Cation Exchange Capacity of 1 meq.; 100 grams of a montmorillonitic clay with, for instance, 55 per cent clay fraction would have a C.E.C. of 55 meq.

Thus E.S.P. can be calculated as:-

$$\frac{100 \times \text{Exchangeable Na (in meq per 100 gm soil)}}{\text{clay percentage}}$$

This correlation was originally worked out for Gezira clays but has also been applied to the clay soils discussed in this report.

In order to check the validity of the afore mentioned assumption for White Nile clays, the ratio clay percentage over C.E.C. has been calculated for as many samples as were available. Ideally this ratio should be 1.00. 78 grey clay samples yielded an average ratio of 1.00 which is entirely satisfactory. Because of this relationship the dark grey clay is presumably montmorillonite, although it does not show the degree of cracking normally associated with this clay mineral.

vii) Micro topography of the surface.

The following types of surface topography can be distinguished in the dark grey clay area:

1. An even surface, pitted with so called "collapse structures". Collapse structures are roundish or oval shaped holes, normally with diameters from 30 to 50 cm. They have almost vertical sides and their average depth is about 25 cm. Presumably they have developed from small caverns which build up underneath the soil surface as one always findsthe original soil surface lying at the bottom of the collapse structure.

2. An uneven surface consisting of microknolls and micro depressions. In extreme cases the difference in height between the top of one and the bottom of the other may amount to as much as 25 cm. Normally the difference is not more than 12.5 cm. In Arabic this kind of surface topography is referred to as "kedyemara".

Typically shrubs grow on the micro hummocks and grasses in the micro depressions. Quartz gravels, if present, normally occur in far greater density on the knolls than in the depressions. Soil cracks on the other hand are mainly concentrated in the shallow depressions.

It is very unusual to find in the field only one kind of micro relief to the entire exclusion of the other. Normally the surface topography is transitional between the two types.

In the section on aerial photo interpretation it has been reported that areas with an outstanding "kedyemara" relief (height difference from 20 to 25 cm) often bear a particularly dense scrub cover. This observation has been used for the approximate delineation of mapping unit Bl. 2c, i.e. the phase with dominantly rough surface topography. (profile description No. 8107).

Since considerable extra expenses must be involved in the levelling of land with such an excessive kedyemara relief, the phase Bl. 2c has been classified as unsuitable.

No clear correlation could be established between soil profiles and surface micro relief. Yet it would appear that the development of a pronounced "kedyemara" relief occurs chiefly in densely vegetated, slightly better drained areas. Such areas are mostly found at some distance from the river.

The mode of origin of the "kedyemara" micro relief is not known. Seasonal expanding of the clay, run off during the rainy period or a combination of both could be involved.

b. Classification.

A chroma of less than 1.5, a mulched top layer and soil cracks are characteristics diagnostic for Grumaquerts. Both the mulch and the cracks being poorly developed however, the dark grey clays must be considered Entisols intergrading towards Vertisols. Hence the name Grumaquertic Orthustents has been chosen for them as it brings out the transitional position of the B1.2 soils.

c. Suitability.

The phases B1.2 a and B1.2 c have been excluded from further investigation because of high overall alkali and irregular micro topography respectively. These limitations have been discussed at length in previous sections. Soil phase B1.2 b, with 67 per cent of the sites having an E.S.P. of more than 20 in the top 90 cm, is considered suitable for investigation at semi detailed level. Overall alkali in this phase is substantially lower than in the north and salinity is practically non existent.

This may still seem a rather high degree of permissible alkalinity, but in view of the satisfactory cotton yields in area 5B there seems no reason to over emphasise the significance of exchangeable sodium percentage.

B1.3 GRUMUSTERTIC ORTHUSTENTS ON CLAY.

a) Morphology and geographical distribution.

Like the very dark grey clays, the Grumustertic Orthustents or brown clays have a cracked zone overlying a hard, compact subsoil. Apart from the colour, the two types differ characteristically in a number of other features. Profile No. 8069 (appendix) is a representative

Grumustertic Orthustent. The brown clay occurs on the higher ground as 7 separate areas scattered along the eastern survey boundary. Most of these areas have been delineated with the help of aerial photographs. A specific "brown clay" photo pattern shows a homogeneous, smooth surface with mainly a light colour tone, virtually devoid of trees and shrubs; locally with scattered dura fields.

In the following two sections all the specific features of the brown clay will be discussed.

i) Brown clay compared with dark grey clay.

For a clearer distinction between the two clay types in the area differentiating characteristics between the two are summed up below.

Brown Clay	Very dark grey Clay
On higher ground near Eastern survey boundary.	Lower areas adjacent to river.
Smooth soil surface; locally with cracks.	Collapse structures or/and "Kedyemara" micro relief and gravel in northern area.
Dominant colours are 10YR 3/2, 2.5Y 3/2 (both very dark greyish brown) or 2.5Y 4/2 (dark greyish brown); gradually changes to (very) dark grey in deeper subsoil.	Dominant colours vary from 10YR4/1 (dark grey) to 5Y 3/1 (very dark grey) or sometimes 5Y 3/2 (dark olive grey); gradually changes to (dark) olive grey in deeper subsoil.
Cracks and mulch fairly well developed. Top horizon has coarse or prismatic structure; part of the individual structural aggregates consist of platy elements.	Cracks and mulch weakly developed. Top horizon has coarse angular or prismatic structure; individual aggregates are without any structural pattern.
Subsoil is hard and massive; may contain hard calcareous nodules and very fine pea iron. (Thin (30 cm) dark coloured (5Y 3/1) extremely firm zones occur in some profiles at depth (below 1.25 m).	Subsoil is hard and massive; normally contains soft and hard calcareous particles and strong brown mottles; occasionally with gypsum at depth.

Poorly drained; higher elevation and deeper cracking produce slightly improved conditions of drainage.	Very poorly drained.
30 per cent of sites have E.S.P. values of more than 20 in top 90 cm.	Even in the less alkaline phase 67 per cent of sites have E.S.P. values of more than 20 in top 90 cm.
Clay matrix does <u>not</u> react with 10 per cent HCl aq; effervescence only with calcareous nodules.	Clay matrix effervesces with 10 per cent HCl aq in nearly all profiles.

ii) Chemical properties.

Alkalinity.

The overall alkalinity of the brown clay has been calculated from 33 sites along the eastern survey boundary. Thirty per cent of the sites have E.S.P.'s of more than 20 in the top 90 cm.

In all six profiles which were investigated E.S.P.'s increase with depth. Reversal of this trend below an average depth of 130 cm was found in two pits.

pH values, free lime status and salinity.

Ninety five per cent of all pH paste values lie between 7.5 and 8.5. In all samples pH 1:5 suspension is somewhat higher than the corresponding pH paste value.

The matrix material of the brown clays does not react with 10 per cent HCl aq; only calcareous nodules and shell fragments which occur in the profile effervesce with hydrochloric acid but not the clay material itself. Only one out of the 33 investigated samples (=3 per cent) has an EC value of more than 4 mmhos/cm. Salinity therefore, is by no means a problem.

Correlation between C.E.C. and clay percentage.

The significance of the correlation between Cation Exchange Capacity and clay percentage has been explained in the section on very dark grey clays.

The average ratio of clay percentage over C.E.C. amounts to 1.01 and has been calculated from 20 samples. Because of this the brown clay is thought to be montmorillonite.

b) Classification.

A chroma of more than 1.5, a mulched top layer and soil cracks characterise the soil type as a Grumustert, but here again mulching and cracks are in general not sufficiently developed to meet the requirements of a Vertisol. The brown clays therefore are intergrades between Entisols and Vertisols and have been classified as Grumustertic Orthustents. Although the mulch layer and cracks are considerably better developed in the brown clays than in the very dark grey clays, at present it is believed that they still fall short of the Vertisol requirements.

It may well be that the mapping unit B1.3 (the Grumustertic Orthustents) includes a number of profiles which qualify for Grumusterts. At the present stage the limit between the two is not yet clearly defined.

c) Suitability.

Being the lowest in overall alkalinity and having no other limitations, the brown clays are recommended for further investigation unless engineering studies prove them unirrigable because of their remote position.

B1.4 MAZUSTERTIC ORTHUSTENTS ON CLAY.

a) Morphology and geographical distribution.

The occurrence of the B1.4 soils is confined to three distinct strips: one South of Sagaya, another one between Jebel Kodi and Jebel Nyefr and a third which is an extension of the Abu Delor ridge. On the physiographic map these strips, which locally may have a slight elevation above the plain level, are defined as "gravel beds overlain by a thin soil cover".

Owing to their specific vegetation (Acacia senegal in two cases and grasses with ant hills in the third) the three strips could be delineated on the prints.

The following features are characteristic of the B1.4 soils:

i) A compact or platy surface layer of 1 or 2 cm thickness which is an incipient surface crust. The reddish colour of the surface as seen at a distance is due to iron stained gravel and coarse sand. In places quartz gravel is quite abundant on the surface.

ii) Cracks are poorly or at least moderately developed and much weaker than in ordinary brown clay profiles.

iii) In some of the profiles gravel beds underly the soil at depths varying from 100 to 200 cm. A number of these characteristics can be found in the description of pit No. 8007 (appendix).

iv) The very dark greyish brown (10YR 3/2) colour and the occurrence of calcareous nodules suggest a close relationship between the parent materials of the Grumustertic Orthustents (B1,3) and Mazustertic Orthustents (B1.4).

b) Classification.

Without the surface crust, mapping unit B1.4 would have been a Grumustertic Orthustent. Due to the compact or platy surface layer however the adjective "Grumustertic" is no longer applicable and becomes "Mazustertic". A Mazustertic Orthustent is related to the Mazusterts as the Grumustertic Orthustent is to the Grumusterts.

Although the surface crust is the only feature expressed in the classification name, it is obvious that the symbol B1.4 stands for all the specific characteristics of the mapping unit. Only the diagnostic features are brought out in the classification whilst the others are implied.

c) Suitability.

The poor development of the cracks, the slightly elevated position, the dense gravel cover at some of the sites and the low clay percentages of others all together render the three "strips" unsuitable for further investigation.

B2 Association and Complexes.

B2.1 ASSOCIATION OF GRUMAQUERTIC AND GRUMUSTERTIC ORTHUSTENTS ON CLAY.

a) Morphology and geographical distribution.

The B2.1 association is a triangular area bounded by the two sandy ridges N.E. and S.E. of El Jebelein. The mapping unit consists of both very dark grey clay (to the West) and brown clay (to the East) but these two soil types cannot be separated from each other at the present density of observation.

Due to human interference (dura fields) little use could be made of the change in vegetation which in other areas indicates the transition from very dark grey to brown clay. On the aerial photographs the transition between the two vegetation types is too gradual and too much interfered with to be conclusive.

b) Classification.

Mapping unit B2.1 has been called an association as the boundary between the two components can only be determined by a more detailed investigation.

The classification of the components has been dealt with previously.

c) Suitability.

A substantial part of the association B2.1 consists of very dark grey clay (Grumaquertic Orthustents). The whole mapping unit B2.1 being located in the middle of the highly alkaline B1.2 a area, it can be safely assumed that the Grumaquertic Orthustents of the association are as alkaline as their adjacent counterparts. It has therefore been decided to exclude the mapping unit B2.1 from further investigation.

B2.2 COMPLEX OF OXIC PSAMMUSTENTS ON SAND AND PSAMMIC ORTHUSTENTS ON SANDY LOAM TO SANDY CLAY LOAM.

a) Morphology and geographical distribution.

The B2.2 complex comprises the soils of the 4 sandy ridges. More details regarding the ridges are given in the physiography chapter.

The soils have reddish colours and sandy textures ranging from loamy sand to sandy clay loam. In virtually all profiles the percentage of sand is 65 or more, but otherwise the sand content appears to differ considerably from ridge to ridge and most likely also within ridges. This is the reason why the ridge soils are defined as a complex. It would appear that the sand grains are predominantly quartz.

Owing to their textures the ridge soils combine free drainage with a good waterholding capacity. The profiles seem to be entirely devoid of free lime as tested with 10 per cent HCl aq.

Apart from a slight degree of cementation at depth (profile No. 8078) and perhaps the reddish coloration no other indication of any soil forming

process could be observed in these soils. Profile description No. 8078 is an example of a Psammic Orthustent.

b) Classification.

Due to the absence of any recognisable profile development the soils of the ridges are considered to be Entisols.

Whether they are Psammustents or Orthustents depends on their texture. Profiles with textures coarser than loamy very fine sand are Psammustents, the finer ones are Orthustents.

Sand percentages and corresponding textural class names being subject to rapid variation, the ridge soils have been mapped as a complex because of the impossibility of delineating the two separate taxonomic units. Difficulties in the classification of individual profiles has arisen from the fact that mechanical analysis results are in terms of the International System whilst in the 7th Approximation textures are based upon the United States Department of Agriculture System.

As far as could be seen in the field the sand grains in the Psammustent profiles consist entirely of quartz whereas their reddish colour is presumably attributable to the liberation of iron oxide from weatherable minerals originally present in the sandy material. If these assumptions are correct, the sands meet the requirements of Oxic Psammustents.

For the other components of the complex the name Psammic Orthustents has been proposed. This emphasises the sandy nature (65 per cent sand) of profiles otherwise not differing from an Orthic Orthustent. (This is a soil without genetic horizons, having a texture finer than loamy fine sand, in a dry climate).

c) Suitability.

The elevated position of the ridges (from 2.5 to 7.5 m above the level of the clay plain) and the sandiness of their soils are obvious limitations to the growth of irrigated cotton. Otherwise the ridge soils appear to be well suited to the cultivation of groundnuts.

B2.3 COMPLEX OF OXIC PSAMMUSTENTS ON SAND AND ORTHIC ORTHUSTENTS ON (GRAVELLY) SANDY CLAY LOAM TO (GRAVELLY) CLAY.

a) Morphology and geographical distribution.

The B2.3 complex is confined to the undulating landscape East of Rabak. As has been explained in the physiography section this landscape is a conglomerate outcrop of which the western part is invaded by sand dunes. Each of these two elements has produced its own particular type of soil. However these two kinds of soil cannot be shown separately on a map due to the fact that patches of sand occur outside the actual dune area. The dunes proper show clearly on the aerial photographs (pattern of dukhn fields). The sandy patches are covered with the same type of vegetation as the conglomerate outcrop and therefore not recognisable on the prints.

The Oxic Psammustents are the soils of the dunes and the afore mentioned sandy pockets in the conglomerate area. Although it has been assumed that no active soil formation is taking place in the Oxic Psammustents (this is implied in the classification) a zone with maximal coloration (B-horizon?) was found in a sand dune profile (site No.8119) and this feature may be related with a pedogenic process. An abridged description of profile 8119 is given below.

0-50 cm	Dry, loose, yellowish red (5YR 4/6) loamy sand.
50-90 cm	Dry, weakly cemented, red (2.5YR 4/6) loamy sand; zone with maximal coloration.
90-200 cm	Very slightly moist, friable, structureless brownish yellow (10YR 6/6) sandy loam with red (2.5YR 4/6) and yellow (2.5Y 7/6) patches.

The other component of the complex, the Orthic Orthustents, has been described previously (mapping unit B1.1).

b) Classification.

Like the sandy profiles of the ridges (mapping unit B2.2) the dune sands have been classified as Oxic Psammustents.

The other component of the complex has a texture finer than loamy very fine sand, lacks any visible profile development and therefore is an Orthic Orthustent. As it is impossible to delineate the sandy patches in the conglomerate landscape, the corresponding soils must be defined as a complex.

c) Suitability.

For several reasons such as undulating relief, elevation, sandiness and absence of cracks the B2.3 area must be excluded from further investigation.

4.4 Recommendations

From the whole group of soil types discussed in the previous section, two are recommended for investigation at semi detailed scale. These are the mapping units B1.2 b and B1.3. The total area of these two soil types equals 172,000 feddans. Thus the area is divided into:-

Recommended for further investigation	172,000 feddans
Unsuitable " " "	329,000 "
Pump schemes and seasonally flooded riverine land ...	139,000 "
Total area	640,000 feddans.

4.5 Additional Recommendations

After re-examination of the field and laboratory data, an interpretation of the land quality to standards similar to those used in Roseires Areas 1 and 5a showed that the following additional lands had favourable development possibilities and should also be covered by semi-detailed soil and land classification survey:-

(i) In the vicinity of Rabak an area of 13,000 feddans of non-saline, non-alkali, loamy and sandy soils suitable for diversified cropping, including horticultural crops.

(ii) To the east of existing irrigated lands from El Hideib southwards to Jebelein an area of 41,500 feddans of clay lands of low salinity and moderate alkalinity, suitable for a long staple cotton rotation.

These additional lands (54,500 feddans) bring to a total of 226,500 feddans the area recommended for semi-detailed soil survey and land classification.

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

The exploratory engineering survey of Area 5B was intended to cover a gross area of some 1,450,000 feddans lying on the east bank of the White Nile between Melut and Rabak, a distance of 357 kilometres.

The actual survey in the field was restricted however, to the section of the White Nile from a point just south of Renk to Rabak, a distance of 160 kilometres with a gross area of 640,000 feddans. Due to the record higher water levels experienced on the White Nile this year roads south of Renk were impassable until very late in the season and this, combined with the uncertain security conditions in the area, resulted in the field work being terminated near Renk.

5.2 Maps and Aerial Photography

5.21 Maps

The following map series of the area are available :-

(a) 1:100,000 scale of the Jonglei and Rainland Series.

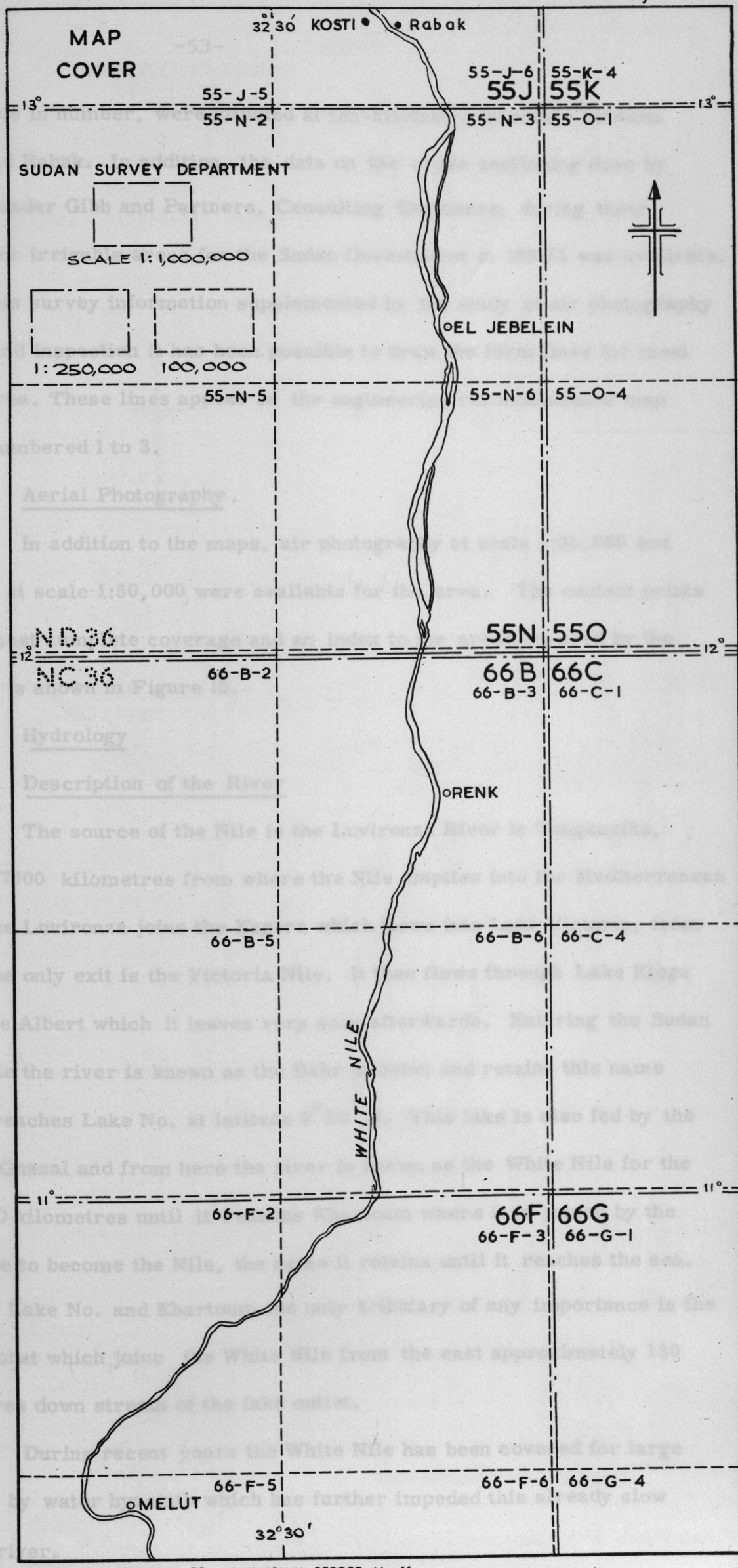
(b) 1:250,000 scale.

(c) 1:1,000,000 scale.

All the above series were produced by the Sudan Survey Department and their respective coverages in area 5B are shown on Figure 14.

Contour cover is almost non-existent along the length of the White Nile under review but the Sudan Survey Department carried out a cross section levelling programme early in 1964. These cross sections,

Figure 14



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thirty-five in number, were situated at ten-kilometre intervals between Melut and Rabak. In addition, the data on the cross sectioning done by Sir Alexander Gibb and Partners, Consulting Engineers, during their survey for irrigable areas for the Sudan Government in 1951/3 was available. Using this survey information supplemented by the study of air photography and ground inspection it has been possible to draw the form lines for most of the area. These lines appear on the engineering reconnaissance map sheets numbered 1 to 3.

5.22 Aerial Photography.

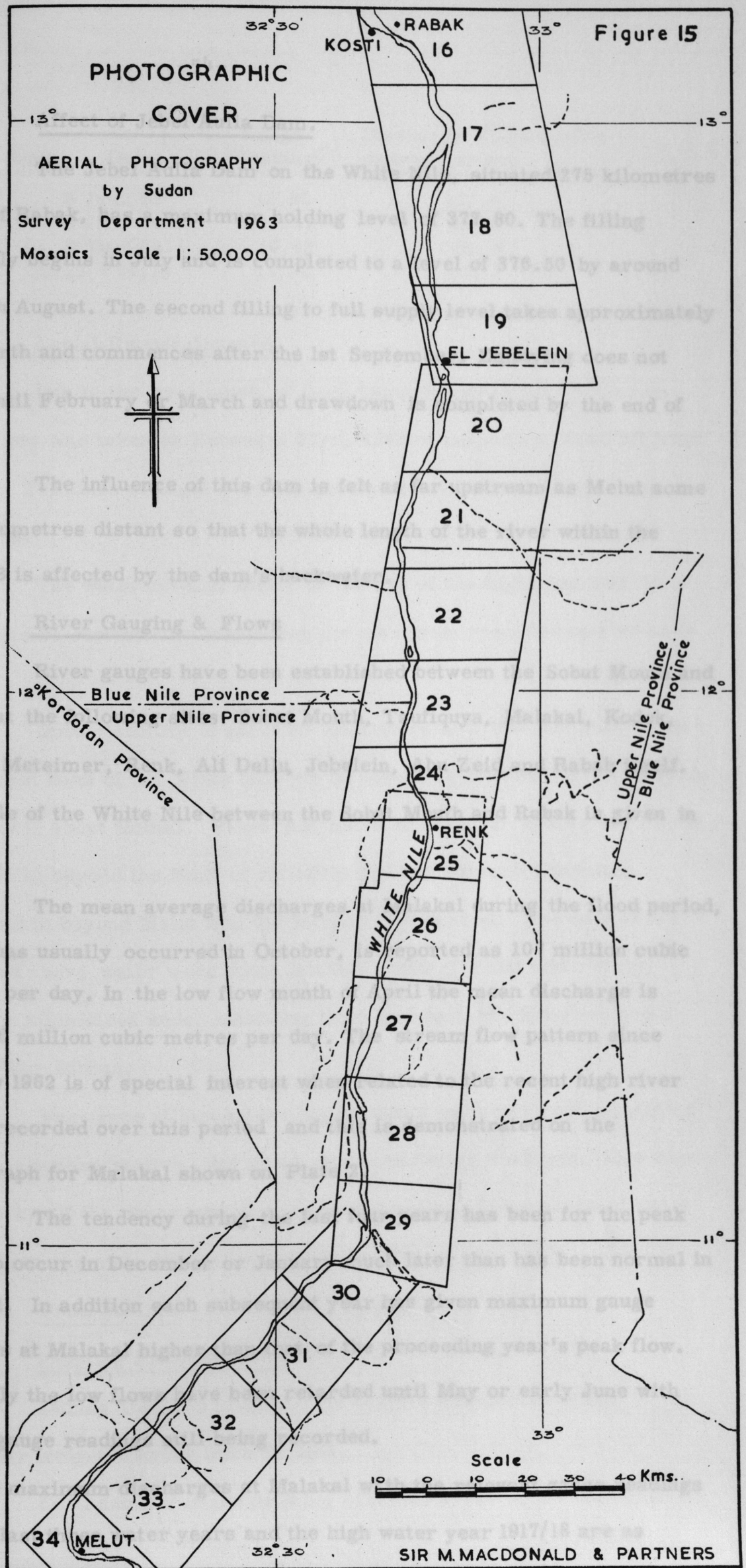
In addition to the maps, air photography at scale 1:25,000 and mosaics at scale 1:50,000 were available for the area. The contact prints gave almost complete coverage and an index to the areas covered by the mosaics is shown in Figure 15.

5.3 Hydrology

5.31 Description of the River

The source of the Nile is the Luvironza River in Tanganyika, some 6,7000 kilometres from where the Nile empties into the Mediterranean Sea. The Luvironza joins the Kagera which flows into Lake Victoria, from which the only exit is the Victoria Nile. It then flows through Lake Kioga into Lake Albert which it leaves very soon afterwards. Entering the Sudan at Nimule the river is known as the Bahr el Jebel and retains this name until it reaches Lake No. at latitude $9^{\circ}50'$ N. This lake is also fed by the Bahr el Ghazal and from here the river is known as the White Nile for the next 960 kilometres until it reaches Khartoum where it is joined by the Blue Nile to become the Nile, the name it retains until it reaches the sea. Between Lake No. and Khartoum the only tributary of any importance is the River Sobat which joins the White Nile from the east approximately 130 kilometres down stream of the lake outlet.

During recent years the White Nile has been covered for large sections by water hyacinth which has further impeded this already slow flowing river.



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5.32 Affect of Jebel Aulia Dam.

The Jebel Aulia Dam on the White Nile, situated 275 kilometres north of Rabak, has a maximum holding level of 377.80. The filling normally begins in July and is completed to a level of 376.50 by around the 20th August. The second filling to full supply level takes approximately one month and commences after the 1st September. Emptying does not start until February or March and drawdown is completed by the end of May.

The influence of this dam is felt as far upstream as Melut some 630 kilometres distant so that the whole length of the river within the area 5B is affected by the dam's backwater.

5.33 River Gauging & Flows

River gauges have been established between the Sobat Mouth and Rabak at the following sites: Sobat Mouth, Taufiquya, Malakal, Kodok, Melut, Meteimer, Renk, Ali Dellu, Jebelein, Abu Zeid and Rabak itself. A profile of the White Nile between the Sobat Mouth and Rabak is given in Plate 1.

The mean average discharges at Malakal during the flood period, which has usually occurred in October, is reported as 107 million cubic metres per day. In the low flow month of April the mean discharge is about 46 million cubic metres per day. The stream flow pattern since January 1962 is of special interest when related to the recent high river levels recorded over this period and this is demonstrated on the hydrograph for Malakal shown on Plate 2.

The tendency during the last four years has been for the peak flows to occur in December or January much later than has been normal in the past. In addition each subsequent year has given maximum gauge readings at Malakal higher than that of the proceeding year's peak flow. Similarly the low flows have been retarded until May or early June with higher gauge readings still being recorded.

The maximum discharges at Malakal with the relevant gauge readings for the last three water years and the high water year 1917/18 are as

follows :-

Water Year	Date	Gauge Reading	Discharge Million cubic metres per day
1962/63	5 Jan. 63	12.96	122.9
1963/64	5 Jan. 64	13.51	137.9
1964/65	5 Dec.64	14.42	215. 9
1917/18	20/23 Feb.18	13.32	168.0

5.34 Aerial Reconnaissance.

Due to the area south of Renk being inaccessible by road an opportunity was taken on February 23rd, 1965 of inspecting Area 5B from the air. The lines of flight over the area south of Jebelein is given on Figure 16.

The water level at Melut on the day of the flight was 386.48 which was 21 centimetres lower than the maximum recorded on February 4/5th.

Good visibility of about 30 kilometres at 2,000 feet showed that on the east bank of the White Nile the flooding was confined to the riverain pastures to about Gelhak. From just north of the Khor Bibban the flooding extended to beyond the limit of visibility and this extensive flooding continued to beyond Melut into the Machar Marsh area. The only areas observed above water were those situated north of Melut and a strip, about 10 kilometres wide, extending from just east of Paloich to south of the Khor Bibban.

Numerous villages were under water and others cut off except for water transportation. No game was seen during the flight. One item noticed by all the observers was the absence of any large areas of water hyacinth in the main channel of the White Nile.

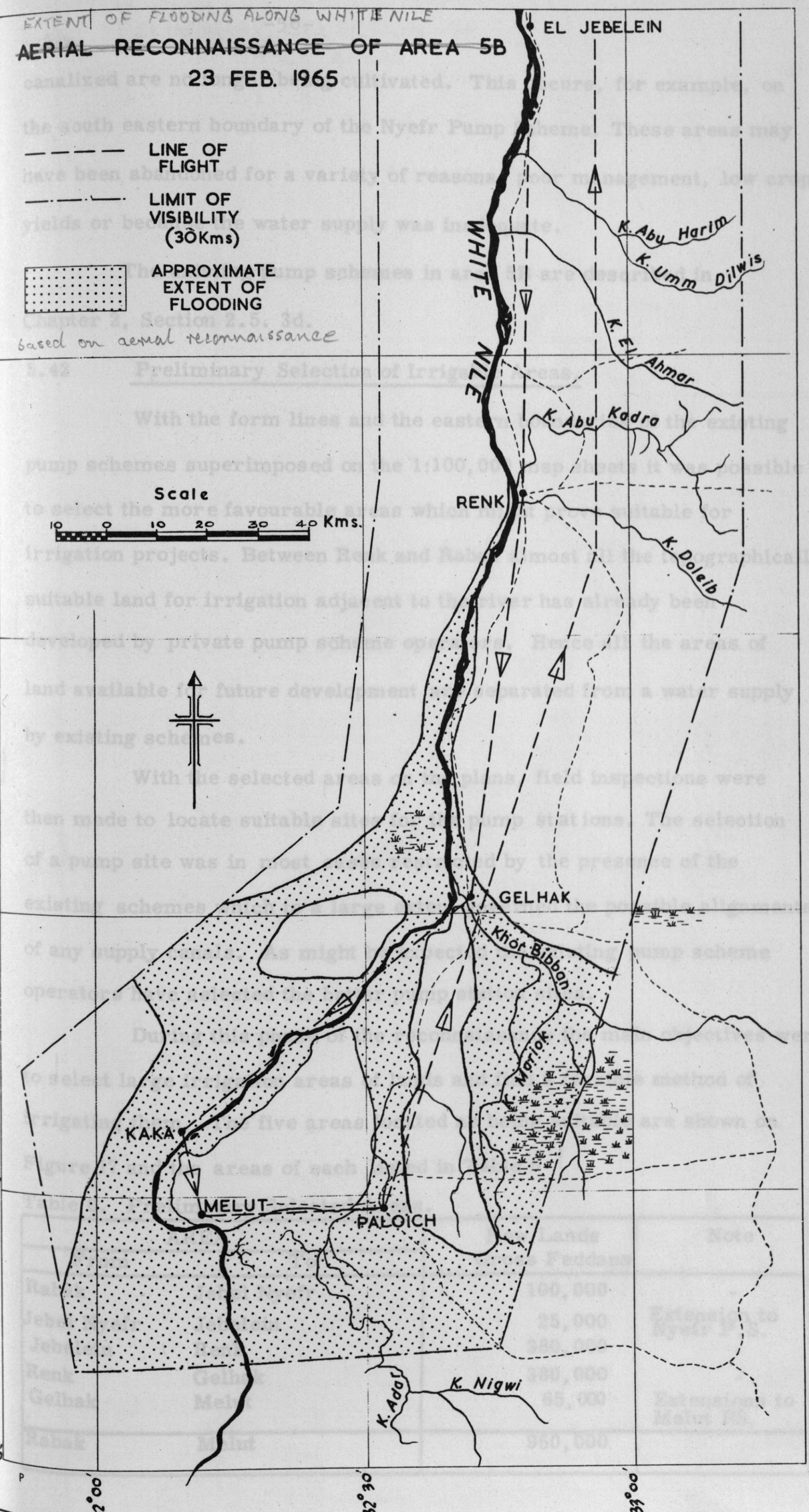
5.4 Field Studies

5.41 Existing Pump Schemes

During the field studies, the eastern boundaries of the presently irrigated areas were defined.

On a number of the existing schemes areas which had been

Figure 16



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canalized are no longer being cultivated. This occurs, for example, on the south eastern boundary of the Nyefr Pump Scheme. These areas may have been abandoned for a variety of reasons, poor management, low crop yields or because the water supply was inadequate.

The existing pump schemes in area 5B are described in Chapter 2, Section 2.5. 3d.

5.42 Preliminary Selection of Irrigable Areas.

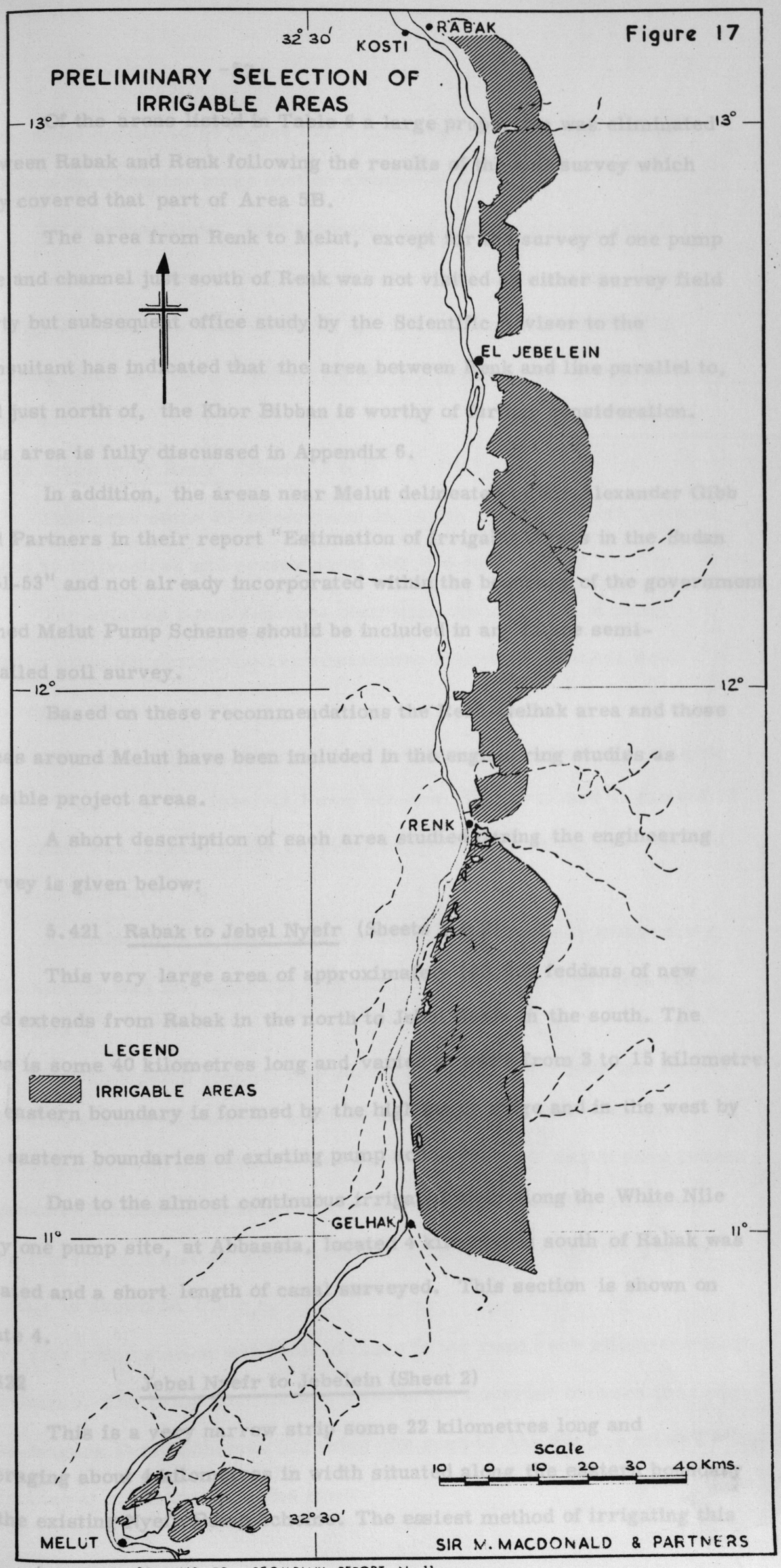
With the form lines and the eastern boundaries of the existing pump schemes superimposed on the 1:100,000 map sheets it was possible to select the more favourable areas which might prove suitable for irrigation projects. Between Renk and Rabak almost all the topographically suitable land for irrigation adjacent to the river has already been developed by private pump scheme operators. Hence all the areas of land available for future development are separated from a water supply by existing schemes.

With the selected areas on the plans, field inspections were then made to locate suitable sites for the pump stations. The selection of a pump site was in most cases restricted by the presence of the existing schemes which to a large extent governed the possible alignments of any supply canals. As might be expected the existing pump scheme operators have selected the better pump station sites.

During this phase of the reconnaissance the main objectives were to select large irrigation areas of lands and find a feasible method of irrigating them. The five areas located as being suitable are shown on Figure 17 and the areas of each listed in Table 6

Table 6. Preliminary Selected Areas.

AREA		New Lands Gross Feddans	Note
From	To		
Rabak	Jebel Nyefr	100,000	-
Jebel Nyefr	Jebelein	25,000	Extension to Nyefr P.S.
Jebelein	Renk	380,000	-
Renk	Gelhak	380,000	-
Gelhak	Melut	65,000	Extensions to Melut P.S.
Rabak	Melut	950,000	



PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 11

Of the areas listed in Table 6 a large proportion was eliminated between Rabak and Renk following the results of the soil survey which only covered that part of Area 5B.

The area from Renk to Melut, except for the survey of one pump site and channel just south of Renk was not visited by either survey field party but subsequent office study by the Scientific Advisor to the Consultant has indicated that the area between Renk and line parallel to, and just north of, the Khor Bibban is worthy of further consideration. This area is fully discussed in Appendix 6.

In addition, the areas near Melut delineated by Sir Alexander Gibb and Partners in their report "Estimation of Irrigable Areas in the Sudan 1951-53" and not already incorporated within the boundary of the government owned Melut Pump Scheme should be included in any future semi-detailed soil survey.

Based on these recommendations the Renk-Gelhak area and those areas around Melut have been included in the engineering studies as feasible project areas.

A short description of each area studied during the engineering survey is given below:

5.421 Rabak to Jebel Nyefr (Sheets 1 & 2)

This very large area of approximately 100,000 feddans of new land extends from Rabak in the north to Jebel Nyefr in the south. The area is some 40 kilometres long and varies in width from 3 to 15 kilometres. Its eastern boundary is formed by the high sandy ridge and in the west by the eastern boundaries of existing pump schemes.

Due to the almost continuous irrigated strip along the White Nile only one pump site, at Abbassia, located 4 kilometres south of Rabak was located and a short length of canal surveyed. This section is shown on Plate 4.

5.422 Jebel Nyefr to Jebelein (Sheet 2)

This is a very narrow strip some 22 kilometres long and averaging about 4 kilometres in width situated along the eastern boundary of the existing Nyefr Pump Scheme. The easiest method of irrigating this

area would appear to be to use the existing Nyefr main canal as the supply with a booster pump station situated at K.4.

This arrangement, with a booster pump giving a static lift of 2 metres, would permit the irrigation of some 8,500 feddans. The surveyed section showing the bank, ground and water levels for the existing canal and the ground levels for the proposed one are given in Plate 4.

5.423 Jebelein to Renk (Sheets 2 & 3)

This area some 90 kilometres in length varies in width between 8 and 25 kilometres and covers about 380,000 feddans

The existing pump schemes restricted the selection of pump station sites but during the reconnaissance four possible sites were surveyed. These were :

(a) At a point 4 kilometres south of Jebelein near the present outdoor station supplying the Jebelein Pump Scheme. The proposed alignment of this canal was located in the corridor between the existing Jebelein and Meheida schemes.

A static lift of 8 metres with a short rising main approximately 300 metres was invisaged for this site. The surveyed section is shown on Plate 4.

(b) A suitable pump channel was surveyed between the Goda and Haleka schemes some 9 kilometres south of the village of Goda. The strip between these two schemes is less than a kilometre wide but does permit access to the undeveloped lands to the rear of the existing schemes. A static lift of 9 metres would be required at this site and the ground profile is shown on Plate 4.

(c) This pump station was located close to the road, one kilometre south of Geigar. The pump channel was sited in the corridor between the Geigar and Magara Pump Schemes following the road to Abu Shalaya after a short distance at right angles to the river.

The static lift for this station is 9 metres. Plate 5 shows the canal headreach section.

(d) To cover the southern portion of the Jebelein-Renk area one site was selected 2 kilometres north of Renk with the pump station sited adjacent to the road. The land rises steadily from the river at approximately one metre per kilometre, see Plate 5, so that a rising main over two kilometers long is proposed. A static lift of 11 metres would provide a full supply level in the canal headreach of 390.5.

5.424 Renk - Gelhak (Sheet 3 & 4)

South of Renk very little land has been developed and air photography indicates there are twelve existing schemes with a total area of not more than 18,000 feddans gross.

The Khor Bibban forms the natural southern boundary to this area but the reconnaissance survey flight on February 23rd, 1965 indicated that flooding extended 5 to 10 kilometres north of the khor. As was expected, almost all the riverain land from Renk to Gelhak was inundated.

The only pump station located was in the north of the area, some 6 kilometres south of Renk. This pump channel is shown on Plate 5 and the short inlet channel surveyed indicates that no rising main is necessary. The static lift for this site would be 6.8 metres.

From the form lines, the information derived from cross sectioning done by the Sudan Survey Department and Sir Alexander Gibb & Partners and the inspection of air photographs it would appear that similar pump sites could be located along the whole length of this area should the soil survey prove that irrigation is desirable.

Secondary pumping could be installed to cover the land on the higher ground along the eastern boundary of the area at a later date.

5.425 Melut Area (Sheet 5)

From the Khor Bibban to the southern boundary of Area 5B at Melut the land is intersected by numerous Khors and drainage channels. During

the air reconnaissance most of the area was seen to be flooded and the only areas which appear worthy of further study are those near Melut which were above the flood level. These areas were demarcated by Sir Alexander Gibb and Partners in their 1951/53 survey and are shown on sheet 5.

5.5 Possible Irrigation Projects

5.51 Rabak to Renk

The areas which have been selected for semi-detailed soil survey between Rabak and Renk are indicated on the engineering plans. For each of these areas a preliminary canalization layout has been prepared. These layouts have been based on form lines obtained from cross sectioning at 10 kilometre intervals and extensive revision will be required when a detailed contour survey is available. Although the form lines may be restricted they do provide sufficient information to evaluate the merits of the five selected areas north of Renk. Four of the projects allow for secondary pumping to command the higher ground along the eastern boundaries of the selected areas. Table 7 summarizes the proposed schemes between Rabak and Renk.

Table 7 Proposed Irrigation Schemes

AREA	SCHEME GROSS AREA FEDDANS			Pump Static Lift metres	
	Primary Pumping	Secondary Pumping	Total	Primary	Secondary
Rabak South	2,500	17,000	19,500	8.9	11.3
Nyefr	8,500	13,500	22,000	2.0	5.1
Tayba	38,000	28,000	66,000	8.8	4.0
Geigar	29,000	-	29,000	8.8	-
Renk North	17,000	12,000	29,000	11.0	9.0
Total	95,000	70,500	165,500	-	-

The Rabak South Scheme could conveniently be combined with the Rabak Area, 6,900 feddans, proposed in the Roseires Soil Survey Report No.6, Rabak to Khartoum.

5.52 Renk to Gehak

The exploratory soil survey did not cover this area but a preliminary layout is shown on the engineering plans for a scheme of 35,000 feddans south of Renk.

5.53 Melut to Gelhak

The areas defined by Sir Alexander Gibb and Partners in the vicinity of the existing Melut Pump Scheme would appear to be logical extensions to that scheme following a satisfactory semi-detailed soil survey. The gross additional area is about 60,000 feddans.

ADDENDUM

TECHNICAL NOTE BY DR. ROBERT SMITH

Technical Note

by

Dr. Robert Smith

Scientific Adviser to the Consultants

In reviewing this draft report I find that an alternative interpretation of the Contract and of the data collected will result in a more straightforward presentation of the results under the following headings :-

1. Soil Survey Methods

Page No.		Chapter 3
28	Section 3.21	2nd Paragraph. The statement regarding contractual requirements is not correct. The density of field observation was not specified in the contract. The recommended procedure for the exploratory survey is as follows :- (a) A rapid undetailed aerial photo analysis giving a broad outline of terrain units for general comparison with the maps prepared by Sir A. Gibb & Partners. (b) A field check of the major soil units as distinguished by Sir A. Gibb & Partners in conjunction with the photo analysis. (c) Field observations beyond the area demarcated by Sir A. Gibb & Partners up to the 20 metre isopotamon or 25 Km. boundary, whichever is nearest to the river provided no major topographic obstacle is encountered. (d) The number of soil pits and bores per surface unit can be kept to a minimum provided a sufficiently representative picture chemically as well as morphologically is obtained from the discrete soil units. It is clear that the exploratory soil survey of the Rabak to Renk sector of the project area amply fulfils this specification. In fact, the density of observation at one site to each 1,972 feddans, falls within the Roseires specification for reconnaissance surveys.
29	Section 3.24	The taking of a bulk sample of soil from the 0-90cm depth is not the best way to sample auger sites.

2. Soil Classification

Page No.		
		Chapter 1
4	Section 1.10	The soils studied in the field could alternatively be classed as Vertisols. It is possible that the weak expression of diagnostic characteristics is related to appreciable moisture content; the soils were examined at the beginning of the dry season. The Grumaquertic Orthustents could alternatively be classified as Grumaquerts. It is believed that the uneven microrelief mentioned in the text is the phenomenon known as Gilgai, a diagnostic feature of Vertisols. The Grumustertic Orthustents could alternatively be classed as Grumusterts.
4,5	Section 1.11	See notes above on Vertisols.
		Chapter 4
34	Section 4.1	(b) Second Paragraph. The brown clays can alternatively be classed as Vertisols.
36	Section 4.3.A	Site No. 8056 is an Orthustent, not a Psammustent.
37	Section 4.3.B1.2	The Grumaquertic Orthustents may alternatively be classed as Grumaquerts
43	Section 4.3.B1.3	The Grumustertic Orthustents may alternatively be class as Grumusterts.
46	Section 4.3.B1.4	The Mazustertic Orthustents may alternatively be classed as Mazusterts

Appendix 1

In my opinion; Pit Nos. 7017, 7021, 7033, 7043, 7044, 7045, 7056, 7083, 7092, 7100, 7104, 7118, 7199, 8018, 8035, 8038, 8050, 8068, 8084, 8085, 8107, 8117, 8124 and 8128 could alternatively be classed as Grumaquerts.

Pit Nos. 8040, 8069, 8089, 8131 and 8134 could alternatively be classed as Grumusterts. Pit No. 7046 could alternatively be classed as a Vertic Orthustent. Pit No. 7047 could alternatively be classed as an Orthic Orthustent and Pit No. 8007 could alternatively be classed as a Mazustert.

3. Land Classification

Page No.		
35	Section 4.2	(ii) I do not accept the soil surveyor's statement that soils with less than 40 per cent clay in the 0-90 cm zone are

age No.		
		unsuitable for development. Although such soils may not be profitable under long staple cotton they are suitable for a wide range of other climatically adapted crops. I have, in fact, recommended for development, an area of sandy soils near Rabak.
36	**Section 4.2**	(iv) Because the degree of cracking in a soil depends on the moisture content at the time of examination I consider that the soil surveyor's field estimate of cracking should not be used as a limiting soils factor in land classification. I have, therefore, included for semi-detailed survey additional lands in the Jebelein area with non saline - non alkali clay soils.
50	**Section 4.3.B2.3**	I consider this soil unit worthy of semi-detailed soil survey with a view to development for orchard and garden purposes
51	**Section 4.4**	After re-examination of the field and laboratory data, an interpretation of the land quality to standards similar to those used in Roseires Areas 1 and 5a showed that the following additional lands had favourable development possibilities and should also be covered by semi-detailed soil and land classification survey:-
		(i) In the vicinity of Rabak an area of 13,000 feddans of non-saline, non-alkali, loamy and sandy soils suitable for diversified cropping, including horticultural crops.
		(ii) To the east of existing irrigated lands from El Hideib southwards to Jebelein an area of 41,500 feddans of clay lands of low salinity and moderate alkalinity, suitable for a long staple cotton rotation.
		These additional lands (54,500 feddans) bring to a total of 226,500 feddans the area recommended for semi-detailed soil survey and land classification in the Rabak to Renk sector of the project area.

APPENDIX 1

SPECIMEN SOIL PROFILE DESCRIPTIONS

OF 35 SITES.

Pit : 7017

Location : Map sheet 1

Topography : Sloping slightly from west to east. Possible sump area.

Cultivation and land use : Rough grazing. Cotton cultivated nearby

Vegetation : Acacia mellifera, Chloris virgata, Schoenefeldia gracilis.

Surface : Loose granular mulch to 5 cm. Few cracks. Abundant kankar and calcium carbonate concretions.

Profile Description :

0- 30 cm	10YR 4/1. Clay. Very slightly moist. Firm. Moderate coarse columnar, strong vertical cracking with finer horizontal cracking. Frequent fine roots and pores. Frequent kankar and calcium carbonate concretions on top. Finely divided calcium carbonate below.
30 - 40 cm	10YR 4/1. Clay. Very slightly moist. Friable. Fairly loose, moderate, fine to medium sub-angular blocky with incipient platiness, forming a transition between the major horizons. Frequent kankar and calcium carbonate deposits.
40 - 200^{+} cm	10YR 4/1 - 5Y 4/1. Clay. Slightly moist. Extremely firm. Massive, no cracks, roots or pores. Small slickensides. Impossible to determine larger ones due to compactness of the soil. Less than 1 per cent finely divided calcium carbonate and gypsum.

Classification : Grumaquertic Orthustent.

Pit: 7021

Location : Map sheet 2

Topography : Sloping slightly from west to east.

Cultivation and land use : Rough grazing.

Vegetation : Acacia mellifera and Acacia nubica scrub with occasional Acacia seyal, approx. 50/feddan. Aristida spp.

Surface : Soft, loose granular mulch to 5 cm. Frequent fine cracks, occasional large ones. Occasional kankar and calcium carbonate concretions. Frequent quartz pebbles and pieces of granite.

Profile Description :

0 - 40 cm — 10YR 4/1. Clay. Very slightly moist. Firm. Moderate coarse sub-angular blocky. Frequent cracks, horizontal and vertical. The vertical ones are pronounced, but not sufficiently to form columnar structure. Frequent small calcium carbonate concretions. Frequent lenses of fine sand. Occasional kankar.

40 - 180 cm — 10YR 4/1 - 3/1, 50 per cent 2.5Y 5/2 - 6/2 mottles at bottom. Clay. Slightly moist, very firm. Massive, abundant slickensides but not very large. Frequent fine cracks. Root remains found below the slickensides at the bottom of the pit. Frequent fine sand lenses. Occasional gypsum crystals. Frequent calcium carbonate concretions, up to 1 cm diameter.

180 - 200^{+} cm — Mottled, 2.5Y 5/2 - 6/2. Clay. Slightly moist. Very firm. Massive.

Classification : Grumaquertic Orthustent.

Pit :	7033
Location :	Map sheet 2
Topography :	Flat.
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia mellifera, Acacia seyal, Capparis decidua 5/feddan. Rottboellia exaltata.
Surface :	Uneven and compact. Abundant large and small quartz pebbles. Occasional cracks.

Profile Description :

0 - 52 cm	2.5Y 5/2 - 5Y 5/2. Clay. Moist at top, slightly plastic below. Very firm. Moderate coarse sub-angular blocky, abundant cracks. Frequent roots at the top. Occasional fine sand lenses. Occasional quartz pebbles.
52 - 200+ cm	10YR 4/1 - 5Y 5/1. Clay. Slightly moist. Very firm. Massive with very few fine cracks. No roots. No slickensides observed. Occasional fine sand lenses 3 per cent soft calcium carbonate aggregates over the bottom 50 cm.

Classification : Grumaquertic Orthustent.

Pit :	7043
Location :	Map sheet 3
Topography :	Flat.
Cultivation and land use :	Nil.
Vegetation :	Occasional Cordia sp. Sorghum sp.
Surface :	Loose granular mulch to 5cm. Abundant calcium carbonate concretions up to 2 cm diameter. Many large collapse structures. Occasional shell fragments and small quartz pebbles.

Profile Description :

0 - 40 cm	Slightly bluer than 5Y 4/1. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky. Frequent large and small cracks. Many fine roots. Frequent sand lenses and infilled cracks. Frequent small calcium carbonate concretions, kankar and shell fragments.
40 - 200^{+} cm	5Y 4/1, 5 per cent mottles of 10YR 5/2 over bottom 100 cm. Clay. Very slightly moist. Extremely firm. Massive. Few fine cracks at the top. 3 per cent calcium carbonate concretions up to 2 cm diameter.

Classification : Grumaquertic Orthustent.

Pit : 7044

Location : Map sheet 3

Topography : Flat.

Cultivation and land use ; Nil.

Vegetation : Acacia seyal, Cordia sp. Dichrostachys glomerata, Grewia sp. , Cadaba rotundifolia, Acacia mellifera, Sorghum sp., Cymbopogon nervatus, Schoenefeldia gracilis.

Surface : Fairly compact, frequent collapse structures. Abundant iron-stained quartz pebbles. Occasional calcium carbonate concretions and shells.

Profile Description :

0 - 40 cm — 5Y 4/1. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky. Frequent fine and larger cracks. Frequent fine roots. Frequent sand lenses and sand in cracks. Abundant fine gravel. Occasional shell fragments and quartz pebbles.

40 - 200^{+} cm — 5Y 4/1. Mottles of 2.5Y 5/2 - 10YR 5/2 increasing with depth. Clay. Slightly moist, very firm, massive. Few fine cracks at top. Sand in the cracks at the top. 3-5 per cent calcium carbonate aggregations.

Classification : Grumaquertic Orthustent.

Pit :	7045
Location :	Map sheet 3
Topography:	Slight slope from east to west.
Cultivation and land use :	Nil.
Vegetation :	Acacia mellifera, Acacia seyal, Cadaba rotundifolia, 20/feddan, Sorghum sp., Cymbopogon nervatus, Schoenefeldia gracilis.
Surface :	Loose granular mulch. Frequent collapse structures, abundant iron stained quartz gravel. Occasional calcium carbonate concretions and shell fragments.

Profile Description :

0 - 40 cm	5Y 4/1 - 10YR 4/1. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky. Frequent large and small cracks, producing almost columnar structure in parts. Frequent roots. Abundant quartz grains in cracks, and occasional pebbles. Occasional kankar, shell fragments, and small calcium carbonate concretions.
40 - 200^{+} cm	Fine mottling producing 5Y 4/1 at the top and 5Y 5/1 5/2 at the bottom. Clay. Slightly moist. Very firm. Massive, frequent fine cracks at the top. Much infilling of cracks by fine sand. 2 per cent calcium carbonate concretions.

Classification : Grumaquertic Orthustent.

Pit : 7046

Location : Map sheet 2

Topography : On the site of a ridge.

Cultivation and land use : Nil.

Vegetation : Acacia mellifera, Acacia senegal, Grewia sp., Chloris virgata, Schoenefeldia gracilis, Aristida sp.,

Surface : Fairly loose fine sub-angular blocky. Uncracked. Abundant quartz pebbles and pea-iron gravel.

Profile Description :

0 - 80 cm	7.5YR 3/2 - 4/2. Clay. Very hard. Moderate coarse sub-angular blocky. Frequent very fine cracks. Abundant pea-iron and quartz gravel.
80 - 140 cm	Depositional layers of quartz pebbles of varying size. Occasional pea-iron gravel intermixed. Occasional angular fragments.
140 - 170 cm	Pea-iron gravel. Occasional angular quartz fragments.
170 + cm	Blocks of micro-crystalline limestone or marble.

Classification : Orthic Orthustent.

Pit :	7047
Location :	Map sheet 2
Topography :	On top of a ridge.
Cultivation and land use :	Rough grazing. Traces of former cultivation.
Vegetation :	Acacia senegal, 10/feddan. Occasional Aristida sp. and Schoenefeldia gracilis.
Surface :	Compact. Skiffs of coarse sand. No cracks.

Profile Description :

0 - 50 cm	5Y 4/4 - 4/6. Sandy clay loam. Very slightly moist. Very firm. Moderate coarse columnar with incipient medium to coarse sub-angular blocky. Abundant fine roots. Fine and coarse sand grains lining the vertical cracks.
50 - 200^{+} cm	2.5Y 4/2 with abundant fine mottles of 10YR 4/2 - 3/2. Sandy clay loam. Very slightly moist. Extremely firm. Weak coarse sub-angular blocky to massive. Occasional fine vertical cracks. Few roots. 3-5 per cent soft calcium carbonate over the bottom 20 cm. Frequent manganese concretions. Frequent sand grains.

Classification : Psammic Orthustent.

Pit :	7056
Location :	Map sheet 3
Topography :	Falling slightly from east to west.
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia seyal, Acacia mellifera, Boscia senegalensis, 10/feddan, Sorghum sp., Cymbopogon giganteum.
Surface :	Uneven. Abundant collapse structures. Thin rain crust and loose mulch to 3 cm. Abundant calcium carbonate concretions, iron concretions and shell fragments. Occasional kankar.

Profile Description :

0 - 50 cm	10YR 4/1. Clay. Very slightly moist. Extremely firm. Moderate coarse sub-angular blocky. Frequent cracks, and occasional large vertical cracks. Abundant fine roots. Fine sand lenses. Abundant quartz grains. Abundant calcium carbonate concretions, shell fragments, iron concretions, kankar and fine gravel.
50 - 200^{+} cm	5Y 4/1. As much as 20 per cent 2.5Y mottles at bottom. Clay. Very slightly moist. Extremely firm. Massive, very few cracks. Occasional roots. Occasional sand lenses and fine gravel at the top. 3 per cent calcium carbonate concretions near the bottom. Frequent sand lenses at bottom.

Classification : Grumaquertic Orthustent.

Pit :	7083
Location :	Map sheet 2
Topography :	Flat.
Cultivation and land use :	Rough grazing on edge of a cotton scheme.
Vegetation :	Acacia seyal, 5/feddan. Sorghum sp., Cymbopogon nervatus, Schoenefeldia gracilis.
Surface :	Slightly uneven. Frequent collapse structures. Loose granular mulch to 3 cm. Frequent small quartz pebbles and gravel.

Profile Description :

0 - 26 cm	10YR 3/1 - 4/1. Clay. Very slightly moist. Very firm. Moderate-strong coarse sub-angular blocky. Frequent cracks, the vertical ones more pronounced than the horizontal ones. Frequent fine roots and occasional large ones. Frequent quartz gravel and occasional pebbles and shell fragmen Occasional coarse sand lenses.
26 - 140 cm	10YR 3/1. Clay. Slightly moist. Very firm. Massive. No cracks or roots. Occasional quartz gravel. A few soft calcium carbonate concretions at the bottom. Frequent black manganese deposits.
140 - 200^{+} cm	5Y 5/2, with fine mottles of 10YR 3/1. Clay. Slightly moist. Very firm. Massive, no cracks or roots. 2-3 per cent soft calcium carbonate concretions. Frequent fine gravel.

Classification : Grumaquertic Orthustent.

Pit : 7092

Location : Map sheet 2

Topography : Flat.

Cultivation and land use : Nil.

Vegetation : Young Acacia seyal and Cadaba rotundifolia, 8/feddan. Sporobolus helveolus, Schoenefeldia gracilis, Chloris virgata.

Surface : Compact. Frequent collapse structures. Loose mulch in places. Coarse sandy skiff and abundant shell fragments.

Profile Description :

0 - 35 cm	5Y 4/1 - 5/1. Sandy clay. Very slightly moist. Extremely firm. Moderate coarse columnar with fine horizontal cracks forming sub-angular blocky structures. Frequent fine roots. Abundant quartz particles and shell fragments.
35 - 103 cm	5Y 4/1, with 5Y 5/2 mottles at bottom. Clay. Slightly moist. Extremely firm. Massive. Occasional fine cracks, and rootlets. Occasional manganese deposits, and 3 per cent soft calcium carbonate deposits with concretions of up to 4 cm diameter.
103 - 200^{+} cm	Mottled with 50 per cent 5Y 5/2 and 50 per cent 10YR 4/1 - 3/1. Clay. Slightly moist. Extremely firm. Massive. No cracks or roots. Occasional small slickensides and poorly formed larger ones. Occasional root remains. Frequent coarse sand particles. Occasional manganese deposits and calcium carbonate increasing to 15 per cent at the bottom.

Classification : Grumaquertic Orthustent.

Pit :	7100
Location :	Map sheet 2
Topography :	Flat.
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia seyal, Cadaba rotundifolia, Acacia mellifera, Grewia sp., 15/feddan, Sporobolus helveolus, Rottboellia exaltata, Schoenefeldia gracilis.
Surface :	Uneven. Compact. Frequent collapse structures. Frequent quartz pebbles and gravel. Occasional calcium carbonate concretions and shell fragments.

Profile Description :

0 - 45 cm	5Y 4/1 - 4/2. Clay. Very slightly moist. Very firm. Moderate to strong coarse sub-angular blocky. Frequent cracks with better development vertically than horizontally. Frequent fine roots. Abundant quartz grains and frequent sand lenses. Occasional quartz pebbles.
45 - 200^{+} cm	5Y 4/1. Mottles at bottom of 5Y 5/2, 10YR 5/6 and 5/8. Clay. Slightly moist. Extremely firm. Massive to weak coarse sub-angular blocky. Occasional fine cracks and roots. Occasional small slickensides. Occasional quartz gravel and manganese deposits. 2 per cent soft calcium carbonate deposits. Occasional iron concretions.

Classification : Grumaquertic Orthustent.

Pit :	7104
Location :	Map sheet 3
Topography :	Flat.
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia seyal, Cadaba rotundifolia, 10/feddan, Schoenefeldia gracilis, Chloris virgata, Hyparrhenia sp. and Aristida sp.
Surface :	Level. Frequent collapse structures. Loose mulch to 3 cm. Abundant quartz pebbles and gravel. Occasional shells.

Profile Description :

0 - 30 cm	10YR 3/1 - 4/1. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky. Frequent cracks. Frequent fine roots. Abundant quartz pebbles gravel and coarse sand. Occasional shell fragments and sand lenses in the cracks.
30 - 136 cm	10YR 3/1 - 2/1. Clay. Slightly moist. Extremely firm. Massive, with a few cracks at the top. Occasional tree roots. Frequent quartz pebbles. 3 per cent calcium carbonate concretions at the bottom. Occasional quartz grains.
136 - 200^{+} cm	5Y 5/2 with 50 per cent mottles of 10YR 3/1 - 2/1. Clay. Slightly moist. Extremely firm. Massive . No cracks or roots. Occasional small slickensides. Occasional quartz pebbles. 3 per cent soft calcium carbonate aggregations.

Classification : Grumaquertic Orthustent.

Pit :	7118
Location :	Map sheet 2
Topography :	Flat
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia seyal, Cadaba rotundifolia, Acacia senegal, Acacia mellifera, Cordia sp. 20/feddan. Patches of Schoenefeldia gracilis, Chloris virgata and Rottboellia exaltata.
Surface :	Firm and compact. Frequent collapse structures and occasional cracks. Frequent quartz pebbles and gravel. Occasional calcium carbonate concretions.

Profile Description :

0 - 38 cm	10YR 4/1. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky and moderate medium sub-angular blocky. Frequent cracks, more pronounced vertically than horizontally. Frequent rootlets, and occasional Acacia mellifera roots. Frequent quartz grains and occasional sand lenses. Occasional shell fragments.
38 - 142 cm	10YR 4/1. Clay. Slightly moist. Very firm. Massive. Occasional fine cracks and tree roots. Occasional quartz grains and 2 per cent soft and hard calcium carbonate.
142 - 200+ cm	5Y 5/1 - 5/2. Mottles of 10YR 6/6 at the bottom. Clay. Slightly moist. Very firm. Massive, no cracks or roots. Calcium carbonate concretions and aggregations increasing to 7 per cent at the bottom.

Classification : Grumaquertic Orthustent.

Pit :	7119
Location :	Map sheet 2
Topography :	Flat.
Cultivation and land use :	Rough grazing.
Vegetation :	Acacia mellifera, Cadaba rotundifolia, Cordia spp. Grewia sp., Acacia drepanolobium, Cymbopogon nervatus, Dinebra retroflexa, Chloris virgata, Schoenefeldia gracilis, Fagonia cretica.
Surface :	Thin rain crust overlying a loose mulch. Frequent cracks. Frequent quartz pebbles, iron concretions and shells.

Profile Description :

0 - 52 cm	2.5Y 5/2 - 5Y 5/2. Clay. Very slightly moist at top to slightly moist lower down. Moderate medium sub-angular blocky and moderate fine sub-angular blocky, in loose aggregations. Abundant very fine cracks, often resembling laminations. Frequent roots. Occasional kankar, quartz pebbles and shell fragments.
52 - 200^{+} cm	2.5Y 5/2 - 5Y 5/2. Clay. Slightly moist. Very firm. Weak coarse sub-angular blocky at the top, with occasional fine cracks. Massive lower down, and no roots. Occasional quartz pebbles. Less than 1 per cent calcium carbonate concretions.

Classification : Grumaquertic Orthustent.

Pit:	8007
Location:	map sheet 1
Topography:	Very gently sloping; in proximity of gravel outcrop.
Cultivation and land use:	Rough grazing.
Vegetation:	Open scrub (Acacia senegal, Acacia mellifera, Cadaba rotundifolia) and grasses (Sehima ischaemoides, Schoenefeldia gracilis).
Surface:	Smooth, hard, platy surface crust with few fine cracks, dispersed antheaps.

Profile Description:

0 - 2 cm	Hard platy surface crust. Clear, smooth boundary.
2 - 25 cm	Dry, hard, coarse angular blocky, 2.5Y 4/2 sandy clay; moderate number of fine cracks; many quartz gravels and some pea iron particles; few roots.
25 - 60 cm	Dry, very hard, massive 2.5Y 4/2 sandy clay; some vertical cracks, gravel as previous layer 7.5YR 6/8 sand lenses.
60 - 140 cm	Dry, very hard, massive 2.5Y 4/2 clay; many very fine (up to 5 mm) quartz gravels and some pea iron (same size); white calcareous mottles and rock particles in lower part of horizon. Gradual, wavy boundary.
140 - 200+ cm	Dry, very hard, massive, 7.5YR 5/8 clay; 2.5Y 4/2 mottles and streaks; many white, soft and hard calcareous mottles; many quartz particles of very coarse sand size.

Classification: Mazustertic Orthustent.

Pit:	8018
Location :	Map sheet 2
Topography:	Level.
Cultivation and land use :	Rough grazing.
Vegetation :	Mainly grasses and some scrub (Acacia mellifera)
Surface :	Smooth; moderately cracked.

Profile Description :

0 - 20 cm	Dry, very hard, coarse angular blocky 5Y 3/2 clay; some sand lenses; cracks; few roots.
20 - 140 cm	Dry, very hard, massive 5Y 3/1 sandy clay; some sand lenses; few fine (up to 2 mm) whitish rock particles; major vertical cracks to a depth of 60 cm.
140 - 200^{+}cm	Dry, very hard, massive 5Y 3/1 clay; common number of whitish rock particles; some gypsum crystals.

Classification: Grumaquertic Orthustent.

Pit :	8035
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Rough grazing.
Vegetation :	Moderately dense stand of Acacia mellifera, Cordia spp., Acacia seyal, Grewia spp.
Surface :	Few, small collapse structures some gravel.

Profile Description :

0 - 23 cm	Dry, hard, coarse angular blocky 5Y 4/2 clay; narrow cracks; moderate number of roots.
23 - 67 cm	Dry, very hard, coarse angular blocky to massive 5Y 4/2 clay; few cracks of which the major ones extend to a depth of approximately 100 cm; few fine rootlets.
67 - 200+ cm	Very slightly moist, very hard, massive 5Y 4/2 clay; regular pattern of faintly contrasting 10YR 5/4 mottles; common number of white calcareous mottles (soft on the outside and hard core; up to 2 cm in size). Profile effervesces strongly with 10 per cent HCl from surface downwards.

Classification: Grumaquertic Orthustent.

Pit :	8038
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Rough grazing
Vegetation :	Few bushes (Acacia mellifera, Cordia spp. Cadaba rotundifolia) but mainly grass (Cymbopogon nervatus).
Surface:	Few small collapse structures; moderate number of cracks; thin soft raincrust.

Profile Description:

0 - 25 cm	Dry, hard, coarse angular blocky 5Y 4/2 clay; cracks; few roots.
25 - 145 cm	Very slightly moist, very hard, massive 5Y 4/2 clay; few cracks (to a depth of 40 cm); common number of fine, white, soft calcareous mottles (size up to 1 mm).
145 - 200^{+} cm	Very slightly moist, very hard, massive 2.5Y 4/2 clay; common number of soft and slightly hard 2.5Y 6/4 mottles and many gypsum crystals.

Classification: Grumaquertic Orthustent.

Pit :	8040
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Rough grazing.
Vegetation :	Dominantly grasses (Sorghum purpureo-sericeum and some Andropogon gayanus) and herbs Abutilon pannosum, Ocimum basilicum and Ipomoea cordofana).
Surface :	Moderate number of small collapse structures; moderate cracking.

Profile Description :

0 - 35 cm	Dry, hard, coarse angular blocky to prismatic 2.5Y 4/2 clay; moderate number of cracks, the majority of which extend to a depth of 40 cm; some fine quartz gravel and white hard calcareous particles; grass roots concentrated in first 6 cm.
35 - 160 cm	Dry, very hard, massive 2.5Y 4/2 clay; thin 10YR 5/8 veneers of sand which infill old cracks; common number of quartz gravels and white hard calcareous particles.
160 - 200^{+} cm	Very slightly moist, extremely hard, massive 2.5Y 4/2 clay; number of calcareous mottles increased as compared with previous layer; sand veneers as described before. Soil matrix does not react with 10 per cent HCl.

Classification: Grumustertic Orthustent.

Pit :	8050
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Rough grazing.
Vegetation :	Grass plain; grass occurs in patches (Aristida plumosa, Cymbopogon nervatus).
Surface :	Considerable number of small collapse structures; otherwise smooth. Thin (4 mm), soft, platy raincrust which is rich in sand grains.

Profile Description :

0 - 25 cm	Dry, hard, coarse angular blocky to prismatic 5Y 5/1 clay; major vertical cracks extend to a depth of 30 cm; some fine granular peds in first 10 cm of cracks; common number of roots in first 10 cm; some 10YR 6/3 sandy inclusions.
25 - 90 cm	Very slightly moist, very hard, massive 5Y 4/1 clay; many fine cracks in all directions; white soft and hard calcareous mottles in lower part of layer.
90 - 200^{+} cm	Very slightly moist, very hard, massive 5Y 5/2 to 5Y 6/2 clay; 5Y 4/1 streaks along old cracks and root channels; common number of faintly contrasting 7.5YR 5/6 mottles; many soft and hard, white, calcareous mottles; abundance and size of these mottles increases downwards in this layer. Strong reaction with 10 per cent HCl throughout profile.

ification: Grumaquertic Orthustent.

Pit :	8056
Location :	Map sheet 2
Topography :	Gently sloping, oblong hummock ("qoz"), top about 2 m above clay plain.
Cultivation and land use :	Abandoned site of inhabitation.
Vegetation:	Grasses (Pennisetum mollisimum, Aristida adscensionis, Schoenefeldia gracilis, Andropogon sp., Eragrostis sp.).
Surface :	Somewhat irregular; moderate quantity of quartz gravel and various other kinds of rock; the rock fragments have an average size of 7.5 cm; pottery shards.

Profile Description:

0 - 75 cm	Dry, weakly cemented, massive, 10YR 3/2 sandy loam; moderate number of white, calcareous concretions; roots to a depth of 35 cm.
75 - 115 cm	Dry, cemented massive, 10YR 5/2 sandy loam; abundance of white calcareous concretions; isolated pieces of black slate and strongly weathered granite.
115 - 200^{+} cm	Dry, strongly cemented to indurated, massive 2.5Y 7/2 sandy loam. In this layer the calcareous concretions do not longer occur as discrete elements but sand grains and calcareous nodules form a homogeneous mass (a caliche). Calcified bones between 107 and 125 cm; pottery shards between 140 and 145 cm.

Classification: Psammic Orthustent intergrading towards Calcorthid.

Pit:	8068
Location :	Map sheet 2
Topography :	Level.
Cultivation and Land use :	Rough grazing.
Vegetation :	Scarce grass (Hyparrhenia sp.) few small scrubs (Cordia sp., Cadaba rotundifolia).
Surface :	Smooth; few small collapse structures; slightly hard, platy, coherent raincrust (thickness 1 cm).

Profile Description :

0 - 33 cm	Dry, hard, coarse angular blocky 5Y 3/1 clay; major vertical cracks extend to a depth of approximately 50 cm and are partly infilled with fine granular peds; fine rootlets in first 8 cm.
33 - 110 cm	Very slightly moist, very hard, massive 5Y 3/1 clay; few white soft calcareous particles; a few bigger roots extend to a depth of 45 cm.
110 - 200+ cm	Very slightly moist; extremely hard, massive clay with 5Y 5/1 matrix colour; abundant white soft and hard calcareous mottles (up to 4 cm in size). Common numbers of 7.5 YR 5/6 mottles.

Classification: Grumaquertic Orthustent.

Pit : 8069

Location : Map sheet 2

Topography : Slightly sloping in Eastern direction

Cultivation and land use : Rough grazing.

Vegetation : Dominantly grass (Dinebra retroflexa); moderate number of scrubs (Cordia sp., Cadaba rotundifolia).

Surface : Regular pattern of many wide cracks; average width of cracks is 6 cm.

Profile Description :

0 - 2 cm	Loose, mulched layer consisting of dry, hard, very fine angular blocky and granular 2.5Y 3/2 peds with clay texture.
2 - 60 cm	Very slightly moist, very hard, prismatic and coarse angular blocky 2.5Y 3/2 clay. The individual prismatic and angular blocky aggregates are separated by wide vertical cracks (up to 6 cm in width) and covered with a thin platy crust of 2 cm thickness. The cracks contain only few of the fine peds as described in the top layer. A common number of fine, hard calcareous particles is found in the clay.
60 - 200^{+} cm	Very slightly moist, very hard, massive, 2.5Y 3/2 clay; many fine (up to 2 mm) hard, calcareous particles with 10YR 2/2 coatings. Soil matrix does not react with 10 per cent HCl.

Classification: Grumustertic Orthustent.

Pit :	8078
Location :	Map sheet 3
Topography :	Top of gently sloping ridge; approximately $7\frac{1}{2}$ m above clay plain.
Cultivation and land use :	Nil, site near village.
Vegetation :	Dominantly grass (Eragrostis sp.); some trees (Boscia senegalensis, Balanites aegyptiaca).
Surface :	Smooth; with thin top layer of dry, loose coarse sand.

Profile Description :

0 - 80 cm	Dry, loose to weakly cemented, structureless, 5YR 4/6 coarse sandy loam; few fine rootlets in first 40 cm.
80 - 150 cm	Dry, moderately cemented structureless 5YR 4/6 coarse sandy loam.
150 - 200^{+} cm	Very slightly moist, moderately cemented, structureless 5YR 5/6 coarse sandy loam; common number of fine (1 to 2 mm) black particles. Profile is non calcareous throughout; average size of coarse sand particles is $1\frac{1}{2}$ mm; a few round holes occur at various depths in the profile.

Classification : Psammic Orthustent.

Pit:	8084
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Grazing.
Vegetation :	Rather dense stand of Acacia seyal with undergrowth of Cadaba rotundifolia and some Grewia sp.
Surface :	Slightly undulating microrelief; incipient collapse structures; soft raincrust of 5 mm thickness; cracks.

Profile Description :

0 - 20 cm	Dry, hard, coarse angular blocky 5Y 4/1 clay; cracks which are partly infilled with fine peds; fine rootlets mainly in first 10 cm.
20 - 70 cm	Very slightly moist, very hard, massive 5Y 4/1 clay dissected by some major vertical cracks; a few white calcareous mottles and some 10YR 6/3 inclusions of sand.
70 - 200+ cm	Very slightly moist, extremely hard, massive clay with mixed colours 5Y 5/2 and 5Y 4/1; common number of white calcareous mottles. Strong reaction with 10 per cent HCl throughout profile.

Classification : Grumaquertic Orthustent.

Pit : 8085

Location : Map sheet 3

Topography : Level; near main irrigation canal.

Cultivation and land use : Grazing.

Vegetation : Grass plain (Cymbopogon nervatus).

Surface : Smooth; some gravel.

Profile Description :

0 - 3 cm	Loose surface mulch. Dry, soft, fine granular 5Y 3/1 sandy clay loam; sandy particles have very coarse sand size; common number of fine rootlets.
3 - 33 cm	Dry, hard, coarse angular blocky to prismatic 5Y 3/1; clay; major vertical cracks extend to an average depth of 50 cm; 10YR 6/3 inclusions of very coarse sand; common number of roots with average thickness of 1 cm.
33 - 200^{+} cm	Very slightly moist, very hard, massive 5Y 3/1 clay; vertical cracks in first 20 cm; common number of white, soft, calcareous mottles. Reaction with 10 per cent HCl throughout profile.

Classification : Grumaquertic Orthustent.

Pit :	8089
Location :	Map sheet 3
Topography :	Slightly sloping; on upper part of old meander slope.
Cultivation and land use :	Grazing.
Vegetation :	Dense grass cover and moderate number of scrubs (Acacia mellifera, Cadaba rotundifolia, Acacia nubica, Grewia sp.).
Surface :	Smooth.

Profile Description :

0 - 6 cm	Loose surface mulch; dry, soft and hard, fine angular blocky 2.5Y 4/2 clay; fine rootlets.
6 - 40 cm	Dry, hard coarse prismatic 2.5Y 4/2 clay; vertical wide cracks extending to a depth of approximately 45 cm; each individual prismatic aggregate consists of platy elements which are slightly tilted; many fine (up to 5 mm) hard calcareous nodules - common number of roots.
40 - 140 cm	Very slightly moist, very hard, massive 2.5Y 4/2 clay; 10YR 6/6 sandy inclusions; calcareous nodules as previous layer.
140 - 200^{+} cm	Very slightly moist, extremely hard, massive 2.5Y 4/2 clay; many hard, big (up to 2 cm) white calcareous nodules and soft 2.5Y 6/4, non calcareous mottles.

Classification: Grumustertic Orthustent.

Pit : 8095

Location : Map sheet 3

Topography : Top of gently sloping hummock; approximately 5 m above level of clay plain.

Cultivation and land use : Abandoned village site.

Vegetation : Very scanty covered with grass Hyparrhenia sp.

Surface : Smooth, pottery shards and alien stone fragments; skiffs of fine gravel.

Profile Description :

0 - 1 cm	Surface crust. Dry, slightly hard, thin platy 10YR 3/2 coarse sandy clay loam.
1 - 150 cm	Dry, slightly hard, structureless, 10YR 3/2 to 2.5Y 3/2 coarse sandy clay loam. Layer contains artifacts (charcoal, pottery shards, soft pieces of bone) and 2.5YR 2/2 gritty patches.
150 - 200^{+} cm	Slightly moist, weakly cemented, structureless 10YR 3/3 coarse sandy clay; sand grains have various colours; faint 7.5 YR 5/6 mottles. Very weak reaction with 10 per cent HCl throughout profile.

Classification : Orthic Orthustent; profile presumably disturbed by human interference.

Pit :	8107
Location :	Map sheet 2
Topography :	Level.
Cultivation and land use :	Grazing.
Vegetation :	Dense scrub growth (Acacia mellifera, Cordia sp. Grewia sp. and some Acacia seyal); grass only in patches (Cymbopogon nervatus, Schoenefeldia gracilis).
Surface:	Irregular microrelief; height difference between "micro knolls" and "micro basins" up to 30 cm; abundant snail shells; moderate number of fine (up to 1 cm) yellow sand stone gravel; thin (3 mm), soft raincrust.

Profile Description :

0 - 40 cm	Dry, hard, coarse angular blocky to prismatic 5Y 4/1 clay; common number of wide (up to $1\frac{1}{2}$ cm) vertical cracks; upper faces of structural elements are thin platy,; roots in first 20 cm.
40 - 115 cm	Very slightly moist, very hard, massive 5Y 4/1 clay; common number of mainly soft, white calcareous nodules.
115 - 200^{+} cm	Very slightly moist, very hard, massive 5Y 4/1 clay; many soft and hard calcareous nodules whose average size has increased as compared with previous layer; common number of 5Y 6/3 mottles. Strong reaction with 10 per cent HCl throughout profile.

Classification : Grumaquertic Orthustent, phase with dominantly rough surface topography.

Pit : 8117

Location : Map sheet 3

Topography : Level.

Cultivation and land use : Grazing.

Vegetation : Moderately dense stand of Acacia mellifera, Cadaba rotundifolia, Cordia sp. Boscia senegalensis and Grewia sp., grasses Cymbopogon nervatus and Hyparrhenia sp.

Surface : Moderately irregular microrelief, iron stained quartz gravel.

Profile Description :

0 - 5 cm	Loose surface mulch. Dry, soft, fine angular blocky 5Y 4/1 clay.
5 - 40 cm	Dry, hard, coarse angular blocky to prismatic 5Y 4/1 clay; common number of wide(up to 3 cm) vertical cracks extending to an average depth of 40 cm; moderate number of gravels; first 20 cm well rooted.
40 - 125 cm	Very slightly moist, very hard, massive 5Y 4/1 clay; few shell fragments and white calcareous mottles.
125 - 200^{+} cm	Very slightly moist, extremely hard, massive 5Y 5/2 clay; abundant, white, soft and hard calcareous elements, partly with nodular shape; 5Y 6/4 and 7.5YR 5/6 mottles.

Classification : Grumaquertic Orthustent.

Pit :	8124
Location :	Map sheet 1
Topography :	Level.
Cultivation and land use :	Grazing.
Vegetation :	Dominantly grass; some young *Acacia nubica*.
Surface :	Smooth, few cracks and few collapse structures; calcareous nodules (up to 1 cm).

Profile Description :

0 - 1 cm	Loose surface mulch. Dry, soft, fine angular blocky 10YR 3/1 clay.
1 - 45 cm	Dry, hard, coarse angular blocky 10YR 3/1 clay; common number of narrow (up to 5 mm) vertical and horizontal cracks; common number of firm, white, calcareous particles; 10YR 6/3 inclusions of sand; fine rootlets in first 8 cm.
45 - 200^{+} cm	Dry, extremely hard, massive 10YR 3/1 clay; horizontal and vertical cracks and narrow but numerous and extend to a depth of more than 2 m; calcareous particles and sandy inclusions as previous layer. Only in layer 0-45 cm matrix clay reacts with 10 per cent HCl.

Classification : Grumaquertic Orthustent.

Pit :	8128
Location :	Map sheet 1
Topography :	Level.
Cultivation and land use :	Grazing.
Vegetation :	Scanty grass cover (Sehima ishaemoides); some scrubs (Acacia mellifera, Cadaba rotundifolia).
Surface :	Smooth; loose, powdery top layer of 5 mm thickness.

Profile Description :

0 - 45 cm	Dry, hard, coarse to medium angular blocky 5Y 4/2 clay; some of the angular blocky elements consist of platy peds; common number of narrow (less than 5 mm) vertical cracks; first 10 cm of cracks infilled with fine peds.
45 - 125 cm	Very slightly moist, friable, massive 5Y 3/2 clay; regular pattern of narrow cracks running in all directions; clusters of calcareous sand grains with colours 7.5YR 5/6 and 7.5YR 8/2; 5Y 6/3 streaks.
125 - 200^{+} cm	Very slightly moist very firm, massive 5Y 5/3 clay; crack pattern as previous layer; many fine, faintly contrasting 2.5Y 5/6 mottles; big white, calcareous particles. Strong reaction with 10 per cent HCl throughout profile; development of vertical cracks very poor.

Classification : Grumaquertic Orthustent.

Pit :	8131
Location :	Map sheet 1
Topography :	Level.
Cultivation and land use :	Rainfed dura field
Vegetation :	Nil.
Surface :	Smooth; some quartz gravel; thin, soft raincrust.

Profile Description :

0 - 4 cm	Loose surface mulch. Dry, hard, fine angular blocky and fine granular 10YR 3/2 clay.
4 - 40 cm	Dry, hard, medium to coarse angular blocky, 10YR 3/2 clay; common number of vertical cracks of which first 20 cm infilled with fine peds; the coarse angular blocky aggregates have a platy structure; majority of roots in layer 0-20 cm.
40 - 110 cm	Very slightly moist, very hard, massive 10YR 3/2 clay; common number of white soft calcareous mottles; fine cracks.
110 - 190 cm	Very slightly moist, extremely hard, massive 10YR 3/1 clay; common number of soft calcareous mottles; few clusters of gypsum crystals.
190 - 200^{+} cm	Very slightly moist, extremely hard, massive 10YR 4/4 clay; abundant gypsum crystals; moderate number of white, hard, calcareous nodules; soft 5YR 4/6 mottles and streaks. Horizon below 190 cm is entirely different from the usual subsoil in the clay profiles.

Classification : Grumustertic Orthustent.

Pit :	8134
Location :	Map sheet 1
Topography :	Level.
Cultivation and land use :	Grazing.
Vegetation :	Dominantly grasses (Cymbopogon nervatus, Aristida hordeacea, Rottboellia exaltata); some Cadaba rotunfidolia.
Surface:	Smooth; few cracks and collapse structures.

Profile Description :

0 - 1 cm	Loose surface mulch. Dry, hard, fine angular blocky and fine granular 10YR 3/2 clay.
1 - 35 cm	Dry, hard, coarse angular blocky 10YR 3/2 clay; some of the coarse angular blocky aggregates have a platy structure; many fine (up to 1 mm) white calcareous particles and pea iron (up to 2 mm) common number of rather narrow vertical cracks.
35 - 125 cm	Very slightly moist, very hard, massive 10YR 3/2 clay; common number of white soft and hard, calcareous mottles.
125 - 195 cm	Very slightly moist, very hard, massive 10YR 3/1 clay; calcareous mottles as previous layer; clusters of gypsum crystals.
195 - 200^{+} cm	Very slightly moist, very hard, massive 10YR 4/3 clay; abundant gypsum needles; many white calcareous mottles. Horizon below 195 cm is entirely different from the usual subsoil in the clay profiles (see also pit 8131).

Classification : Grumustertic Orthustent.

APPENDIX 2

CHEMICAL ANALYSES RESULTS OF 109 NATURAL HORIZON SAMPLES AND 253 FIXED DEPTH SAMPLES.

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis				Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
7017	0-40	9.75	8.8	4.6	104	17	20	10	53	8.0	34.0	43	79.0
	40-200	9.7	8.9	3.6	153	8	20	9	63	9.4	36.2	61	59.4
7021	0-40	9.47	8.45	0.55	70	8	25	12	55	0.52	13.1	50	26.2
	40-200	9.03	8.15	4.2	88	6	27	9	58	5.5	21.5	53	40.6
7033	0-52	9.8	8.87	0.96	61	15	14	21	50	0.8	21.2	49	43.3
	52-200	9.95	9.25	1.6	121	10	12	18	60	2.7	30.1	58	52.0
7043	0-40	9.22	8.35	0.88	58	19	24	8	49	0.6	11.4	50	22.8
	40-200	9.30	8.46	1.6	74	21	17	11	51	1.5	18.5	51	36.3
7044	0-40	9.10	8.40	0.68	49	23	20	13	44	0.4	11.2	47	23.8
	40-200	9.35	8.15	0.96	72	16	15	10	59	0.7	16.9	60	28.2
7045	0-40	9.70	8.62	0.92	57	18	18	10	54	0.6	16.2	54	30.0
	40-200	9.50	8.90	1.2	72	14	9	13	64	1.1	21.3	64	33.3
7046	0-80	8.20	7.7	0.3	74	8	15	13	64	0.1	3.1	65	4.8
7047	0-40	7.75	6.99	0.34	39	21	45	5	29	0.15	3.0	26	11.5
	60-200	8.53	7.80	1.6	47	18	45	8	29	0.8	5.6	26	21.5
7056	0-50	9.05	8.45	1.5	59	18	23	8	51	1.0	16.6	54	30.7
	50-200	9.26	8.55	3.4	76	13	18	13	56	3.4	22.2	56	39.7
7083	0-26	8.95	7.85	0.44	60	30	13	16	41	0.2	4.6	43	10.7
	26-140	8.90	8.15	2.1	63	22	16	13	49	1.75	11.8	52	22.7
	140-200	9.04	8.20	1.8	77	16	15	13	56	1.54	14.5	55	26.4

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis				Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
7092	0-35	9.40	8.51	0.8	48	37	14	10	39	0.7	8.8	42	21.0
	35-103	9.51	8.97	1.0	60	31	9	11	49	0.7	16.9	54	31.3
	103-200	9.59	8.89	0.96	62	26	9	11	54	0.6	20.2	55	36.7
7100	0-45	9.08	8.26	1.6	57	29	9	16	46	1.15	10.8	47	22.9
	45-200	9.00	8.28	2.8	67	20	13	13	54	2.4	20.8	56	37.2
7104	0-30	8.35	7.92	0.36	61	24	16	11	49	0.3	8.1	54	15.0
	30-136	8.68	8.34	1.95	47	18	20	11	51	1.05	16.5	55	30.0
	136-200	8.88	8.39	1.4	67	19	16	11	54	1.2	18.8	57	32.9
7118	0-38	8.52	8.02	0.72	42	22	18	11	49	0.4	9.2	55	16.7
	38-142	9.00	8.33	1.1	56	24	16	9	51	0.9	12.7	52	24.4
	142-200	8.93	8.40	1.52	77	17	11	11	61	1.5	16.9	60	28.2
7119	0-52	9.37	8.78	2.6	96	8	12	11	69	3.4	31.8	68	46.8
	52-200	9.28	8.82	1.5	108	8	5	16	71	2.2	33.0	74	44.6
8007	0-25	9.25	7.9	0.27	49	39	12	11	38	0.2	4.6	39	11.8
	25-60	9.42	8.37	0.42	48	30	18	12	40	0.3	9.3	38	24.4
	60-140	9.5	8.4	2.4	60	30	3	14	53	2.4	18.0	47	38.3
8018	0-20	9.62	8.55	0.54	56	12	24	19	45	0.4	15.6	44	35.5
	20-140	9.3	8.35	3.8	67	11	35	11	43	4.0	22.8	43	53.0
	140-200	8.7	8.1	6.4	67	11	25	9	55	7.6	20.8	50	41.6
8035	0-23	9.02	8.48	2.4	61	9	14	15	62	1.8	18.6	61	30.5
	23-67	9.02	8.42	7.6	69	7	11	15	67	6.4	18.0	65	27.7
	67-200	9.32	8.82	3.6	92	6	7	12	75	3.7	33.5	73	45.8

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis				Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand		Silt	Clay				
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	0.02-0.002 mm	0.002 mm				
8040	0-35	8.15	7.85	0.28	69	9	14	12	65	0.3	3.7	64	5.8
	35-160	8.31	7.88	1.3	71	7	11	15	67	1.1	12.5	66	18.9
8038	0-25	7.99	7.55	0.44	72	6	7	15	72	0.4	8.4	70	12.0
	25-145	8.35	7.72	1.8	73	8	7	18	67	1.6	13.4	66	20.3
8050	0-25	8.88	8.42	0.75	43	20	18	15	47	0.3	11.7	50	23.4
	25-90	9.55	9.12	1.16	72	14	11	15	60	0.5	28.7	59	48.6
	90-165	9.19	9.07	1.3	99	10	13	12	65	1.0	29.0	65	44.6
8056	0-75	8.05	7.95	0.42	29	23	57	5	15	0.15	2.2	17	12.9
	75-115	8.28	8.03	0.6	33	21	52	7	20	0.25	1.4	20	7.0
	115-200	8.71	8.62	1	28	21	52	7	20	0.35	2.0	20	10.0
8068	0-15	8.17	7.82	0.46	52	21	24	14	41	0.25	4.5	43	10.4
	15-33	8.90	8.22	0.75	51	18	22	11	49	0.5	11.5	52	22.1
	33-59	9.18	8.42	1.2	54	18	15	16	51	0.8	15.2	51	29.7
	59-85	8.71	8.48	1.4	61	17	18	11	54	0.9	17.5	54	32.4
	85-110	8.88	8.48	1.3	73	15	15	11	59	1.45	20.1	58	34.6
	110-200	9.00	8.45	1.3	71	17	18	11	54	1.2	20.4	55	37.1
8069	0-60	8.39	7.86	0.9	68	10	20	11	59	0.8	12.4	59	21.0
	60-125	7.75	7.59	3.8	76	10	18	11	61	3.8	16.2	60	27.0
	125-200	8.05	7.70	3.2	86	6	14	11	69	3.5	18.1	69	26.2
8078	0-80	6.09	4.39	0.18	17	62	23	1	14	0.02	0.8	16	5.0
	80-150	5.36	4.04	0.12	21	52	28	1	19	0.03	0.8	18	4.4
	150-200	6.19	4.55	0.18	21	44	36	4	16	0.03	0.8	17	4.7

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis				Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
8084	0-20	8.61	8.04	0.55	50	22	6	16	56	0.4	6.8	55	12.4
	20-45	8.96	8.28	0.95	51	12	31	8	49	0.64	9.0	52	17.3
	45-70	8.75	8.20	2.4	66	21	12	8	59	2.0	20.8	60	34.6
	70-95	8.83	8.35	2.6	70	6	24	14	56	2.3	19.3	63	36.4
	95-120	8.81	8.45	1.9	78	8	25	11	56	1.8	16.6	60	27.6
	120-145	8.82	8.36	1.6	100	8	20	11	61	2.0	18.0	59	30.6
8085	0-3	7.33	7.40	0.75	38	25	30	19	26	0.96	0.2	24	0.8
	3-33	7.99	7.72	0.44	50	18	22	14	46	0.19	2.2	50	4.4
	33-50	8.75	7.75	0.78	51	23	20	11	46	0.5	6.3	59	12.9
	50-75	8.70	8.25	1.3	63	25	13	13	49	1.0	13.0	51	25.5
	75-100	8.80	8.20	2.0	64	21	19	11	49	1.7	15.5	52	29.8
	100-125	8.81	8.20	2.4	71	26	12	11	51	2.1	16.3	52	31.3
	125-150	8.64	8.21	2.8	72	14	19	11	56	2.5	15.1	60	25.2
8089	0-6	7.79	7.35	0.2	84	5	23	6	66	0.02	1.6	65	2.5
	6-40	8.05	7.70	0.26	100	4	16	11	69	0.25	4.5	68	6.6
	40-140	8.30	7.80	1.0	68	7	13	14	66	0.7	10.1	64	15.8
	140-200	8.25	7.70	1.1	78	9	14	13	64	0.97	8.6	66	13.0
8095	0-100	8.06	7.60	9.0	36	48	15	16	21	0.58	1.8	20	9.0
	150-200	7.95	7.58	4.0	41	38	10	6	46	0.7	2.5	50	5.0
8107	0-20	8.09	7.9	0.55	43	21	14	15	50	0.42	0	52	0
	20-40	8.89	8.32	0.8	55	21	14	15	50	0.7	7.7	50	15.4
	40-65	8.85	8.3	1.4	55	17	13	13	57	0.83	14.8	53	27.9
	65-90	7.08	8.42	1.2	59	20	15	13	52	1.02	13.0	49	26.5
	90-115	9.13	8.48	1.56	70	16	12	12	60	1.05	16.1	54	29.8
	115-140	8.41	7.9	1.4	73	6	14	13	67	1.1	8.5	70	12.2

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis				Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand		Silt	Clay				
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	0.02-0.002 mm	0.002 mm				
8117	0-5	8.22	7.89	0.62	70	14	9	20	57	0.35	0.05	59	0.1
	5-40	9.2	8.32	0.73	58	16	7	12	65	0.56	17.8	69	25.8
	40-80	8.3	8.03	2.8	67	9	14	15	62	2.5	14.3	64	26.2
	80-125	8.62	8.08	0.85	66	7	11	15	67	0.66	8.1	63	12.9
8124	0-25	8.92	8.36	5.0	76	11	20	9	60	4.85	15.5	53	29.2
	25-45	8.93	8.32	3.4	74	9	19	10	62	3.5	18.1	56	32.3
	45-75	8.98	8.38	3.1	74	2	24	8	66	2.6	21.4	58	36.8
	75-105	8.95	8.37	2.3	94	4	19	12	65	2.8	21.2	54	39.2
8128	0-20	8.82	8.39	1.3	61	0	28	27	45	0.9	13.1	49	26.7
	20-45	9.76	9.34	8.0	63	0	13	25	62	7.1	38.9	55	70.7
	45-85	9.81	9.67	10.8	74	0	13	30	57	12.4	43.6	57	76.5
	85-125	9.65	9.48	9.0	84	0	30	10	60	10.6	49.4	57	86.7
8131	0-20	8.32	7.9	0.42	117	0	28	12	60	0.43	0.4	62	0.6
	20-40	8.72	7.98	0.51	77	0	25	13	62	0.38	4.0	63	6.4
	40-75	8.8	8.28	1.1	74	0	23	15	62	0.92	10.7	65	16.5
	75-110	8.47	7.92	3.6	75	0	20	15	65	3.18	12.8	68	18.8
8134	0-35	8.42	7.93	0.42	64	6	29	13	52	0.24	0.2	54	0.4
	35-65	8.8	8.23	0.65	64	6	29	11	54	0.56	6.6	56	12.2
	65-95	8.41	7.97	2.3	64	4	26	10	60	1.9	10.1	60	16.8
	95-125	8.35	7.86	3.2	72	1	27	12	60	2.9	12.3	55	22.4

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
7001	0-90	46	14	40	0.82	46	0.60	7.8	19.5	B 1.3
7002	"	59	6	35	0.18	38	0.10	1.1	3.1	B 2.3
7003	"	39	11	50	3.96	82	4.20	27.0	54.0	B 1.2a
7004	"	59	11	30	0.60	37	0.20	3.4	11.3	B 2.3
7005	"	44	11	45	0.39	53	0.12	7.5	16.7	B 1.3
7006	"	39	11	50	5.20	85	6.40	31.6	63.2	B 1.2a
7007	"	24	16	60	3.60	81	4.30	26.9	44.8	B 1.2a
7008	"	39	11	50	1.82	85	2.40	27.2	54.4	B 1.2a
7009	"	34	13	53	1.04	79	0.98	19.0	35.8	B 1.2a
7010	"	41	14	45	0.25	49	0.10	2.7	6.0	B 1.1
7011	"	29	16	55	1.00	64	0.44	18.0	32.7	B 1.2a
7012	"	39	11	50	4.00	78	4.30	16.5	33.0	B 1.2a
7013	"	31	14	55	1.70	70	1.40	18.6	33.8	B 1.2a
7014	"	21	19	60	5.30	80	5.70	31.9	53.1	B 1.2a
7015	"	24	16	60	7.20	88	8.70	33.3	55.5	B 1.2a
7016	"	29	16	55	7.50	70	6.90	28.3	51.4	B 1.2a
7017	"	26	14	60	2.98	121	5.00	33.4	55.6	B 1.2a
7018	"	34	13	53	1.75	50	0.10	16.3	30.7	B 1.4
7019	"	49	13	38	4.50	92	5.10	34.5	90.7	B 1.2a
7020	"	24	16	60	0.92	68	0.32	13.3	22.1	B 1.2a
7021	"	34	11	55	1.70	70	1.30	12.3	22.3	B 1.2a
7023	"	49	13	38	1.98	51	1.20	10.4	27.3	B 1.4
7024	"	44	13	43	0.65	52	0.25	6.5	15.1	B 1.4
7025	"	24	16	60	1.42	59	0.81	11.2	18.7	B 1.2a
7026	"	41	14	45	0.96	63	0.30	15.3	34.0	B 1.2a
7027	"	31	14	55	0.43	61	0.10	7.1	12.9	B 1.4
7028	"	24	21	55	1.56	72	0.51	33.1	60.1	B 1.2a
7029	"	59	6	35	1.04	52	0.24	9.4	26.8	B 1.4
7030	"	29	13	58	1.65	66	1.18	16.8	28.9	B 1.2a
7031	"	29	13	58	1.15	58	0.63	12.2	21.0	B 1.3
7032	"	36	14	50	2.50	62	1.7	14.3	28.6	B 1.3
7033	"	31	19	50	0.84	64	0.30	20.5	41.0	B 1.2a
7034	"	24	16	60	2.22	99	2.50	28.7	47.8	B 1.2a
7035	"	36	14	50	1.8	62	1.23	13.2	26.4	B 1.2a
7036	"	44	11	45	0.74	72	0.00	14.8	32.9	B 1.2a
7037	"	25	12	63	1.30	81	1.42	10.2	16.2	B 1.2a

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0–0.02 mm.	Silt 0.02–0.002 mm.	Clay 0.002 mm.						
7038	0-90	35	12	53	3.00	78	1.10	21.3	40.1	B 1.2a
7039	"	28	19	53	3.40	75	3.50	22.1	41.7	B 1.2a
7040	"	20	17	63	1.14	67	1.02	23.78	37.7	B 1.2a
7041	"	18	16	66	2.55	78	1.56	46.4	70.3	B 1.2c
7042	"	15	19	66	7.00	76	7.30	31.9	48.3	B 1.2a
7043	"	43	11	46	0.38	60	0.30	13.3	28.9	B 1.2a
7044	"	43	14	43	0.76	70	0.70	12.5	29.7	B 1.2a
7045	"	38	14	48	0.92	55	0.54	17.5	36.4	B 1.2a
7046	"	24	15	61	0.22	73	0.18	2.6	4.3	B 1.1
7047	"	65	7	28	0.80	47	0.41	5.2	18.5	B 2.2
7048	"	43	14	43	3.00	69	2.80	13.2	30.7	B 1.2a
7049	"	38	14	48	0.84	63	0.80	16.8	35.0	B 1.2a
7050	"	45	22	33	3.20	70	3.00	9.0	27.3	B 1.2a
7051	"	40	12	48	1.60	67	1.50	15.7	32.7	B 1.2a
7052	"	30	14	56	1.48	75	1.30	22.7	40.5	B 1.2a
7053	"	33	14	53	1.50	65	1.22	14.0	26.4	B 1.2a
7054	"	30	12	58	3.20	72	3.10	17.7	30.5	B 1.2a
7055	"	20	14	66	2.10	76	2.10	25.5	38.6	B 1.2a
7056	"	40	12	48	2.10	87	2.40	19.6	40.8	B 1.2a
7057	"	18	21	61	2.20	73	2.10	28.5	46.7	B 1.2a
7058	"	15	12	73	4.00	80	4.2	30.2	41.4	B 1.2a
7059	"	20	12	68	5.80	81	6.5	40.5	59.6	B 1.2a
7060	"	18	16	66	6.00	87	6.7	13.3	20.1	B 1.2a
7061	"	65	9	26	2.44	38	1.24	28.4	100	B 1.2a
7062	"	35	12	53	1.28	90	1.36	27.0	51.0	B 1.2a
7063	"	35	12	53	0.90	62	0.48	21.9	41.2	B 1.2a
7064	"	28	9	63	1.50	67	0.99	25.4	40.3	B 1.2a
7065	"	28	11	61	2.52	72	1.89	27.7	45.4	B 1.2a
7066	"	38	9	53	2.20	71	1.96	32.4	61.0	B 1.2a
7067	"	13	16	71	6.0	73	5.6	31.2	43.9	B 1.2a
7068	"	18	14	68	6.0	70	5.8	31.8	46.8	B 1.2a
7069	"	15	12	73	3.40	92	4.35	30.8	42.2	B 1.2a
7070	"	35	14	51	1.52	63	1.10	22.5	44.1	B 1.2a
7071	"	38	11	51	2.10	65	1.62	15.2	29.8	B 1.2a
7072	"	28	16	56	1.02	68	0.75	29.6	52.8	B 1.2a
7073	"	30	14	56	1.88	70	1.40	20.6	36.8	B 1.2a

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
7074	0-90	25	17	58	1.90	80	1.60	27.2	46.9	B 1.2a
7075	"	24	13	63	2.20	95	1.86	33.3	52.9	B 1.2a
7076	"	43	11	46	0.92	59	0.58	10.6	25.8	B 1.2a
7077	"	20	12	68	1.98	73	1.82	25.0	36.8	B 1.2a
7078	"	15	14	71	3.0	83	3.10	24.5	34.5	B 1.2a
7079	"	43	11	46	1.70	63	1.28	16.7	36.3	B 1.2a
7080	"	40	14	46	1.36	61	0.92	18.3	39.8	B 1.2a
7081	"	33	11	56	0.88	73	0.72	17.3	30.9	B 1.2a
7082	"	24	13	63	1.0	105	1.06	15.3	24.3	B 1.2a
7083	"	45	12	43	0.85	59	0.52	6.7	15.6	B 1.2b
7084	"	43	11	46	1.30	66	0.66	3.3	7.2	B 1.2b
7085	"	43	11	46	1.20	54	0.54	13.1	28.4	B 1.2b
7086	"	33	14	53	1.15	57	0.64	9.4	17.7	B 1.2b
7087	"	35	12	53	1.12	55	0.42	8.4	15.9	B 1.2b
7088	"	35	12	53	1.70	55	0.70	10.9	20.6	B 1.2b
7089	"	20	12	68	3.20	103	3.60	32.4	47.6	B 1.2b
7090	"	30	12	58	2.10	63	1.40	16.2	27.9	B 1.2b
7091	"	20	14	66	2.00	82	1.94	23.3	35.0	B 1.2b
7092	"	50	12	38	0.84	49	0.24	9.4	24.8	B 1.2b
7093	"	35	12	53	1.10	64	0.72	12.5	23.6	B 1.2b
7094	"	40	9	51	1.55	67	1.10	9.3	18.3	B 1.2b
7095	"	40	12	48	1.30	57	0.42	14.0	29.2	B 1.2b
7096	"	38	16	46	1.10	57	0.28	12.9	28.0	B 1.2b
7097	"	33	11	56	1.12	64	0.48	16.3	29.1	B 1.2b
7098	"	33	11	56	0.85	60	0.45	8.3	14.8	B 1.2b
7099	"	30	12	58	1.40	60	0.76	10.0	17.2	B 1.2b
7100	"	35	14	51	0.96	53	0.26	12.1	24.3	B 1.2b
7101	"	43	14	43	1.70	59	0.95	4.6	10.7	B 1.2b
7102	"	33	14	53	2.40	63	1.75	6.6	12.5	B 1.2b
7103	"	45	9	46	0.40	51	0.13	2.3	5.0	B 1.3
7104	"	45	12	43	1.00	53	0.46	12.7	29.5	B 1.2b
7105	"	65	7	28	8.50	35	0.35	0.4	1.4	A 2
7106	"	23	14	63	3.30	54	2.00	19.6	31.1	B 1.2b
7107	"	28	11	61	1.35	67	0.84	14.4	23.6	B 1.2b
7108	"	8	11	81	3.20	83	3.10	14.9	18.4	B 1.3
7109	"	63	6	31	0.60	44	0.17	7.8	25.2	B 2.2

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
7110	0-90	30	12	58	0.60	57	0.14	3.1	5.4	B 1.3
7111	"	68	1	31	0.42	45	0.00	1.2	3.9	A 2
7112	"	13	11	76	1.60	55	0.68	5.7	7.5	B 1.3
7113	"	55	7	38	0.44	44	0.12	1.9	5.0	B 2.2
7114	"	70	4	26	0.18	31	0.00	0.8	3.1	B 2.2
7115	"	50	12	38	0.80	54	0.40	7.2	18.9	B 1.2b
7116	"	38	11	51	1.40	56	0.90	10.7	21.0	B 1.2b
7117	"	20	22	58	2.60	72	2.40	27.2	46.9	B 1.2b
7118	"	33	14	53	0.90	52	0.53	9.5	17.9	B 1.2b
7119	"	25	24	51	2.20	78	2.30	33.3	65.3	B 1.2b
7120	"	28	9	63	0.96	70	0.52	31.9	50.6	B 1.2b
8001	"	41	14	45	5.4	77	5.2	24.4	54.2	B 1.2a
8002	"	31	11	58	5.9	89	6.7	24.5	42.2	B 1.3
8003	"	36	14	50	1.15	58	0.7	8.9	17.8	B 1.3
8004	"	34	13	53	1.32	90	1.28	26.7	50.4	B 1.2a
8005	"	31	14	55	1.80	70	1.4	21.8	39.6	B 1.2a
8006	0-25	64	12	24	0.40	37	0.1	1.1	4.6	B 1.1
8007	0-90	49	11	40	0.56	47	0.28	6.9	17.3	B 1.4
8008	"	89	1	10	1.80	24	0.03	1.17	11.7	B 2.2
8009	"	30	6	64	1.08	42	0.4	8.00	26.7	B 1.3
8010	"	34	13	53	1.22	56	0.42	10.4	19.6	B 1.3
8011	"	39	16	45	2.30	77	1.73	11.9	26.4	B 1.2a
8012	"	51	9	40	2.10	52	1.04	9.36	23.4	B 1.2a
8013	"	31	14	55	1.28	60	0.43	8.8	16.0	B 1.3
8014	"	56	9	35	0.60	41	0.00	4.8	13.7	B 1.3
8015	"	26	11	63	0.95	62	0.22	10.6	16.8	B 1.3
8016	"	29	16	55	0.75	68	0.10	8.7	15.8	B 1.3
8017	"	49	11	40	4.5	53	1.5	6.5	16.3	B 1.1
8018	"	44	11	45	1.65	56	0.7	9.7	21.6	B 1.2a
8019	"	51	9	40	3.8	55	2.26	11.3	28.2	B 1.3
8020	"	51	9	40	0.60	58	0.00	6.4	16.0	B 1.2a
8021	"	36	11	53	1.50	61	0.00	16.8	31.7	B 1.2a
8022	"	41	14	45	2.2	67	1.5	15.7	34.9	B 1.2a
8023	"	36	14	50	0.76	62	0.10	9.9	19.8	B 1.1
8024	"	46	11	43	2.60	62	1.54	21.3	49.5	B 1.2a
8025	"	39	11	50	1.18	68	0.57	14.6	29.2	B 1.2a

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
8026	0-90	56	1	43	0.88	39	0.00	5.2	12.1	B 1.1
8027	"	62	7	31	1.70	67	1.34	9.1	29.4	B 1.2a
8028	"	55	4	41	1.50	58	1.02	11.78	28.8	B 1.2a
8029	"	37	14	49	0.75	57	0.42	19.2	39.2	B 1.2a
8030	"	32	12	56	0.70	70	2.4	21.6	38.6	B 1.2a
8031	"	37	12	51	0.76	74	0.74	20.1	39.4	B 1.2a
8032	"	40	14	46	0.65	55	0.41	10.8	23.4	B 1.2a
8033	"	32	14	54	1.00	58	0.72	13.3	24.6	B 1.2a
8034	"	17	19	64	4.50	79	0.52	49.1	76.6	B 1.2c
8035	"	25	14	61	3.40	77	4.15	24.6	40.3	B 1.2a
8036	"	25	14	61	0.80	65	0.66	7.7	12.6	B 1.3
8037	"	20	14	66	0.92	69	0.70	14.9	22.6	B 1.2a
8038	"	25	6	69	0.65	70	0.52	11.5	16.7	B 1.2a
8039	"	25	9	66	0.65	68	0.51	12.3	18.6	B 1.2a
8040	"	30	1	69	0.36	66	0.25	6.9	10.0	B 1.3
8041	"	35	4	61	1.80	70	1.60	15.2	24.9	B 1.2a
8042	"	42	4	54	2.30	59	1.76	16.6	30.7	B 1.2a
8043	"	37	7	56	1.90	61	1.54	12.1	21.6	B 1.2a
8044	"	30	4	66	2.80	65	2.44	20.0	30.3	B 1.2a
8045	"	30	1	69	1.90	74	1.66	29.5	42.8	B 1.2a
8046	"	12	4	84	5.00	87	5.50	32.9	39.2	B 1.2a
8047	"	40	1	59	2.70	66	2.30	22.1	37.4	B 1.2a
8048	"	45	1	54	2.40	59	1.48	17.3	32.0	B 1.2a
8049	"	30	4	66	2.80	76	2.84	31.2	47.2	B 1.2a
8050	"	40	4	56	1.30	52	0.78	16.8	30.0	B 1.2a
8051	"	17	4	79	3.30	83	1.32	29.9	37.8	B 1.2a
8052	"	22	7	71	3.20	46	2.06	55.5	78.0	B 1.2a
8053	"	27	2	71	4.40	77	5.00	44.0	62.0	B 1.2a
8054	"	40	6	54	1.08	61	0.76	13.6	25.2	B 1.2a
8055	"	40	4	56	1.30	77	1.34	16.3	29.1	B 1.2a
8056	"	76	7	17	0.32	27	0.68	1.7	10.0	A 2
8057	"	30	6	64	1.90	71	1.76	18.2	28.4	B 1.2a
8058	"	32	2	66	2.50	56	2.40	14.4	21.8	B 1.2a
8059	"	37	7	56	1.00	80	0.90	1.91	34.1	B 1.2a
8060	"	38	10	52	0.84	65	0.32	18.5	35.6	B 1.2a
8061	"	48	10	42	1.30	56	0.84	10.4	24.8	B 1.2a

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
8062	0-90	35	11	54	2.20	72	2.10	17.9	33.1	B 1.2a
8063	"	20	13	67	2.60	97	3.40	28.6	42.7	B 1.2a
8064	"	25	11	64	1.30	88	1.10	30.1	47.0	B 1.2a
8065	"	40	11	49	2.60	66	2.50	19.1	39.0	B 1.2a
8066	0-85	55	21	24	0.70	44	0.22	4.6	19.2	A 2
8067	0-90	18	10	72	0.50	68	0.25	10.9	15.1	B 1.3
8068	"	38	10	52	1.40	57	1.00	10.6	20.4	B 1.2a
8069	"	30	11	59	2.20	66	1.73	9.5	16.1	B 1.3
8070	"	35	8	57	1.30	58	0.94	11.5	20.2	B 1.2a
8071	"	45	8	47	1.10	59	0.74	10.5	22.3	B 1.2b
8072	"	48	10	42	0.68	49	0.24	9.4	22.4	B 1.2b
8073	"	43	5	52	0.60	57	0.29	5.3	10.2	B 1.2b
8074	"	30	11	59	0.75	64	0.56	8.2	13.9	B 1.2b
8075	"	45	6	49	0.69	58	0.36	6.8	13.9	B 1.2b
8076	"	50	8	42	0.90	54	0.54	8.3	19.8	B 1.2b
8077	"	53	8	39	1.00	47	0.36	11.6	29.7	B 1.2b
8079	"	45	11	44	1.10	38	1.90	7.7	17.5	B 1.2b
8080	"	20	11	69	0.92	68	0.50	16.3	23.6	B 1.2b
8081	"	33	5	62	1.10	71	0.54	17.9	28.8	B 1.2b
8082	"	18	15	67	2.80	84	3.20	26.4	39.4	B 1.2b
8083	"	23	18	59	2.00	75	1.50	28.5	48.2	B 1.2b
8084	"	38	10	52	1.20	60	0.82	8.8	16.9	B 1.2b
8085	"	45	11	44	0.70	58	0.37	2.0	4.6	B 1.2b
8086	"	33	10	57	2.20	68	1.88	10.1	17.7	B 1.2b
8087	"	23	10	67	1.50	69	1.20	15.6	23.3	B 1.2b
8088	"	20	11	69	1.60	64	1.20	16.4	23.8	B 1.3
8089	"	23	10	67	0.38	68	0.17	6.6	9.9	B 1.3
8090	"	35	13	52	1.20	63	0.87	13.9	26.7	B 1.2b
8091	"	38	8	54	1.28	64	0.64	18.2	33.6	B 1.2b
8092	"	18	10	72	0.70	81	0.51	9.1	12.7	B 1.3
8093	"	20	36	44	1.10	56	0.42	12.4	28.2	B 1.2c
8094	"	23	5	72	1.30	68	0.84	20.8	28.9	B 1.3
8095	"	65	16	19	15.0	32	0.56	1.4	7.4	A 2
8096	"	43	8	49	1.50	54	0.40	10.4	21.2	B 1.2b
8097	"	28	15	57	1.50	58	0.72	14.5	25.5	B 1.2b
8098	"	63	5	32	0.65	47	0.23	8.6	26.8	B 1.2b
8099	"	53	8	39	0.65	51	0.32	7.3	18.7	B 1.2b

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.						
8100	0-90	34	13	53	0.42	60	0.22	5.8	11.0	B 1.2b
8101	"	34	13	53	2.90	58	2.10	13.5	25.4	B 1.2b
8102	"	37	10	53	2.40	69	1.90	19.3	36.4	B 1.2b
8103	"	39	10	51	1.80	58	1.30	15.5	30.4	B 1.2b
8104	"	24	18	58	1.48	67	0.10	15.9	27.4	B 1.2c
8105	"	14	15	71	1.70	75	1.50	19.7	27.8	B 1.2b
8106	"	29	13	58	0.55	64	0.32	14.1	24.3	B 1.3
8107	"	22	17	61	1.20	63	0.96	17.4	28.5	B 1.2c
8108	0-45	17	17	66	3.20	87	3.70	16.7	25.3	B 1.2b
	45-90	42	12	46	4.90	65	3.90	14.1	30.6	B 1.2b
8109	0-45	22	15	63	1.14	71	1.07	13.3	21.1	B 1.2b
	45-90	22	15	63	1.60	69	1.30	12.7	20.2	B 1.2b
8110	0-90	44	10	46	0.75	60	0.38	6.0	13.0	B 1.2b
8111	"	39	13	48	0.70	59	0.44	10.0	20.8	B 1.2b
8112	"	24	15	61	1.05	58	0.72	11.3	18.5	B 1.2b
8113	"	24	15	61	1.70	70	1.20	15.6	25.6	B 1.2b
8114	"	17	15	68	0.95	67	0.68	20.1	29.6	B 1.3
8115	"	19	15	66	1.05	68	0.76	11.2	17.0	B 1.3
8116	"	32	12	56	1.10	59	0.74	18.1	32.3	B 1.2c
8117	"	32	7	61	0.92	60	0.60	20.6	33.8	B 1.2b
8118	"	19	10	71	2.00	79	1.87	15.7	22.1	B 1.2a
8119	"	84	3	13	0.24	22	0.55	0.6	4.6	B 2.3
8120	"	44	13	43	0.40	52	0.20	3.8	8.8	B 1.4
8121	"	22	15	63	1.80	77	1.64	14.4	22.8	B 1.2a
8123	"	79	5	16	0.62	28	0.17	3.0	18.8	A 2
8124	"	29	8	63	4.30	58	3.10	30.5	48.4	B 1.2a
8125	"	34	10	56	3.10	74	2.60	27.8	49.6	B 1.2a
8126	"	27	15	58	3.60	94	4.20	30.2	52.1	B 1.2a
8127	"	27	10	63	2.30	94	2.60	36.6	58.1	B 1.2a
8128	"	14	18	68	8.40	67	7.60	48.4	71.2	B 1.2a
8129	"	19	15	66	3.60	78	3.7	21.1	32.0	B 1.2c
8130	"	19	15	66	2.50	73	2.1	13.1	19.9	B 1.3
8131	"	22	17	61	1.10	73	0.91	7.9	13.0	B 1.3
8132	"	34	13	53	1.40	65	0.98	9.0	17.0	B 1.3
8133	"	37	10	53	0.42	62	0.15	7.8	14.7	B 1.3
8134	"	29	13	58	1.32	65	0.97	12.6	21.7	B 1.3

APPENDIX 3

NAMES, COTTON YIELDS AND SIZES OF PUMP SCHEMES

Cotton Yields

Name of pump scheme	Yield of cotton in kantars/feddan								Average Area in feddan
	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	
1 El Mamoun	-	-	-	-	2.0	4.7	2.6	0.9	60
2 Rabak	-	-	-	5.4	4.9	7.0	5.9	5.5	150
3 Hilat Abas	-	-	-	-	-	-	0	-	200
4 El Omara	-	-	-	3.9	2.1	2.0	-	2.3	150
5 Khor Agwal	-	-	-	4.2	5.4	6.5	6.7	6.9	400
6 El Makhada	-	-	-	-	-	-	1.7	3.6	200
7 El Abyad	-	-	-	3.4	4.7	4.6	4.1	4.1	400
8 El Hideib North	-	-	-	2.3	3.5	4.5	1.3	1.1	200
9 El Hideib	-	-	-	2.0	7.0	6.3	5.0	5.4	68
10 El Bahya	-	-	-	0.8	1.7	2.1	3.7	2.4	400
11 El Zeif	-	-	-	1.1	2.2	2.3	3.7	1.3	400
12 El Aradeeb	-	-	-	3.6	2.6	5.2	4.2	2.5	300
13 El Amal	-	-	-	1.2	3.3	6.0	4.7	3.0	200
14 Sharat	-	-	-	4.1	6.2	8.0	5.7	7.5	400
15 El Islah	-	-	-	2.9	3.7	7.3	4.0	2.4	300
16 Tabat	-	-	-	-	-	-	-	-	150
17 Taxabon	-	-	-	-	-	-	-	-	400
18 El Marwa	-	-	-	3.7	7.7	7.8	6.8	5.2	200
19 Um Kwayka	-	-	-	2.6	2.5	6.4	4.9	4.0	60

Cotton Yields (Cont.)

Name of pump scheme	Yield of cotton in kantars/feddan								Average Area in feddan
	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	
20 Awlad Abas	-	-	-	3.4	2.4	3.9	-	1.6	60
21 Aradil El Jebelein	-	-	-	2.2	2.8	4.7	4.2	2.9	160
22 Nyefr	-	-	-	2.2	3.5	4.2	4.7	2.2	3,000
23 Mehd El Sharief I	-	-	-	4.2	3.1	6.2	3.1	2.0	150
24 Mehd El Sharief II	-	-	-	5.3	6.9	9.9	5.2	5.2	300
25 El Makhalif	-	-	-	1.3	3.1	5.9	2.5	2.4	68
26 El Furat	-	-	-	-	-	-	0.7	0	300
27 Abu Ramad	-	-	-	1.0	3.2	5.0	1.1	1.9	150
28 El Adara	-	-	-	3.2	3.8	6.2	4.7	2.0	300
29 El Magabi	-	-	-	2.7	5.0	5.3	2.8	2.0	500
30 El Warad	-	-	-	3.2	2.2	6.4	4.1	3.5	300
31 Debat Basin	-	-	-	3.2	6.0	6.7	6.0	2.0	400
32 El Alagaya	-	-	-	2.8	2.1	3.9	3.9	4.1	300
33 El Gama'a	-	-	-	1.2	3.0	5.4	2.8	3.5	500
34 Mona	-	-	-	6.7	7.4	6.8	5.2	4.3	300
35 El Adl	-	-	-	6.8	11.2	5.7	7.0	3.3	150
36 Goda	-	-	-	3.7	2.7	4.8	4.2	0.8	5,000
37 Goz Fami	4.3	2.0	2.6	4.8	4.4	5.3	3.6	1.4	290
38 Halaka	5.5	2.4	3.3	5.8	5.7	7.5	6.7	2.2	557

Cotton Yields (Cont.)

	Name of pump scheme	Yield of cotton in kantars/feddan								Average Area in feddan
		56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64	
39	Remeila North	-	-	-	-	1.0	7.7	7.5	4.0	203
40	Remeila	6.4	3.6	7.2	6.7	6.1	7.8	5.5	3.1	571
41	Remeila West	-	-	7.4	6.3	1.0	5.4	2.5	3.7	45
42	Tayba	5.7	3.0	4.9	4.2	3.8	6.0	5.7	4.1	741
43	Birkat el Agab	3.2	3.8	5.6	5.3	5.1	4.5	4.6	2.5	4,973
44	Geigar	4.8	2.9	3.8	4.3	3.4	4.5	5.0	3.3	980
45	Magara	3.8	2.4	2.2	4.0	4.5	5.8	4.1	4.0	540
46	Karshwal	-	2.2	-	-	-	-	-	-	25
47	Abu Kadra	-	-	-	-	4.5	3.9	2.6	5.2	3,250
48	Fiawar North	3.7	4.1	6.6	2.8	5.3	5.4	4.2	3.7	670
49	Fiawar South	2.6	1.9	3.0	1.3	3.8	1.9	2.5	2.6	206
50	Khor el Agazi	-	-	-	-	-	4.2	3.8	2.8	157
51	El Warrad	-	-	-	3.3	2.9	4.0	3.6	1.1	57
52	Bandit	3.3	4.1	2.2	2.2	3.3	6.1	5.9	2.2	354
53	Latbiour	-	-	4.1	3.2	-	4.1	4.6	1.5	530
54	Majak	3.8	3.2	-	3.4	2.8	3.2	3.2	1.7	230
55	Debat Alali	-	-	-	-	-	1.9	-	1.2	615

Notes:
1. The pump schemes are listed in order of occurrence from North to South along the White Nile.
2. Schemes nos. 48-55 are South of Renk.
3. 1 kantar = 44.9 kg ginned cotton.

APPENDIX 4

RESULTS OF 22 PERMEABILITY TESTS.

PERMEABILITY TEST RESULTS

Site	Texture	Clay%	Layer in cm.	K in m per day	Soil Type
7021	clay	58	65-105	0.008	Very dark grey clay
7033	do.	60	50- 90	0.001	do.
7043	do.	51	60-110	0.0006	do.
7044	do.	59	50- 90	0.003	do.
7045	do.	64	60-100	0.002	do.
7047	sandy clay loam	29	80-120	0.033	Soil of sandy ridge
7056	clay	56	52- 92	0.002	very dark grey clay
7092	do.	49	50- 90	0.001	do.
7100	do.	54	55- 95	0.003	do.
7104	do.	51	45- 85	0.002	do.
7118	do.	51	59-102	0.002	do.
8007	do.	53	60-115	0.010	brown clay
8018	sandy clay	43	60-100	0.009	very dark grey clay
8035	clay	75	62-107	0.002	do.
8040	do.	67	60-100	0.064	brown clay; cracks ?
8050	do.	60	63-103	0.0003	very dark grey clay
8068	do.	57	55-100	0.010	do.
8069	do.	61	55-111	0.024	brown clay; cracks ?
8084	do.	56	60-105	0.005	very dark grey clay
8085	do	49	57-107	0.008	do.
8089	do.	66	67-107	0.031	brown clay
8107	do.	52	60-100	0.004	very dark grey clay

APPENDIX 5

COMMENTARY ON PHOTO INTERPRETATION MAP OF WHITE NILE EAST BANK BETWEEN RENK AND JEBEL AHMED AGHA

COMMENTARY ON PHOTO INTERPRETATION MAP OF WHITE NILE EAST BANK BETWEEN RENK AND JEBEL AHMED AGHA.

1. Definition of the area

The interpreted region is part of area 5B. Due to flooding and political disturbances field work in area 5B could not take place south of Renk. Therefore photo interpretation has been carried out in order to obtain some general information about the land south of Renk. The White Nile Bank south of Jebel Ahmed Agha being regularly flooded, it was decided that the photo interpretation could be confined to the area between Renk and Jebel Ahmed Agha. The eastern boundary of the interpreted region is defined by the extent of the photo cover or the survey limit as marked on the mosaic, whichever is nearer to the river.

2. Purpose and limitations of the photo interpretation map

The photo interpretation map serves a three fold purpose:

a) It shows areas which can be immediately excluded from field investigation (e. g. the "toich" land and the dissected meander belt).

b) It gives a general picture of the topography (ridges, drainage pattern). Access to the area is indicated by roads and traces.

c) It may help in a more accurate delineation of soils when future field observations show that a certain interpretation boundary coincides with a soil boundary.

It must be borne in mind that aerial photo interpretation is only a minor part of the procedure which eventually results in a soil map. A photo interpretation map therefore, although a useful means, can never replace a soil map.

The accuracy of the interpretation map has been adversely affected by the poor quality of the mosaic. In particular on mosaic sheet No. 25 identical points may be as far apart as one cm (which would be 500 m in the field).

3. The landscape

By and large the interpreted area is morphologically very similar to the one between El Jebelein and Renk: a uniform, flat plain sloping to the east very gently as is indicated by the position of the 20 m isopotamon. Immediately south of Renk the isopotamon swings to the east and then remains roughly parallel to and well away from the river.

The monotony of the landscape is only interrupted by a few irregularities such as the ridges near Renk and Gelhak and the pinnacle like rock-outcrop Jebel Ahmed Agha.

Most of the plain is covered with scrub of considerable density, but grassland also occurs especially near the river. It is likely that most of this grassland is a result of human activity as is demonstrated by the numerous burning patterns. It may well be on the other hand that part of the grassland along the eastern boundary is natural rather than the result of fire.

The scrubland is intensively utilised by man for woodcutting and grazing.

Only 7 sizable pump schemes occur between Renk and Debbat Al'al and there are no more between them and the Government pump scheme at Melut well to the south.

Two river terraces are supposed to occur, if indeed they are terraces because they are only slightly lower than the adjacent land. A familiar phenomenon are the "debbats" low, isolated mounds, a short distance from the river, although they are less abundant here than in the northern area.

Two shallow depressions, presumably old infilled river channels or creeks could be delineated, the southernmost of the two, apart from being in a lower position, seems to have a slightly irregular surface relief.

An unusual element in the landscape is formed by the Khor Doleib. Apparently this little river has cut its way through the V-shape ridge near Renk and subsequently produced a relatively extensive meanderbelt plus a very distinct delta at its confluence with the Nile.

A few small areas are shown on the map which do not differ topographically from their environment but only in photo pattern (kind and/or density of vegetation). It is possible that these patterns are due to human interference as they occur along inland roads.

Although no specific statements can be made regarding the soils, it may be safely assumed that the plain in the interpreted area is predominantly clay. In the land between Rabak and Renk about 75 per cent of all sites have a clay percentage exceeding 50 but only by a fairly small amount, whereas the surroundings of Melut (Soil Survey Report of Melut-East Pump scheme by F.H. Beinroth) are reported to have an average clay content of 75.8 per cent. It is conceivable that owing to the presence of the sandy debbats a lower average clay percentage prevails in sites near the river, but the influence of the debbats would be confined to a fairly narrow strip along the Nile. This should be considered when evaluating the sites analysed in the Sir A. Gibb report. It is also justifiable to assume that the trend towards a lower overall alkalinity as observed in the southern part of the Rabak-Renk region, will continue in the interpreted area. Beinroth (see above) found an average exchangeable sodium percentage of 6.1 in the top 60 cm for the clays of the Melut-East Pump Scheme, but this may be due to the slightly elevated position of the Melut Pump Scheme.

APPENDIX 6

NOTES ON THE PROJECT LANDS FROM RENK to MELUT

by

DR. ROBERT SMITH

NOTES ON THE PROJECT LANDS FROM RENK TO MELUT

by

Dr. Robert Smith

I. Method of Appraisal

Because high river levels had caused flooding on the access road south of Renk, the field inspection of the project area was confined to the Rabak-Renk sector of about 620,000 feddans. Although it was not possible for the field survey parties to carry out an exploratory survey of the Renk to Melut sector of the project area, an attempt was made to delineate the areas which might be irrigated there.

The general method of appraisal involved an office study of all existing data including recent air photographs, photo mosaics, maps, survey department cross sections and the 1953 Report and maps of Sir Alexander Gibb and Partners. This study was strengthened by an aerial inspection of the whole project area from Rabak to Melut and return, on 23 February 1965.

The soil analyses presented in the 1953 report of Sir Alexander Gibb and Partners were examined carefully and reinterpreted in the light of Sudanese and international research findings over the past ten years. An attempt was made to correlate the soil characteristics as shown by clay content, total soluble salts on 1:5 suspension, and Sodium Value with the Roseires soil survey specifications based on clay content, E.C. on soil paste, and Exchangeable Sodium Percentage (E.S.P.). An approximation from the Gibb' data then enabled us to make a rough evaluation of the project area soils for cotton and other crops according to the specifications agreed with the World Bank in August 1964.

An examination of the records of flow in the White Nile also yielded useful information. Since 1962 increased overflow from the Central African lakes has each year raised the level of the White Nile.

The Malakal hydrograph shows that in November-December 1964 and part of January 1965 the river level remained steady at the unprecedented high level of 14.4 metres on the gauge (389.5 metres above mean sea level at Alexandria) as compared with the 30 year (1918-47) average maximum of 12.3 metres in November. This high river level has caused extensive flooding of riverain lands on both sides of the river from Melut to Renk as seen by the aerial inspection party on 23/2/1965. The records show that the minimum river level is also higher; in 1964 the minimum river level, in May, was 11.6 metres on the Malakal gauge as compared with the 30 year (1918-47) average minimum of 10.05 metres in April. These sustained high river levels have adversely affected lateral drainage into the White Nile. From Khor Bibban southwards, the khors draining from the Ethiopian foothills have caused extensive flooding on the plain because their outfall is blocked. In February 1965 it was observed that huts in the erstwhile permanent village of Paloich were standing in about one metre of floodwater and that the inhabitants had left for higher ground.

II. The Defining of Irrigable Areas

From Rabak to Renk the eastern boundary of the project area is defined mostly by the 20 metre isopotamon which here lies on a well-defined escarpment delimited by the 390 and 405 metre contours. At Jebel Nyefr, Jebelein and Renk this high ground lies within 5 kilometres of the river but between these localities it recedes to the eastwards to form embayments which, between Jebelein and Geigar, attain in places a maximum width of 25 kilometres.

South of Renk this escarpment swings away south-eastwards and then parallels the White Nile at a distance of about 30 kilometres to the vicinity of Jebel Jogdeid where it turns eastwards towards the foot of the Ingessana hills. About two-thirds of the eastern boundary of the project

area between Renk and Gelhak lies at the specified distance of 25 kilometres from the White Nile.

South of Gelhak a major topographic obstacle appears in the Khors Bibban and Mariok which enter the White Nile from the southeast. The present extensive flooding in all the khors from Jebel Achmed Agha southwards to Melut limits the project area here to a few islands of high ground, the largest of which lie within the Melut bend of the White Nile and include the existing Melut pump project. See figures 16 and 17 in the text of the Report.

III. The Project Area from Renk to Gelhak

As mentioned above, about two-thirds of the eastern boundary of the project area between Renk and Gelhak lies at the specified distance of 25 kilometres from the White Nile. To the north, the eastern boundary is formed by the escarpment at the edge of higher ground which approaches to within four kilometres of the White Nile opposite the town of Renk. The southern boundary of this rather compact block of about 400,000 feddans lies on the Khor Bibban which flows from south east to north west to join the White Nile between Gelhak and Jebel Achmed Agha.

This Section of the project area is in Upper Nile Province. Renk is the largest town in the area and is the administrative headquarters for the district. Adjacent to the river there are eight small pump irrigation schemes growing long staple cotton, within 36 kilometres of Renk. Further south there are few villages near the river until one reaches the trading station at Gelhak. South of Gelhak the road to Paloich is now impassable because of flooding at the crossing of the Khor Bibban and at other khors further south. The reason for the lack of population in the project area between Renk and Gelhak is that the local population prefer to live on the higher ground about 20 to 30 kilometres to the east

of the river where living conditions are healthier, especially in the wet season. The subsistence economy of the people is based on the possession of cattle and other livestock and on a system of shifting cultivation whereby sufficient grain for their needs is produced during the wet season when about 500 to 600 mm. of rain is received in the project area.

The exploratory type of soil survey carried out by Sir A.Gibb & Partners in 1951-53 provides useful information about the soil pattern in the project area. The maps at scale 1:25,000 show the following soil groups and sub-groups :-

1. On the Present Flood Plain of the White Nile

(i) Clays and silts of the seasonally inundated "toich" lands.

(ii) Clays frequently underlain by sand, at a slightly higher level than the "toich" lands, and often carrying vegetation of Acacia woodland or grassland.

(iii) Sandy clays and sandy loams of aggraded banks of river and drainage channels, ridges and islands, at the time of the Gibb's survey above flood level and usually carrying a vegetation of Acacia woodland or scrub, sometimes interspersed with grassland.

(iv) Soils of drainage areas, usually occupying small areas at the upper edge of the flood plain.

From Renk to Banga, a distance of about 43 kilometres, the present flood plain is bounded on the east side by the channel of the Wadi Gasir el Abyad, the northern part of which is permanently flooded. As a result of their surveys Sir A. Gibb & Partners selected here a number of small areas of land totalling 1220 feddans for development as small pump schemes for cotton production. The Consultants recognised the difficulty of access to these areas but considered that, under the conditions existing at the time, no serious developmental problems were

likely to arise. The unprecedented rise in Nile levels since 1962 has undoubtedly altered the picture; much of the "toich" land is now permanently flooded, some of the higher lands are affected by flooding, and access to the highest parts of the flood plain is undoubtedly more difficult than it was in 1951-53. Under these circumstances one doubts whether any areas on the flood plain should be developed for cotton cultivation although the conditions might be suitable for other crops such as rice or jute.

2. On River Terraces Adjacent to the Flood Plain

This high ground forms a zone of varying width up to 4 Km. wide which carries the road from Renk to Gelhak and on which are located the riverain towns and villages of the project area. The air photographs clearly show the presence of old river channels and other features of an old flood plain, now well above the highest flood levels of the river. The survey cross-sections show a topography of banks and intervening swales with variations in altitude of about 2 to 3 metres. The Gibb's soil maps show a broad pattern of clays with grassland and sometimes with Balamites woodland at the lower levels, interspersed with higher areas of sandy clays and sandy loams carrying a vegetation of acacia woodland in the north and broad leaved woodland in the south.

Most of the 13,400 feddans of land selected by the Consultants for irrigated cotton development lie in this zone, close to suitable pump sites near the river. The soils are variable but the Consultants showed an obvious preference for the clay soils of the old channels and backwaters, where available. The large area (6,600 feddans) near Banga village has the most typical of the soils of the river terrace zone. Of the six sites sampled two could be classified as land class 2, two as land class 3a, one as land class 6s (T.S.S. = 0.73%) and one, on higher ground as land class 3 l. These analyses show that the clay soils are generally well suited to cotton cultivation and that the coarser textured soils could be

used for climatically adapted crops other than cotton. We consider that this area should be covered by semi-detailed soil survey.

3. On Lake Deposits at a Higher Level than the River Terraces.

This level plain area, lying mostly between the 386 and 390 metre contours, was probably once the bed of an extensive lake into which the White Nile discharged, together with local drainage systems. The soil pattern is shown on the Gibb's soil maps as sandy clays and sandy clay loams underlain by clay, with occasional strips of clays and sandy clays of drainage channels. The vegetation associated with these soils is mostly acacia woodland and scrub with occasional areas of Balanites woodland or grassland. The plain is described in general terms as having light textured soils which in some parts are remarkably hard and compacted, while in others they are friable and very uneven with numerous holes and depressions. In some parts a surface deposit of quartz sand is common. The total salt content and sodium value in these soils are generally low and high salinity does not appear to be a problem. They are not cultivated extensively.

An interpretation of the 47 soil analyses, in the light of the land class specifications agreed with the World Bank in August 1964, gives the following picture :-

Approx. Land Class	Per Cent of Sites
2	4
3a	2
3 1	17
3a1	43
4 1	19
6a	15
	100

In view of the dominance of land classes 3a1, 3 1, and 4 1, one would expect that the land is not very suitable for long staple cotton because of the correlation between clay content and cotton yields worked out for the Dueim and Gezira areas by Finck & Ochtman. In

view of the low salinity and moderate alkalinity, however, the lands should be regarded as potentially suitable for other climatically adapted crops under irrigation as follows :-

(i) Fibre crops such as jute, kenaf, sunn hemp, roselle and selected strains of short and medium staple cotton.

(ii) Cereal crops such as dura, dukhn, rice, maize and introduced sorghums and millets.

(iii) Oilseeds such as groundnuts, sesame, safflower, castor, sunflower and possibly soyabeans

(iv) Fodders such as lubia, phillipesara, clitoria, guinea grass and sudan grass.

(v) Pulses such as pigeon pea, cowpea and lubia

(vi) Garden crops such as onions, garlic, chillies, tomatoes and melons.

(vii) Industrial crops such as sugar cane, tobacco and forest plantations.

(viii) Fruits such as mangoes, bananas, citrus and guavas.

We consider that these lands should be covered by semi-detailed soil survey.

Table I, which follows, gives an approximate land classification of all 61 soil sample sites in the Renk to Gelhak area.

TABLE I. Approximate Land Classification of 61 Sites in the Renk to Gelhak Area.

Site No.	Approximate Land Class (U.S.B.R. Standards)
ME 35	3 al
" 36	3 al
" 37	3 al
" 38	4 l
" 39	3 al/6a
16E 1	3 al
" 2	3 al
" 3	3 al/6a
" 4	3 a
" 5	3 al/6a

Site No.	Approximate Land Class (U.S.B.R. Standards)
17E 1	3 1
" 2	3 al
" 3	4 1/6a
" 4	3 al
" 5	3 al
" 6	6 a
ME 40	4 1
" 41	4 1
" 42	4 1
" 43	3 1
" 44	3 1
" 45	4 1
" 46	3 1
" 47	3 1
18E 1	3 1
" 2	3 1
" 3	3 1
" 4	4 1
" 5	3 al
" 6	3 al
" 7	3 al/6a
19E 1	3 al
" 2	2
ME 48	4 1
" 49	4 1
" 50	6 s
" 51	4 1
20E 1	3 1
" 2	2
" 3	2
" 4	3 al
" 5	3 al
" 6	3 al
21E 1	2
" 2	3 a
" 3	2
" 4	3 al
ME 52	3 a
" 53	4 1
" 54	2
" 55	3 a
" 56	2
23E 1	2
" 2	3 al
" 3	3 al/6a
ME 57	3 al
24E 1	3 al
" 2	4 1
" 3	3 al
" 4	3 al
" 5	6 a

IV. The Project Area from Gelhak to Melut

This part of the project area forms part of a vast lowland plain, subject to inundation, which extends unbroken from the White Nile to the Ethopian foothills. The Consultants pointed out in 1953 that, owing to the flat topography and the large areas which lie below the high flood level of the White Nile, seasonal flooding and waterlogging occur and for this reason large areas were regarded as unsuitable for irrigation development. Since 1962, the unprecedented high level of the White Nile has aggravated the drainage problem and lands that in 1951-53 were seasonally flooded are now more or less permanently inundated. Because of the extensive flooding in all the knors from Jebel Achmed Agha southwards to Melut the irrigable lands in this sector are limited to a few islands of high ground within the Melut bend of the White Nile including the existing Melut pump project.

This section of the project area, lying in Upper Nile Province, is peopled largely by Dinkas whose largest villages are in the Paloich-Melut area. The Dinka depend for their livelihood mostly on cattle and other livestock, but in the better drained parts of Melut district good crops of dura are grown when the distribution of rainfall is satisfactory.

Melut is the only sizeable town and is the administrative centre of the district. Nearby is the government pump irrigation project of 10,000 feddans built in 1962 to produce long staple cotton, on the recommendation of the Gibbs' report of 1953. Since the road to the north and to the south has been cut by flood waters Melut has been dependent on the river steamers for its communications and supplies.

The maps of Sir A. Gibb & Partners show that sandy clay and sandy clay loam soils, similar to those in the Renk-Gelhak sector, extend southwards from Jebel Achmed, Agha to about latitude $10^{\circ}37\frac{1}{2}'$ north. These lands are in the extensively flooded zone and, because of the poor drainage, they are considered unsuitable for irrigation development.

Within the Melut bend of the White Nile there is a well defined ridge of somewhat higher ground. Melut town and the pump installations of the government irrigation project lie on the highest parts of this low ridge which also carries the Melut - Paloich road for much of its length. The ridge has a comparatively steep southern slope facing the White Nile and the Khor Katalok. To the north, however, the slope is more gradual, resulting in an area of somewhat higher land about 10 to 12 kilometres wide. This are itself is crossed by a number of drainage channels which cut it into smaller segments which have been designated as blocks W37, W38, W39, W40, W41 and W42 by Sir A.Gibb & Partners. The total gross irrigable area of these blocks is 53,560 feddans.

The soils are described as follows :-

"The physical and chemical characteristics of the soils in the district are remarkably uniform. They are deep, heavy, grey to dark grey clays of sub-group 4a. Large deep cracks form during the dry season and they become hard and compacted with a cloddy structural form. The analysis of 24 representative samples taken from soil pits in these areas showed the following results :- clay percentage ranged from 59 to 84 (average 74), total salt percentage ranged from 0.04 to 0.20 (average 0.07) and sodium value ranged from 4 to 15 (average 11). Owing to the flat totopraphy, the impermeable nature of the soils and the fairly high annual rainfall (650 millimetres), flooding and waterlogging occur in low lying sites during the wet season. This fact has necessitated the exclusion of much land otherwise suitable for irrigation"

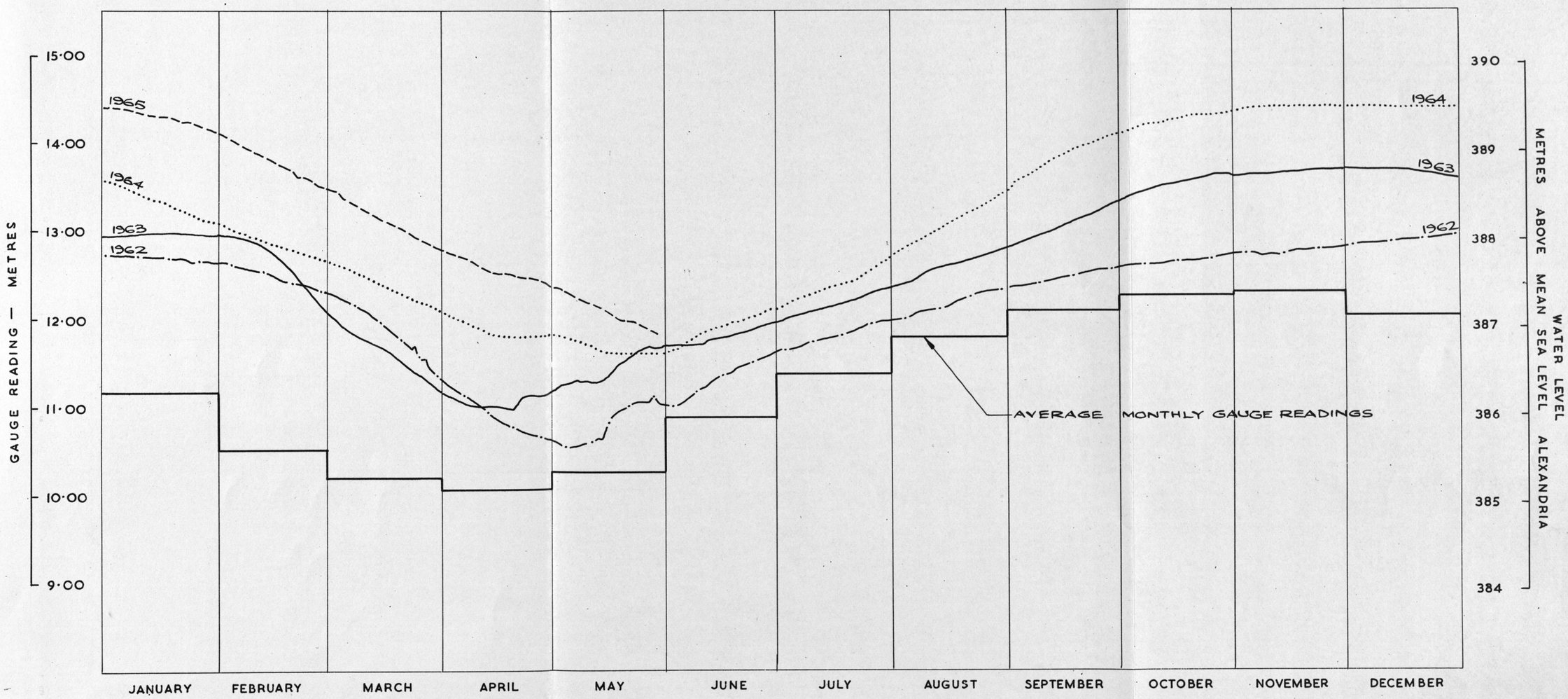
The Gibbs soil maps show the irrigable areas to be mostly under natural grassland, cultivated in places, but with some Balanites open woodland to the north of block W39.

Our examination of the soil analyses shows them to be soils of high clay content, non-saline and non-alkali. If soil structure and drainage status were similar to that of the Gezira plain we should classify the

land as belonging to land class 2. Because of drainage limitations, however, which can only be accurately assessed by field examination, we consider that the sites would fall within the range of land classes 3d, 4d and 6d.

The Gibb's report identifies a number of good pump sites and suggests that one of the areas near Melut should be developed as a pilot project with the purpose of carrying out further agricultural research into suitable cropping patterns for the irrigable lands in the Melut bend. The report points out that in these southern areas where more humid conditions prevail and where flooding occurs due to the poor drainage then pests, weeds and diseases may be limiting factors in the economic production of long staple cotton and, should this prove to be the case, it was suggested that rice be grown as an alternative crop. We endorse these views and recommend that agricultural research work should be carried out at the Melut government pump irrigation project with the view to testing climatically adapted crops other than long staple cotton such as rice, jute, kenaf, sunn hemp, dura, maize, introduced sorghums and millets, fodders, sugar cane, vegetables and fruits.

We consider that about 60,000 feddans of land in the Melut bend should be covered by a semi-detailed soil and land classification survey.



NOTE

1. THE HYDROGRAPHS FOR 1962, 1963, 1964 AND 1965 (TO MAY ONLY) ARE BASED ON DAILY GAUGE READINGS.
2. THE AVERAGE MONTHLY GAUGE READINGS WERE OBTAINED USING THE MONTHLY RECORDS FOR THE 30 YEAR PERIOD 1918–1947.
3. THE ZERO OF THE MALAKAL GAUGE IS 375·11 ABOVE MEAN SEA LEVEL ALEXANDRIA AND THE KHARTOUM GAUGE ZERO IS 363·00

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE
ROSEIRES SOIL SURVEY

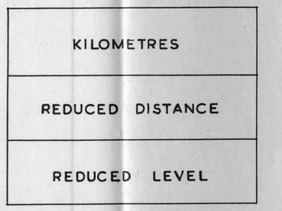
HYDROGRAPH FOR MALAKAL

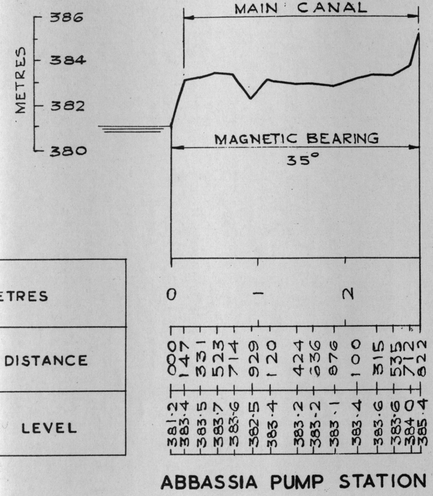
SIR M.MACDONALD
& PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON W.C.1

SCALES
AS SHOWN

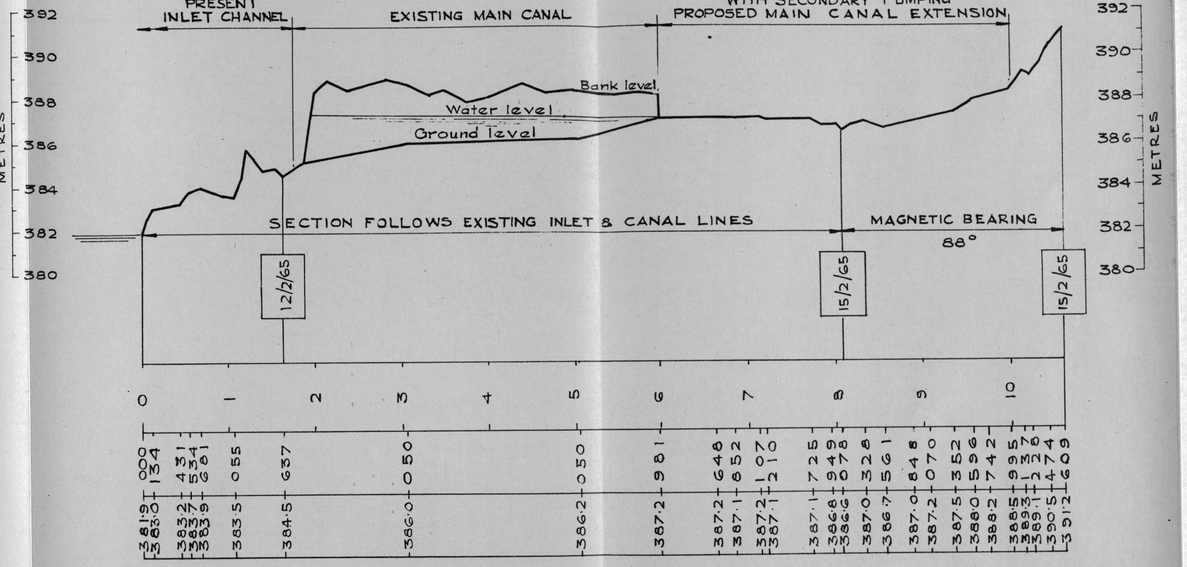
DRG. No. SU 213
DATE: NOV; 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 11





ABBASSIA PUMP STATION



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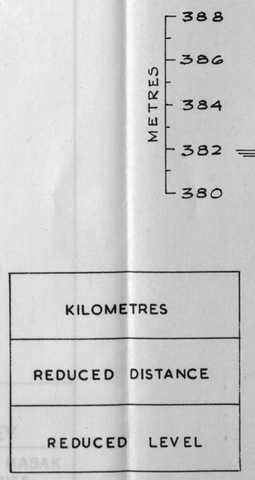

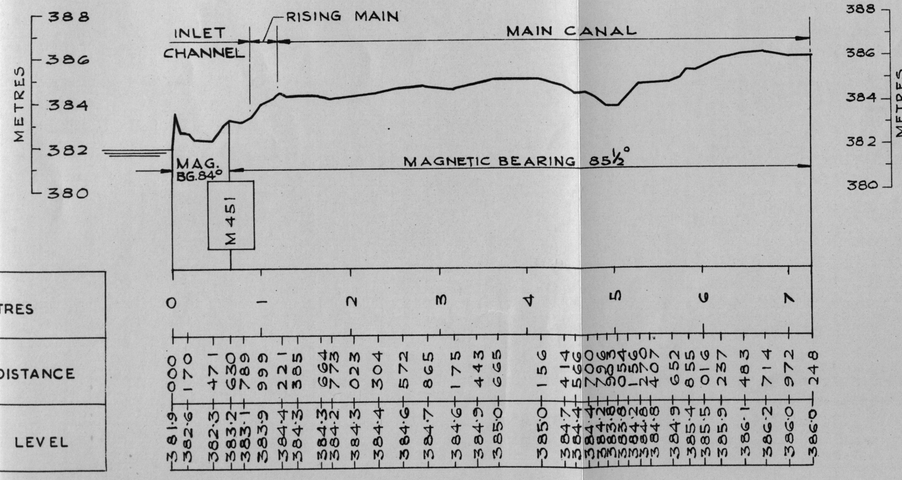

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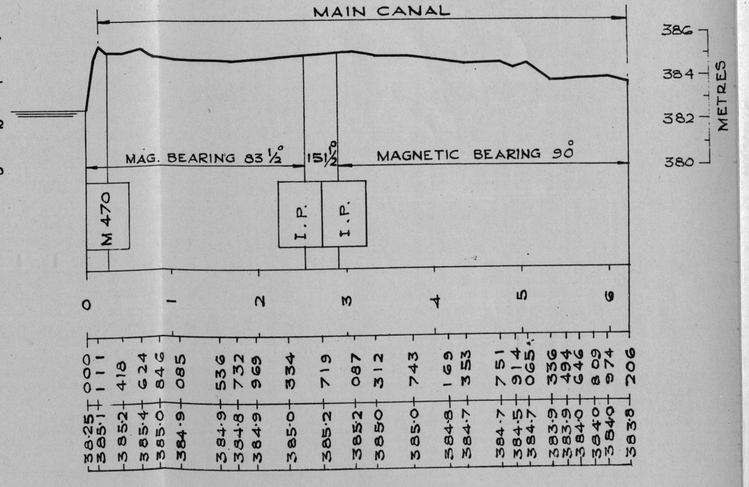
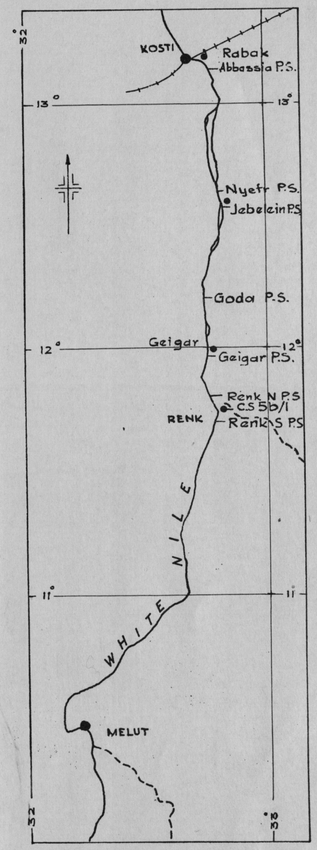


GODA PUMP STATION



KEY PLAN
SCALE:- 1:2,000,000

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE
ROSEIRES SOIL SURVEY

WHITE NILE EAST BANK, MELUT TO RABAK
RECONNAISSANCE SURVEY LINES
FOR PUMP CHANNELS

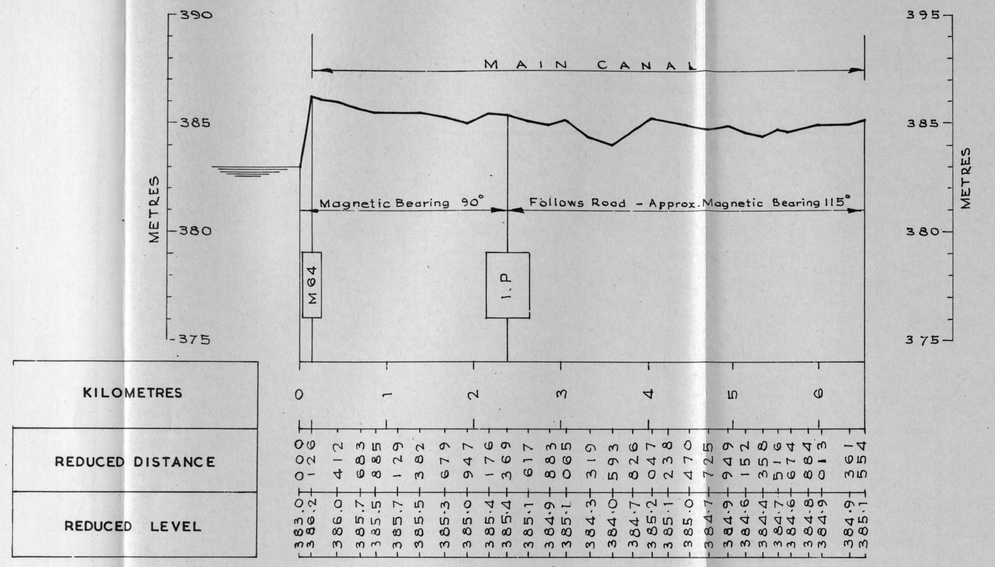
SIR M. MACDONALD
& PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON W.C.1

SCALE
AS SHOWN

DRG. No. SU 215

DATE: NOV. 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 11



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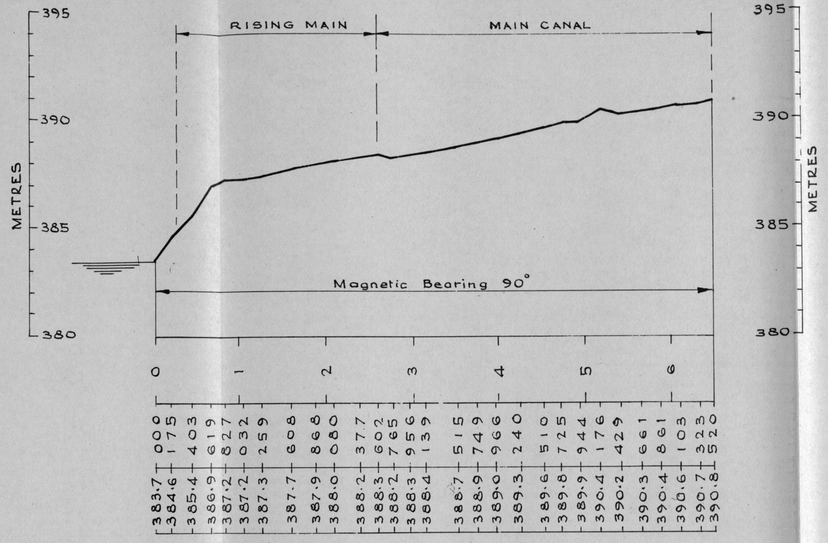

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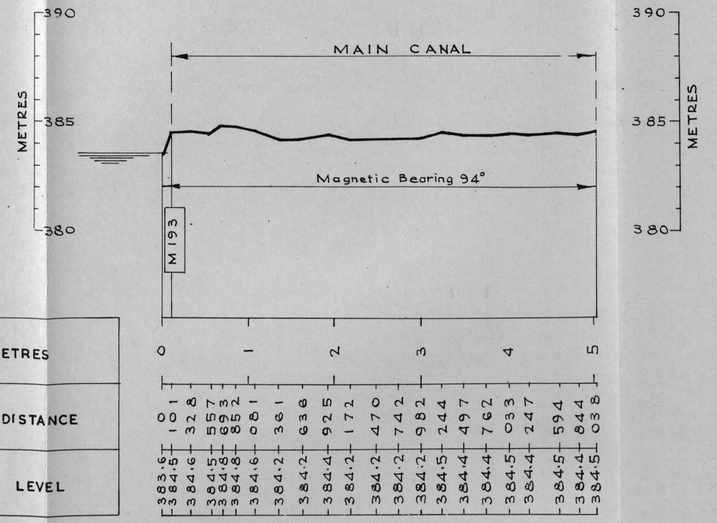

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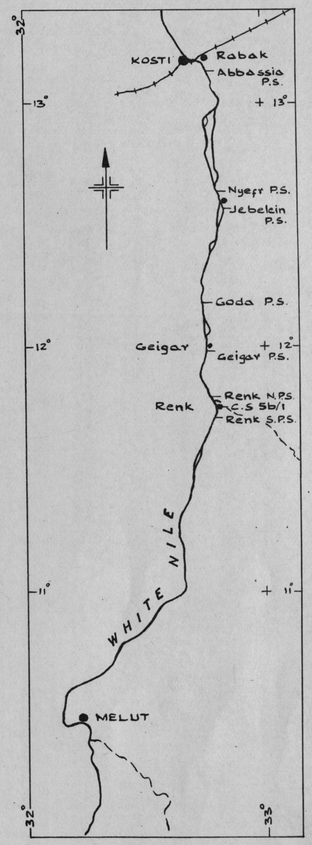


KEY PLAN
SCALE:- 1: 2,000,000

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE
ROSEIRES SOIL SURVEY

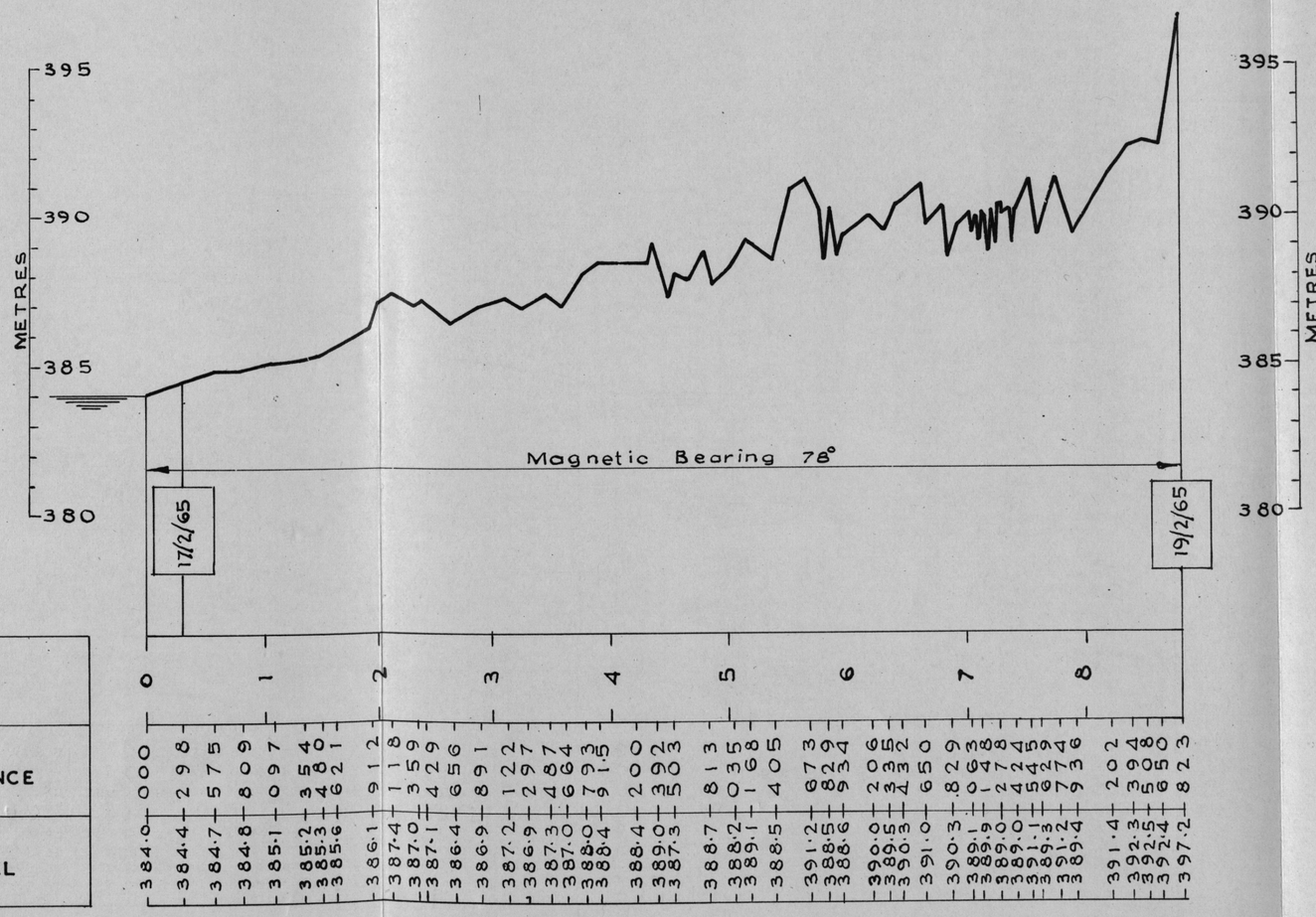
WHITE NILE EAST BANK, MELUT TO RABAK
RECONNAISSANCE SURVEY LINES
FOR PUMP CHANNELS

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

SCALE
AS SHOWN

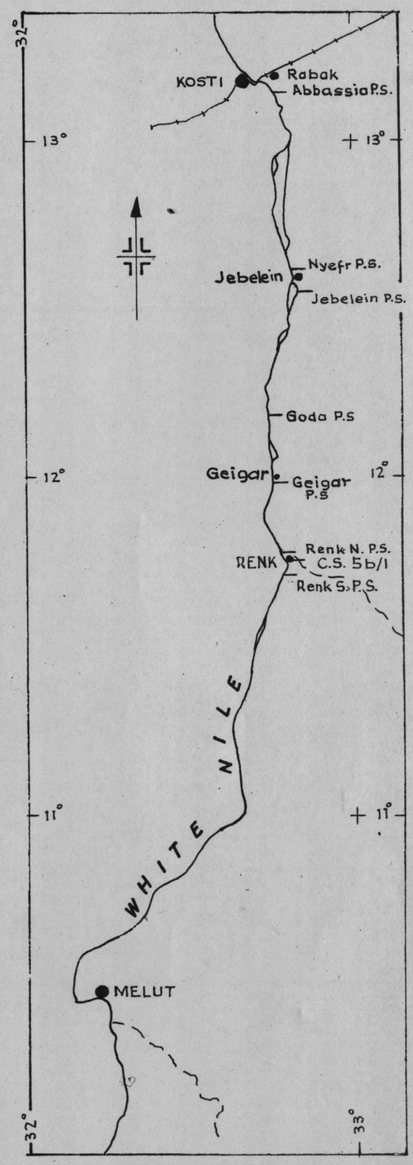
DRG. No. SU 217

DATE: NOV, 1965



KILOMETRES	0	000	1	912	2	824	3	736	4	648	5	560	6	472	7	384	8	296
REDUCED DISTANCE	384·0	384·4	384·7	384·8	385·1	385·2	385·3	385·6	386·1	387·4	387·0	387·1	386·4	386·9	387·2	386·9	387·3	387·0	388·0	388·4	388·4	389·0	387·3	388·7	388·2	389·1	388·5	391·2	388·5	388·6	390·0	389·5	390·3	391·0	390·3	389·1	389·9	389·0	391·1	389·3	391·2	389·4	391·4	392·3	392·5	392·4	397·2
REDUCED LEVEL	298	575	809	097	354	480	621	912	118	359	429	656	891	122	297	487	664	793	915	200	392	503	813	035	168	405	673	824	934	206	335	432	650	829	063	148	278	424	592	746	736	202	398	550	823

SECTION 5b/1



KEY PLAN
Scale 1 : 2,000,000

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
WHITE NILE EAST BANK, MELUT TO RABAK RECONNAISSANCE SURVEY SECTION 5b/1	
SIR M. MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON-W.C.1	SCALE AS SHOWN DRG. No. SU 216 DATE: NOV; 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 11