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THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

ROSEIRES SOIL SURVEY

REPORT No. 10

DINDER TO RAHAD
EXPLORATORY SOIL TRAVERSES

AND

EXTENSIONS TO RAHAD PROJECT
EXPLORATORY ENGINEERING SURVEYS

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

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
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JULY 1965

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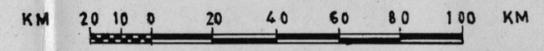
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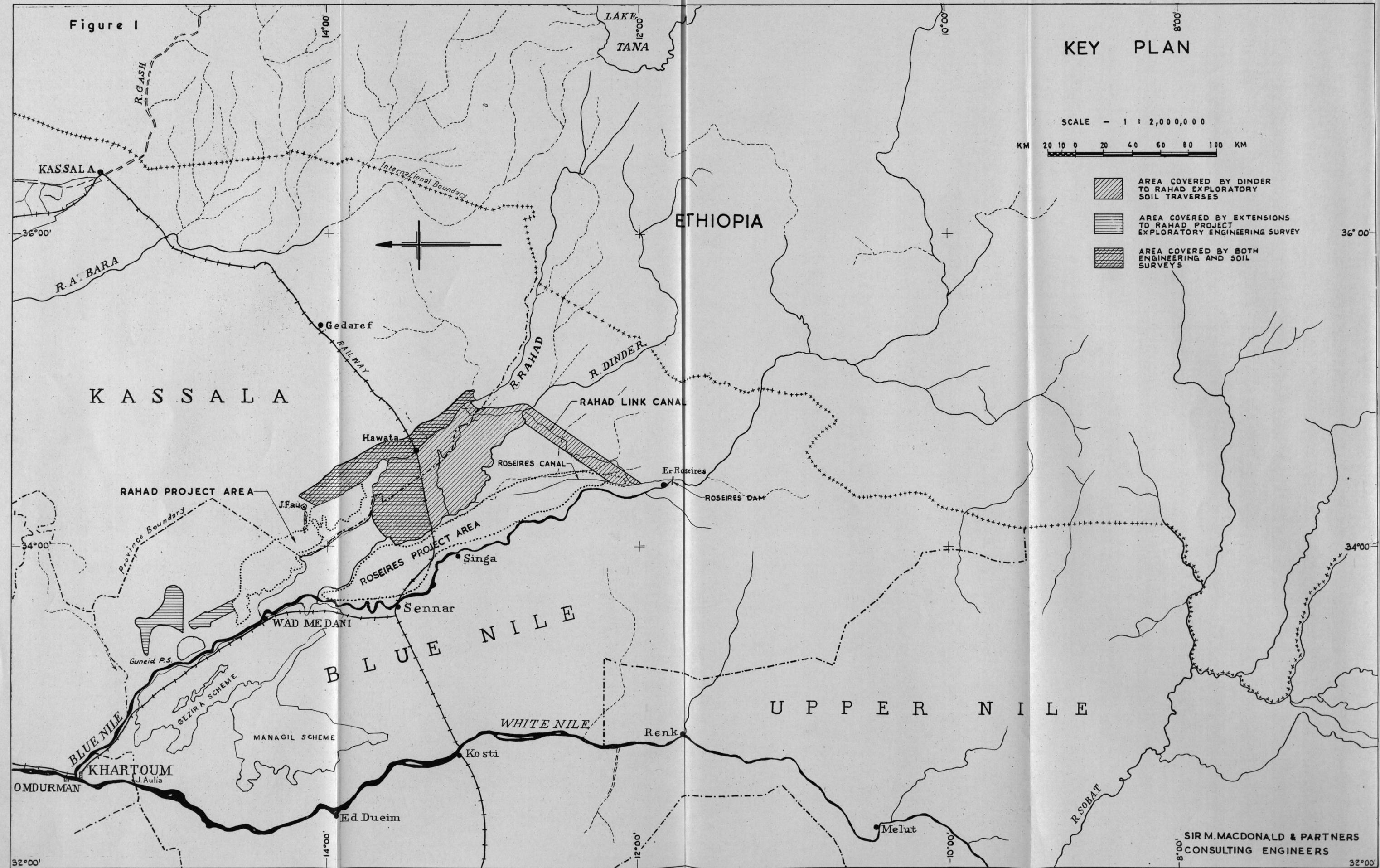
Figure 1

KEY PLAN

SCALE - 1 : 2,000,000



-  AREA COVERED BY DINDER TO RAHAD EXPLORATORY SOIL TRAVERSES
-  AREA COVERED BY EXTENSIONS TO RAHAD PROJECT EXPLORATORY ENGINEERING SURVEY
-  AREA COVERED BY BOTH ENGINEERING AND SOIL SURVEYS



SIR M. MACDONALD & PARTNERS CONSULTING ENGINEERS

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CHAPTER I

SUMMARY

1.1 The project area covered an area of approximately 2 million feddans, and completed the survey of irrigable land on the Blue Nile east bank. To the west and north the land has been surveyed, on the east is high ground, and to the south is the game-reserve.

INTRODUCTION

1.2 The area is underlain by Umm Ruwaba series, with surface deposits of alluvium. The abundant khor running through the area, associated with the rivers Rahad and Dinder, give it a dissected and rolling topography which may be topographically unsuitable for large-scale agriculture. Due to the lack of information, particularly with regard to the suitability and quality of the soils, in an area bounded by high land east of the River Rahad; the eastern boundary of area 2a and the southern boundaries of areas 3b and 3c (extension); and the Dinder game reserve in the south; it was decided to undertake a rapid traverse survey of the area, in order to provide basic information for the evaluation of potential irrigation projects in the Blue Nile basin.

It must be emphasised that the survey was conducted along a series of traverses, (see map at back of report) and whilst the results give some indications of the types of soils encountered, it must not be assumed that the survey constitutes a true reconnaissance or exploratory survey. The density of sampling was only 17 per cent of the accepted limit for a reconnaissance survey.

1.4 The railway line between Addis Ababa and Hawata is an approximate boundary between the Umm Ruwaba series to the north and Acacia savanna to the south. The southern corner of the area is given over to Amharic Combrana. The population of the area is given over to Amharic Combrana. The population of the area is given over to Amharic Combrana.

1.6 In the main agriculture is limited to subsistence farming of dura, (*Sorghum vulgare*), simeim (*Sesamum indicum*), and vegetables on riparian lands. There are two cotton schemes on the Rahad east bank, one north and one south of Hawata.

1.7 The area was surveyed by making use of existing tracks, roads and traces to cover the area as uniformly as possible. Sites were placed at 5 kilometre intervals. Boreas were sampled at fixed depths from 0 to 45 cm, and 45 to 90 cm. Pits were sampled in the same way, and according to natural horizons.

CHAPTER 1

SUMMARY

- 1.1 The project area covered an area of approximately 2 million feddans, and completed the survey of irrigable land on the Blue Nile east bank. To the west and north the land has been surveyed, on the east is high ground, and to the south is the game-reserve.
- 1.2 The area is underlain by Umm Ruwaba series, with surface deposits of alluvial clay. The abundant khors running through the area, associated with the rivers Rahad and Dinder, give it a dissected and rolling relief, which may be topographically unsuitable for large-scale development.
- 1.3 Rainfall increases appreciably in a south-easterly direction, along the line of the river systems, from about 580 mm in the north to approximately 800 mm in the south. (Roseires has an average of 776 mm).
- 1.4 The railway line between El Gueisi and El Hawata is the approximate boundary between Acacia mellifera thornland to the north and Acacia seyal savannah in the south. The south-west corner of the area is given over to Anogeissus-Combretum hartmannianum savannah.
- 1.5 The population is concentrated on the rivers and the Khor Atshan, at perennial watering places. The indigenous population has been gradually infiltrated by 'westerners' from Nigeria and Chad.
- 1.6 In the main agriculture is limited to subsistence farming of dura, (Sorghum vulgare), simsim (Sesamum indicum), and vegetables on riparian lands. There are two cotton schemes on the Rahad east bank, one north and one south of Hawata.
- 1.7 The area was surveyed by making use of existing tracks, roads and traces to cover the area as uniformly as possible. Sites were placed at 5 kilometre intervals. Bores were sampled at fixed depths from 0 to 45 cm, and 45 to 90 cm. Pits were sampled in the same way, and according to natural horizons.

CHAPTER 2

- 1.8 The profiles showed typical montmorillonitic clays, with a sub-angular block top horizon, massive lower horizons and little in the way of colour differentiation. The outstanding feature was the prominence of the 2.5 Y hues, which were very noticeable in the south.
- 1.9 Salinity was negligible throughout the area. E.S.Ps. 's were low in the south, but fairly high in the north, while second horizon values tended to be much higher than the top throughout.
- 1.10 The soils were classified as Vertisols, according to the American 7th Approximation, with one outstanding Entisol.
- 1.11 The land classification was based on the U.S.D.A. system, and the area was mapped according to suitability for further investigation, as indicated by the land classes of individual sites. The following recommendations were made:

Land recommended for semi-detailed survey,

West of the River Rahad, approximately	140,000 feddans
The Rahad east bank	360,000 "
Total:	500,000 feddans

Land recommended for reconnaissance survey,

approximately 1,850,000 feddans.

The region south of the Dinder is almost uninhabited, and roads are absent, apart from the traces on the southern boundary.

The region between the Khor Atshan and the river Dinder is thought to be a high, uninhabited treeless plain. The only track across follows an old Forestry Department trace from Aboda to Guweig. The other villages on the Khor have no direct connection with the Dinder, but follow the graded road between Shamir and Wad el Ageili, and there join the main Hawata - Guweis road.

There are graded roads down both sides of the Dinder, but only as far south as Nur El Gelil on the east bank. The main road runs down the east bank of the Rahad, and on the west bank a road exists north of Hawata. South of the railway line, a trace parallels the Rahad, and

CHAPTER 2

THE ENVIRONMENT

2.1 LOCATION AND GENERAL DESCRIPTION OF THE PROJECT AREA

The western boundary of the area is the River Dinder and the Khor Aqaliyin; the northern boundary, the Khor El Zeraf, a cut-off channel between the Rahad and the Dinder; and the southern boundary, the link-canal trace. To the east, the area extends beyond the River Rahad. It is delineated in the south by the 455.0 metres contour, between the railway line and the Khor Simsim, and north of the railway line, by the East Bank canal, as far as Jebel Fau. The inner boundary of this extension is the survey limit of area 3C (extension). Previous areas of survey enclose the area on the north and west; these are 3C (extension), 3B, 3A and 2A.

The area is a rolling, undulating plain, dissected by abundant khors and old water courses, and probably with severe topographic limitations to development. The rivers Rahad and Dinder are dry throughout the summer, but contain numerous stagnant pools which provide water for the villages. The principal khor is the Khor El Atshan, which rises near the Rahad, runs parallel to it as far as the railway line, and then follows the latter into the Dinder. It holds perennial water and is the water supply of numerous villages on its northernmost stretch. The Khor Aqaliyin on the western boundary also has perennial pools.

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There are graded roads down both sides of the Dinder, but only as far south as Nur El Gelil on the east bank. The main road runs down the east bank of the Rahad, and on the west bank a road exists north of Hawata. South of the railway line, a trace parallels the Rahad, and

connects with the link-canal line, by a system of re-opened Forestry Department traces. North of the railway line, an old Soil Conservation road runs from El Hasira to Dar Chemola, and a track crosses it at Umm Darraga, running from Allatifa to the railway line east of Gueisi.

East of the Rahad, the Gedaref road follows the railway line, and the road to Denabo crosses the area from Tuneidba.

2.2 GEOLOGY AND PHYSIOGRAPHY

2.21 Solid Geology

The area originally took the form of a large depression in Basement Complex material. This still constitutes the solid geology of the adjacent Butana grasslands, and the narrow strip of the area on its north-eastern boundary stretching out to Jebel Fau. Between the mid-Tertiary and Pleistocene periods the depression was gradually filled in by unconsolidated sands and clayey sands, and this Umm Ruwaba series constitutes the solid geology of the greater part of the area. A bore within this area at Khor Atshan showed the Basement Complex to be below the level of rock in the White Nile valley at Dueim. It is not thought that Umm Ruwaba series is exposed at the surface.

2.22 Recent Deposits

The surface clay is thought to have been deposited by the Blue Nile and its tributaries, in the pluvials between the late, Middle-Pleistocene and the early Upper-Pleistocene periods. It is a thick, alkaline, basaltic alluvium brought down from the Ethiopian highlands.

There is a possibility that clay overlying Basement Complex on the eastern edge of the area is formed in situ.

2.23 Physiography

The area slopes generally from south-east to north-west, and is drained by the rivers Dinder and Rahad. It is much dissected by khors and old river channels, the principal of which is the Khor Atshan, which carries overspill from the River Rahad to the River Dinder, and may represent a previous course of the Rahad. Shallow depressions

hold water throughout the year, and extensive lakes were found in places, such as the one near the village of Aboda. The other main drainage channel is the Khor Aqaliyin, which again holds water throughout the year and drains into the River Dinder. Many smaller khors are present. The many khors give the area a far from flat appearance overall, and this is accentuated near the rivers, particularly in the south towards the Blue Nile, along the River Dinder, and along the River Rahad in the north. These areas of rolling land often extend a considerable distance from the rivers.

Another outstanding feature, the extent of which could not be determined, is a high grassland plateau between the Khor Atshan and River Dinder.

It can be seen that topographic limitations will probably restrict a good deal of otherwise potentially irrigable land.

2.3 CLIMATE

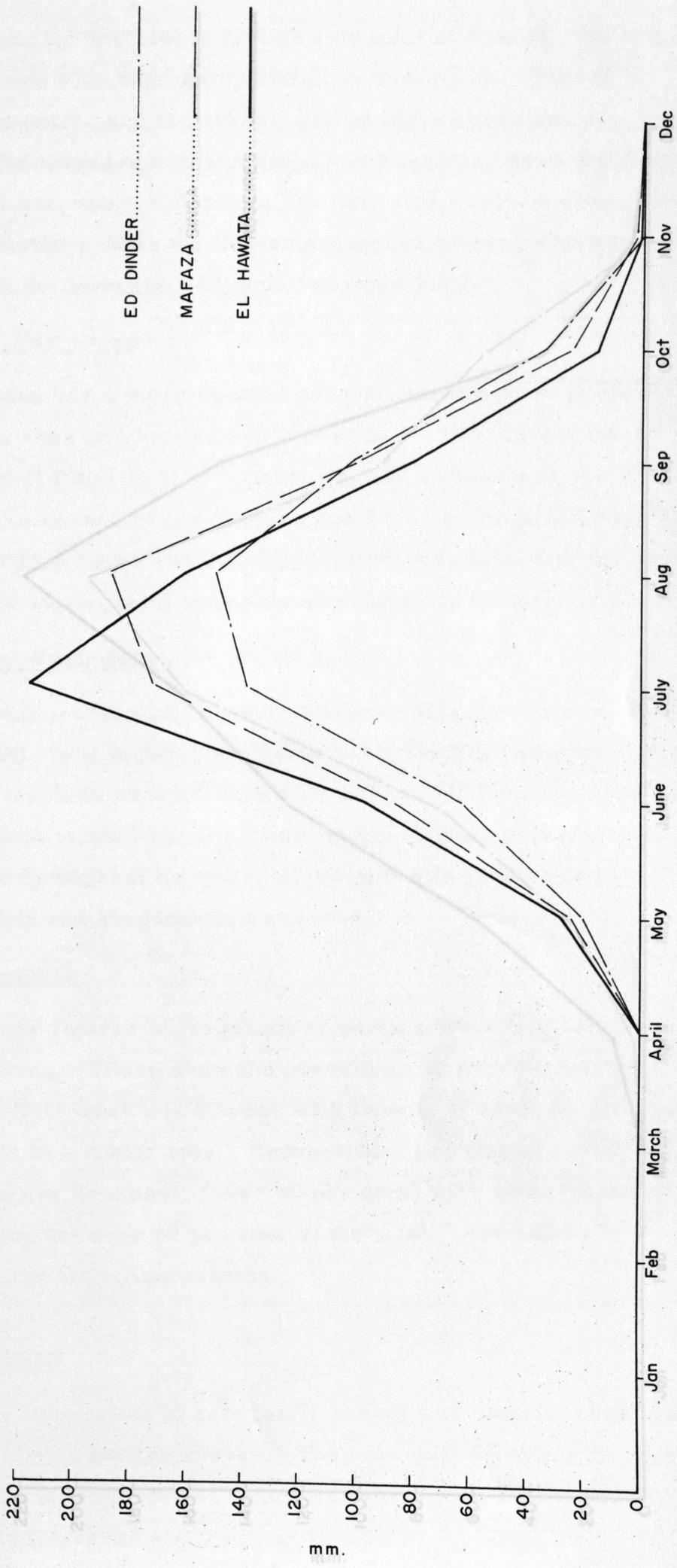
Introduction

A study of the climate of the area is made difficult by the absence of any first-class meteorological stations within the area. All such stations are concentrated on the Blue Nile, i. e. Sennar, Singa, Tozi and Roseires, and the nearest one east of the Nile is at Wad el Huri, 90 km outside the area. There are however, rainfall stations at El Gueisi, Mafaza and Hawata, within the area, and the figures can be studied in detail. It was necessary to interpolate results from other stations in the hope that these will give some idea of the climate of the adjacent project area.

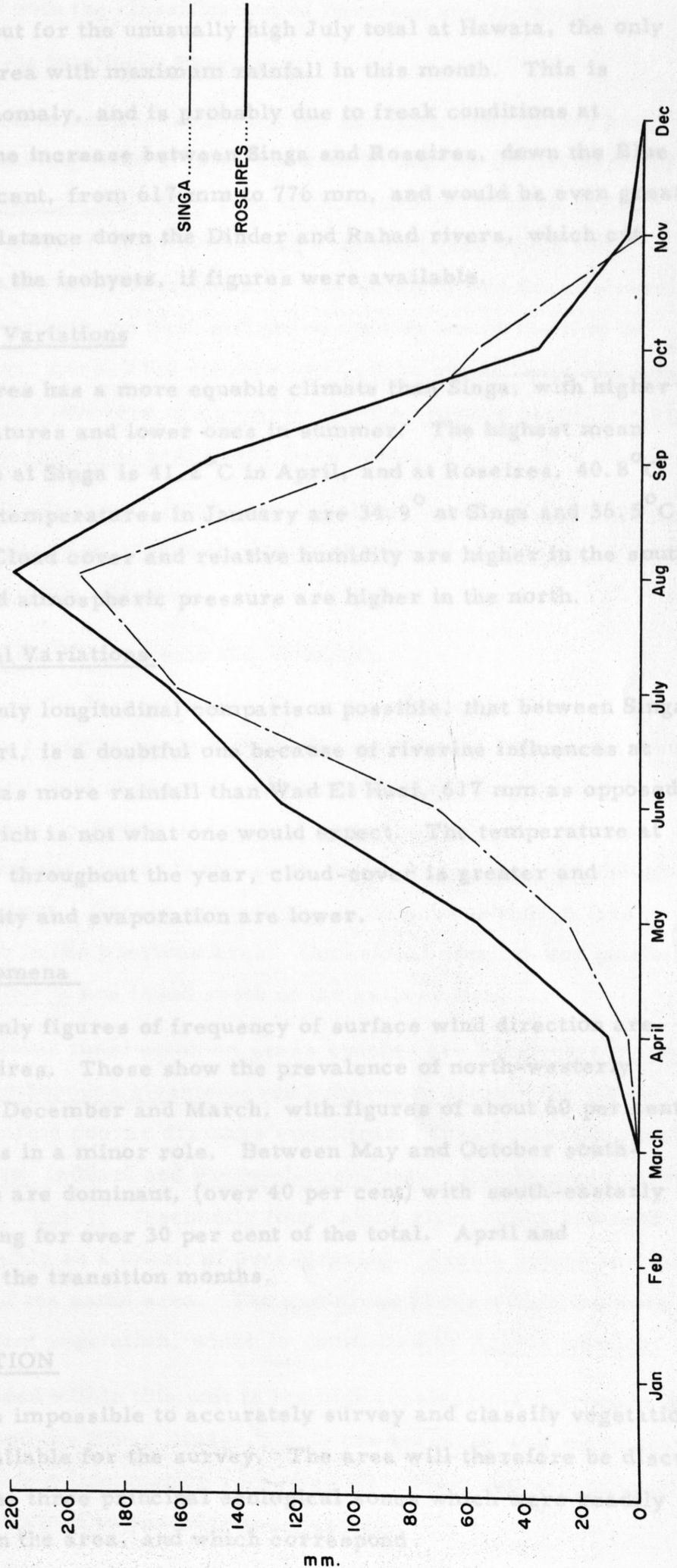
Rainfall

The rainfall map of the Sudan shows the isohyets running across the area in a north-east, south-west direction, at right angles to the directions of the two river systems. Therefore, a point on the Rahad will receive more rainfall than a point of the same latitude on the Dinder. This is shown on the accompanying diagrams with El Hawata having much higher figures than Ed Dinder. Mafaza has slightly higher figures than Hawata, as expected, but the difference would be

MEAN MONTHLY RAINFALL (mm) BETWEEN 1931-1960
AT ED DINDER, MAFAZA AND EL HAWATA



MEAN MONTHLY RAINFALL (mm) BETWEEN 1931-1960
AT SINGA AND ROSEIRES



much greater but for the unusually high July total at Hawata, the only station in the area with maximum rainfall in this month. This is obviously an anomaly, and is probably due to freak conditions at some time. The increase between Singa and Roseires, down the Nile, is significant, from 61 mm to 776 mm, and would be even greater for a similar distance down the Dinder and Rahad rivers, which are directly across the isohyets, if figures were available.

Latitudinal Variations

Roseires has a more equable climate than Singa, with higher winter temperatures and lower ones in summer. The highest mean maximum at Singa is 41.0°C in April and at Roseires, 40.8°C in May. The temperatures in January are 34.9° at Singa and 36.1°C at Roseires. Cloud cover and relative humidity are higher in the south, and atmospheric pressure are higher in the north.

Longitudinal Variations

The only longitudinal comparison possible, that between Singa and El Huri, is a doubtful one because of riverine influences at El Huri. Singa has more rainfall than El Huri, 547 mm as opposed to 381 mm, which is not what one would expect. The temperature at Singa is higher throughout the year, cloud-cover is greater and relative humidity and evaporation are lower.

Wind Phenomena

The only figures of frequency of surface wind direction available are those for Roseires. These show the prevalence of north-westerly winds between December and March, with figures of about 60 per cent, and north winds in a minor role. Between May and October south-westerly winds are dominant, (over 40 per cent) with south-easterly winds accounting for over 30 per cent of the total. April and November are the transition months.

2.4 VEGETATION

It was impossible to accurately survey and classify vegetation in the time available for the survey. The area will therefore be discussed according to the types of vegetation which are recognizable in the area, and which correspond

much greater but for the unusually high July total at Hawata, the only station in the area with maximum rainfall in this month. This is obviously an anomaly, and is probably due to freak conditions at some time. The increase between Singa and Roseires, down the Blue Nile, is significant, from 617 mm to 776 mm, and would be even greater for a similar distance down the Dinder and Rahad rivers, which cut directly across the isohyets, if figures were available.

Latitudinal Variations

Roseires has a more equable climate than Singa, with higher winter temperatures and lower ones in summer. The highest mean daily maximum at Singa is 41.2°C in April, and at Roseires, 40.8°C in April. The temperatures in January are 34.9° at Singa and 36.5°C at Roseires. Cloud cover and relative humidity are higher in the south, evaporation and atmospheric pressure are higher in the north.

Longitudinal Variations

The only longitudinal comparison possible, that between Singa and Wad El Huri, is a doubtful one because of riverine influences at Singa. Singa has more rainfall than Wad El Huri, 617 mm as opposed to 583 mm, which is not what one would expect. The temperature at Singa is higher throughout the year, cloud-cover is greater and relative humidity and evaporation are lower.

Wind Phenomena

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2.4 VEGETATION

It was impossible to accurately survey and classify vegetation in the time available for the survey. The area will therefore be discussed according to the three principal ecological zones which were readily recognisable in the area, and which correspond

fairly closely with the classification of Harrison and Jackson.

2.41 Acacia Mellifera Thornland

Harrison and Jackson place the southern limit of this belt along a line running from slightly north of El Mafaza to just north of El Guweisi. Acacia mellifera does occur dominant at sites further south than this, but it is probable that a detailed map would show much of this area to be transitional. The scrub in this area is rarely very dense, and both the bush and grass species would seem to be of poor quality. Associated species are Cadaba rotundifolia and Acacia nubica. Smaller numbers of Capparis decidua, Acacia seyal, Boscia sp., and occasional Balanites aegyptiaca were found.

Grass cover was patchy and consisted mainly of Cymbopogon nervatus, Sorghum sp. (addar), Sorghum purpureo-sericeum, Chloris virgata and Aristida species.

2.42 Acacia Seyal - Balanites savannah

This is the largest ecological group within the area. The density of tree cover is fairly high increasing towards the south, and along the rivers, and in places is almost pure Acacia seyal and Balanites aegyptiaca. Acacia fistula and Acacia campylacantha are found in increasing numbers towards the south, as is Acacia senegal though to a lesser degree. Cadaba rotundifolia is ubiquitous though less numerous than in the previous area. Occasional small dense patches of Acacia mellifera are found south of the railway line.

The three most common grass species are Sorghum purpureo-sericeum, Cymbopogon giganteum and Ischaemum afrum, the latter possibly indicating poorer drainage conditions. Other common species are Sorghum sp. (addar) and Rottboellia exaltata. Cymbopogon nervatus is uncommon, but is frequently found along river banks and near villages, possibly as a result of over-grazing. Acacia nubica is often a frequenter of the same area. The numerous khors within the area carry a different vegetation, which is dominated by Acacia nilotica.

Included within this unit is the high treeless plain between the Khor Atshan and the River Dinder. Only one traverse was made across it, and insufficient information regarding its extent and vegetational species was obtained to consider it separately.

The grass was predominantly 4ft. high Sorghum purpureo-sericeum and Cymbopogon giganteum, with smaller amounts of Cymbopogon proximus and Setaria sp.

2.43 Anogeissus - Combretum hartmannianum Savannah

Along the link-canal line, Combretum hartmannianum is found right across to the River Dinder, but the area proper may be considered to commence at the Khor Kenana trace, and develop southwards. The woodland is often dense, and many varieties are found in close proximity with each other. The commonest are Combretum hartmannianum, Acacia campylacantha, Sclerocarya birrea, Entada sudanica, Combretum aculeatum, Anogeissus schimperi, Acacia fistula, Acacia seyal, Balanites aegyptiaca and Acacia senegal. Occasional Adansonia digitata were found.

Grass species were similar to the previous area.

TABLE 2.4 Arabic Vernacular Names of the Vegetation in the Rahad-Dinder Area.

	<u>Grasses and Herbs</u>
Addar	<u>Sorghum sp.</u>
Anis	<u>Sorghum purpureo-sericeum</u>
Ansora	<u>Cymbopogon giganteum</u>
Umm Belila	<u>Rottboellia exaltata</u>
Bus	<u>Ischaemum afrum</u>
Danab El Kadis	<u>Aristida hordeacea</u>
Abu Gagra	<u>Brachiara brigantha</u>
Gaw	<u>Aristida sp.</u>
Halfa	<u>Setaria sphacelata</u>
Abu Harba	<u>Beckeropsis nubica</u>
Mahareib	<u>Cymbopogon proximus</u>
Mamlehar	<u>Dinebra retroflexa</u>
Mamshat	<u>Asparagus sp.</u>
Mustehi	<u>Chloris virgata</u>
Nal	<u>Cymbopogon nervatus</u>

2.5. POPULATION AND LAND USE

Grasses and Herbs (Cont.)

2.51 Population

Rehan	Ocimum basilicum
Runta	Chrozophera plicata
Umm Sabiba	Schoenefeldia gracilis
Umm Sheiko	Andropogon gayanus
Waika	Hibiscus esculentis
	Hyparrhenia sp.

Trees

Habil	Combretum hartmannianum
Hashab	Acacia senegal
Heglig	Balanites aegyptiaca
Kadad	Dichrostachys glomerata
Kakamot	Acacia campylacantha
Kitr	Acacia mellifera
Kurmut	Cadaba rotundifolia
Laot	Acacia nubica
Layum	Sclerocarya birrea
Luban	Entada sudanica
Mukhet	Boscia senegalensis
Nabak	Ziziphus sp.
Shayheit	Combretum aculeatum
Sileng	Anogeissus schimperi
Sunt	Acacia nilotica

2.52 Present Land Use

Talh	Acacia seyal
Talh Abiad	Acacia fistula
Tebeldi	Adansonia digitata
Tundub	Capparis decidua
Ushar	Calotropis procera

The culture of almost all the trees in the area is given over to subsistence farming. The exception is the case of two cotton schemes, one north and south of Hawata, and the other on the east bank of the Rahad. For the rest, the staple crop is sorghum (*Sorghum vulgare*) in patches near the villages, and simsim (*Sesamum indicum*), grown in small areas often at considerable distance from the village. Many villages along the Rahad and Dinder grow vegetables on the bed of the dried up river, and on the steeply sloping banks near stagnant pools. A "shaduf" was noted in operation at Hawata.

2.5 POPULATION AND LAND USE

2.51 Population

The area is very sparsely populated overall, with the main centre of habitation being in the vicinity of the Rivers Rahad and Dinder, and the Khor Atshan. The principal villages are Hawata, Mafaza and Tuneidba on the Rahad, and Abu Hashim on the Dinder, with El Guweisi just outside the project area. The Khor Atshan provides water for several villages, over a 20 km stretch between Wad El Ageili and Shallay. The reason for the existence of these villages is given by Barbour. In 1946, in an effort to develop the area, four "hafirs" were dug, land was divided up into strips and allotted to each village, and crop rotations were devised. The experiment failed, however, and the population of the villages decreased, with the exception of the village of Shamir which increased. The increase here is attributed to the influence of the sheikh who was a "westerner" and strong religious leader. Today, the only large villages are Wad El Ageili, Shamir and Shallay.

The original inhabitants of most of the area are the Kawahla tribe, but they have gradually been infiltrated by large groups of western migrants from Nigeria, (Fellata), and Chad, (Takrouiri). During the winter large numbers of nomads migrate down the area from the Butana, with large herds of camels and cattle. These are mainly Rufa'a esh Sharq, though a few Hadendowa were seen.

2.52 Present Land Use

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Charcoal burning is important in areas where Acacia seyal is abundant, as is gum collecting, principally from Acacia seyal, but also from Acacia senegal. Fishing is practiced in the larger stagnant pools. The fish are strung on lines from tree to tree, to dry in the sun. The price decreases in proportion with the age of the fish.

No aerial photography was available, other than for a small area along each side of the River Rahad, and the principal aids to navigation in the area were Sudan Survey Department maps, 55K, 55L, 55O and 55P at a scale of 1:250,000. These maps were published in the 1930's and 1940's and are grossly inaccurate today. Most of the roads shown do not exist, the course of rivers and khors is unreliable, villages are often wrongly positioned and a great many have been renamed. As a base-map, Sir Murdoch MacDonald and Partners drawing S. N. 24 was used, being the only map providing coverage for the whole of the area west of the Rahad. Here again the course of rivers and khors is often inaccurate, due to it being based on the original Sudan Survey maps.

This survey was on a broad exploratory basis, the idea being to provide fairly adequate cover of the area by means of a series of traverses across the area, using existing roads, tracks and traces. As very few of these were mapped at the time of survey and the surveyor had to map the line of traverse as he proceeded, traces were preferable to ordinary roads, in that they usually progressed in straight lines, and a change of direction was measured by compass bearings. In the south of the area M. M. P. traces were used, in conjunction with drawing S. U. 88, which showed the link-canal trace. This was not used on the survey but acted as a base line for location of the nearby link-canal line, by means of bench-marks. Other traces used were Forestry Department traces and Soil Conservation roads. Many of them were almost completely overgrown in parts, and difficult to distinguish in grassland areas.

In the northern part of the area there were few traces, and roads had to be used. The difficulties of mapping were increased by the absence of bench-marks, and the only ground-control was villages which could be identified on the Sudan Survey maps. Along the River Rahad mosaic overlays were used to facilitate location. The main difficulty with using roads is that the better ones always follow the river, and the soils a possible riverine influence.

CHAPTER 3

SOIL SURVEY METHODS

3.1 NAVIGATION AND LOCATION

No aerial photography was available, other than for a small area along each side of the River Rahad, and the principal aids to navigation in the area were Sudan Survey Department maps, 55K, 55L, 55O and 55P at a scale of 1:250,000. These maps were published in the 1930's and 1940's and are grossly inaccurate today. Most of the roads shown do not exist, the course of rivers and khors is unreliable, villages are often wrongly positioned and a great many have been renamed. As a base-map, Sir Murdoch MacDonald and Partners drawing S.N. 24 was used, being the only map providing coverage for the whole of the area west of the Rahad. Here again the course of rivers and khors is often inaccurate, due to it being based on the original Sudan Survey maps.

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3.32 A later extension of the area reached away from the Rahad to Jebel Fau, adjacent to area 3C extension. Access was obtained by using the outside trace in 3C extension, which has beacons every 2 kilometres for location.

3.2 SOIL SURVEY PROCEDURES

The selected traverses were sampled every 5 kilometres, giving a total of 151 sites, comprised of 141 bores and 10 pits. All bores were to 2 metres, and were sampled to fixed depths from 0-45 cm and from 45 to 90 cm. Soil and land classification mapping of the area is not possible on as broad a survey as this and without photography. It was therefore decided to sample each site to a semi-detailed specification, with the aim of providing the maximum amount of information at specific sites.

All bore sites were fully described according to natural horizons, the identification of which in a bore sample is usually limited to colour and texture. The instrument used was the 5 cm Jarret auger.

3.4 METHODS OF CHEMICAL ANALYSES

The pits were dug to a depth of 2 metres and sampled throughout by natural horizons, as well as by fixed depth, as in the case of bore sites. They are described according to natural horizons, in greater detail than the bores, more emphasis being placed on structure.

Where riverine influence was suspected at sites along the roads, bores have been placed off the road at a distance of up to 5 kilometres away from the river.

3.3 CHEMICAL ANALYSES OF SAMPLES

3.31 Fixed Depth Samples

E.C. in mmhos/cm., on the saturation extract.

Saturation percentage.

Mechanical analysis, into sand, silt and clay. (International fractions).

Soluble sodium in me/100 gms of soil.

Total extractable sodium in me/100 gms of soil.

3.32 Natural Horizon Samples

pH of a 1:5 suspension.

pH of the soil paste.

E. C. in mmhos/cm., on the saturation extract.

Saturation percentage.

Mechanical analysis into, coarse sand, fine sand, silt and clay. (International fractions).

Soluble sodium in me/100 gms of soil.

Total extractable sodium in me/100 gms of soil.

Cation exchange capacity in me/100 gms of soil.

3.33 Number of Samples Analysed

Number of 'fixed-depth' samples 302

Number of 'natural-horizon' samples 27

Total: 329

3.4 METHODS OF CHEMICAL ANALYSES

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

1. 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.

2. pH

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

3. Electrical Conductivity

Calculated by using a solubridge on the saturation extract.

4. Soluble Sodium in the Saturation Extract

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

5. Total Extractable Sodium

12.5 grams of soil were soaked in 50 mls 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.

6. Saturation Percentage

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

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

7. 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).

3.5 MAP COMPILATION

Field work was carried out mainly on Sir Murdoch MacDonald and Partners drawings S.N.24, S.U.88 and S.N.20, at a scale of 1:250,000, based on Sudan Survey Department maps 55G, 55K, 55L, 55O and 55P, at the same scale.

CHAPTER 4

As a result of field-work during the 1964-65 season, Sir Murdoch MacDonald and Partners drawings S.N. 72 and SN. 85 were produced, and were combined to form a base-map for the present area.

From this a land recommendation map was produced, based, in the main, on the distribution of 'good' class sites, and showing in addition the soil and land classes of each site, and the principal villages and communications.

The sites were numbered from 7121 to 7271.

Bore sites are represented - ⁷¹⁷⁶ A11.9a

Pit sites are represented - ⁷²³⁴ Δ _{A12.4a}

a surface relief with gilgai and other forms of collapsed structures, and massive cracks, up to 10 cm wide in the south of the area. These cracks often combine to form an irregular mosaic, with blocks of between 20 and 40 cm diameter. During the dry season, loose surface material is swept down the cracks, and churned within the top horizon during the subsequent rainy season. The cracks do not close entirely during the rains, and provide a means of drainage within the top horizon. Drainage does not occur to any extent below this.

It is possible that the natural horizons visible are the result of successive deposits of a different kind, containing varying amounts of different clay types, but still predominantly montmorillonitic.

4.2 PHYSICAL PROPERTIES

4.21 Soil Colour

Great difficulty was experienced in colour identification in the field, due to there being very little variation throughout the area, or within the profile. Such variation as was apparent, was due to the presence or absence of a greenish tinge, which gave the impression of obscuring the basic 10YR hue to varying degrees. Colours tended to darken slightly, down the profile, in the second horizon, but whether the darkening was due to the 10YR hue or the green component was difficult to determine. This caused most of the soils to be coloured as intergrades usually between the two components 10YR and 2.5Y. The

CHAPTER 4

PEDOLOGY

4.1 SOIL FARMING PROCESSES

Very little is known regarding the pedological processes within this area. Drawing analogies with surrounding areas, it would seem to be of alluvial origin, deposited by successive flooding of the Blue Nile, and its tributaries, the Dinder and Rahad.

The soils are largely montmorillonitic clays, with the associated property of expansion on wetting and contraction on drying. Alternate wet and dry seasons, with expansion and contraction, produce a surface relief with gilgai and other forms of collapsed structures, and massive cracks, up to 10 cm wide in the south of the area. These cracks often combine to form an irregular mosaic, with blocks of between 20 and 40 cm diameter. During the dry season, loose surface material is swept down the cracks, and churned within the top horizon during the subsequent rainy season. The cracks do not close entirely during the rains, and provide a means of drainage within the top horizon. Drainage does not occur to any extent below this.

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dominant hue was quoted first, and the "modifying" hue second. Thus 75 per cent of all the sites had a 2.5Y influence (includes one site with 5Y influence), and approximately 30 per cent of all sites had a colour of 10YR 3/2 - 2.5Y 3/2 (very dark grey-brown), in the top horizon. The green colour was not always obvious in the dry surface soil, but became so on wetting. One area where this was apparent, was in the south on the link-canal line. Here the hues were so green that no appropriate colour was found in the Munsell chart. In an effort to describe the various shades of colour, 26 permutations of 10YR and 2.5Y hues were used.

When it was noticed that the greenest area was also class 2 land, it was thought that there might be a correlation between soil colour and E.S.P., but this is not so. Although the class 6a land to the north has a reduced 2.5Y influence, this is thought to be due to the longitudinal variation. The sites with the highest top-horizon E.S.P.'s all have a strong 2.5Y influence.

The third horizon, where it exists, is based on colour change. In a large number of sites there is no change within 2 metres, and it is presumed to take place at greater depth. It is usually manifested by pronounced mottling, where the bottom horizon colour is very different from the one above, similar to the mottling associated with gleying. In the south along the link-canal line the bottom horizon is yellowish to brown with colours of 10YR 5/4 (yellowish brown), 10YR 4/3 and 7.5 YR 4/2 (brown to dark-brown). On the Rahad east bank, the soils in the north towards Jebel Fau all have a 10YR 4/3 bottom. For the rest of the area there is very little differentiation, and any change in the bottom horizon is limited to a gradual transition to 10YR 4/2 (dark grey-brown).

4.22 Texture

All the sites sampled throughout the area had clay topsoils. This was ensured in order that the sites might be representative of the clay plains of the area. Many of the traverses, followed the line of rivers and khors, but wherever riverine influence was detected in the form of lighter textures, a detour was made. The clay percentage of the second horizon was usually lower than the top. The accompanying

CLAY PERCENTAGE DISTRIBUTION WITHIN THE FIXED DEPTH SAMPLES

figure shows the maximum number of sites in the top horizon to have between 70 and 75 per cent clay, but the second horizon between 60 and 65 per cent. The average top horizon has a clay percentage of 69 per cent, and the bottom, only 62 per cent. This increasing sandiness with depth is manifested throughout the area, with the exception of the northern part of the Rahad east bank area, towards Jebel Fau, which has fairly even figures for both horizons. The area in which it is most strongly developed, is the area between the River Rahad and the Khor Atshan, below the railway line. This is the Rahad spill area, and typical sites have clay figures of 71 per cent on the top horizon and 26 per cent in the second, 74 per cent in the top and 21 per cent in the second.

4.23 Consistency

The consistency of these heavy clay soils is almost entirely dependent on their moisture content. The top horizon, usually dry, is extremely hard or very hard, and below that, there is a very slight moisture content, it is extremely firm or very firm. Increasing amounts of sandy material in the lower horizons render the soil firm, and in exceptional cases, friable. A heavy storm at the end of March made the topsoil sticky and plastic for a time. When auge ring, consistency is only determinable for the topsoil, which peds can be obtained by digging. For the rest, the soil is subjected to great pressures; ground up to dust if it is dry, and compressed into compact mass when moist.

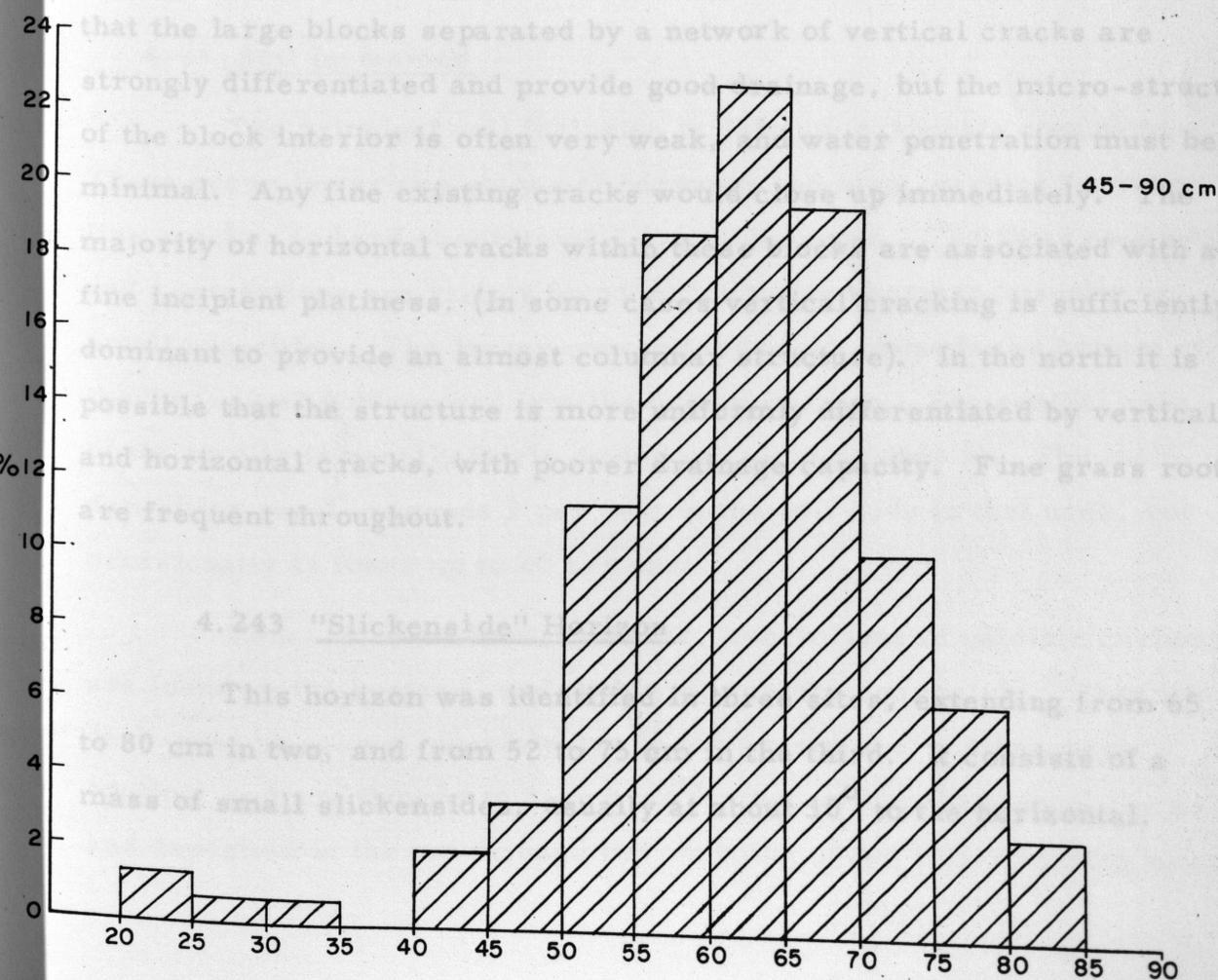
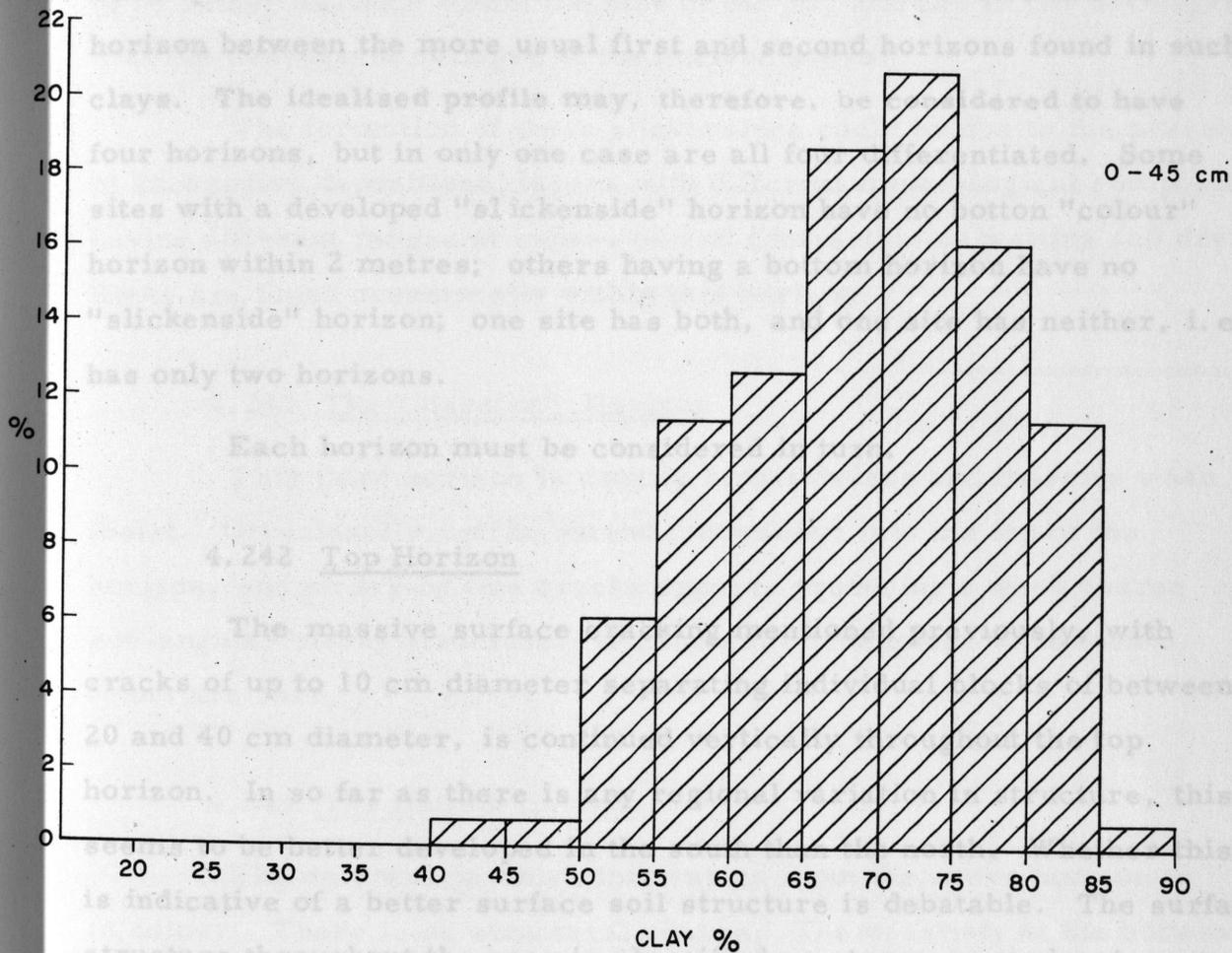
4.24 Structure

4.241 Introduction

Structure is only discernible in pits, and was not included in bore sample descriptions, for the same reasons as those given for consistency. Due to the lack of time available, only 10 pits were dug in this area, and this makes attempts at diagnosing structural variations within the area, difficult. All the pits, however, show a uniformity of profile which it is hoped reflect the uniformity of the area as a whole.

The pits usually show three horizons within the top 2 metres. The first is a marked structural change from the second, and the third is due to colour difference. In one pit there is a 4th horizon, and in

CLAY PERCENTAGE DISTRIBUTION WITHIN THE FIXED DEPTH SAMPLES



On drying out, cracks develop between slickenside faces, with the most of the others there is a semblance of one, which is not sufficiently developed to be differentiated. This is a transitional "slickenside" horizon between the more usual first and second horizons found in such clays. The idealised profile may, therefore, be considered to have four horizons, but in only one case are all four differentiated. Some sites with a developed "slickenside" horizon have no bottom "colour" horizon within 2 metres; others having a bottom horizon have no "slickenside" horizon; one site has both, and one site has neither, i. e. has only two horizons.

Each horizon must be considered in turn.

4.242 Top Horizon

The massive surface cracking mentioned previously, with cracks of up to 10 cm diameter separating individual blocks of between 20 and 40 cm diameter, is continued vertically throughout the top horizon. In so far as there is any regional variation in structure, this seems to be better developed in the south than the north. Whether this is indicative of a better surface soil structure is debatable. The surface structure throughout the area is classified as strong or moderate, coarse, sub-angular blocky. In the south this refers to macro-structure, in that the large blocks separated by a network of vertical cracks are strongly differentiated and provide good drainage, but the micro-structure of the block interior is often very weak, and water penetration must be minimal. Any fine existing cracks would close up immediately. The majority of horizontal cracks within these blocks are associated with a fine incipient platiness. (In some cases vertical cracking is sufficiently dominant to provide an almost columnar structure). In the north it is possible that the structure is more uniformly differentiated by vertical and horizontal cracks, with poorer drainage capacity. Fine grass roots are frequent throughout.

4.243 "Slickenside" Horizon

This horizon was identified in three sites, extending from 65 to 80 cm in two, and from 52 to 75 cm in the third. It consists of a mass of small slickensides, usually at about 30° to the horizontal.

On drying out, cracks develop between slickenside faces, with the formation of strong, medium, angular blocky structures. These tend to be rather unstable within the face of the pit, and are easily dislodged, with the consequent collapse of the horizon above.

The formation of these slickensides could be due to the presence of successive depositional layers with different mineralogical composition, having different ranges of expansion and contraction on wetting and drying. Roots are found occasionally within this horizon.

4.244 The "Massive" Horizon

This third horizon is usually structureless and massive when moist. Occasionally cracks extend from above into the top of the horizon, and on drying fine cracks appear, producing a weak coarse sub-angular blocky structure. Occasional slickensides were found. Roots are rare.

4.245 The Bottom Horizon

The only way in which this varies from the above horizon is in colour. There is no structural change. The massivity at the bottom of the above horizon is continued, with no cracks visible.

4.25 Soil Inclusions

The principal soil inclusion is calcium carbonate concretions. These occur in various stages of hardness and size, varying from soft fine specks, to hard concretions 2 cm in diameter. The finer concretions and aggregations are mainly found within the top horizon, usually in small quantities. The larger concretions occur towards the bottom of the "massive" horizon and into the bottom horizon. The central area of the profile is usually fairly devoid of calcium deposits. The main deposition rarely exceeds 5 per cent of the soil body in that area, but occasionally is found up to 20 per cent.

Kankars, very hard, rounded, concretions of calcium carbonate, are found on the surface, and within the top horizon mainly. They are dark-grey in colour, possibly due to the presence of a manganese coating, and are thought to have been formed within the body of the soil, and deposited in the top through the churning of the self-mulching process

(Worrall 1957). These concretions are relatively absent in the south of the area. Their southern limit is approximately in the area of the El Gueisi - Hawata railway line. It may be coincidental that this limit is also the approximate southern boundary of the Acacia mellifera thornland.

Gypsum crystals were found in small quantities at a few sites. Other inclusions, usually found on the surface and within the top horizon are, shell fragments, quartz grains and occasional iron-stained quartz pebbles. The quartz grains within the top horizon were naturally more numerous in soils with sandy horizons lower down.

4.3 CHEMICAL PROPERTIES

4.31 Salinity

Salinity is expressed as electrical conductivity in millimhos/cm. From the accompanying table it can be seen that salinity is negligible throughout the area, with only 1 per cent of sites having an E.C. of between 4 and 5 in the top horizon. The area with the lowest salinity is along the link-canal line; the area of unusually green clay. As salinity is a criterion of classification, the following table shows the E.C. range of the fixed-depth samples.

TABLE 4.3

E.C.	0-1	>1-2	>2-3	>3-4	>4-5	>5-6	>6-7
0-45 cm	59%	27%	11%	2%	1%	-	-
45-90 cm	22%	30%	28%	8½%	8½%	2%	1%

4.32 Exchangeable Sodium

The principal criterion in the soil and land classification is the exchangeable sodium percentage (E.S.P.). Experiments on the Gezira Research Station have shown that clay percentage can be substituted for C.E.C. in the calculation, with reasonable accuracy; thus $E.S.P. = \frac{\text{ex. Na}}{\text{clay\%}} \times 100$. The basis for the assumption is that the Gezira clay plains are basically montmorillonitic, to the extent that 100 gms of clay has a C.E.C. of approximately 100, therefore a soil with 60 per cent clay will

have a C.E.C. of 60.

The accompanying diagrams show the distribution of E.S.P. within the fixed depth horizons. Within the top horizon, the high figure of 10 per cent with E.S.P.'s of less than 2, reflects the low E.S.P. values of the class 2 land along the link-canal line. The second horizon has much higher E.S.P.'s than the top, which, while being due to higher exchangeable sodium figures is also influenced by lower clay percentages.

4.33 Cation Exchange Capacity

C.E.C. determinations were carried out on the 'natural-horizon' samples of 10 pits. For purposes of classification, the E.S.P.'s of bore sites were calculated using clay per cent, as described elsewhere. To confirm the correlation between C.E.C. and E.S.P., C.E.C. was calculated as a percentage of the clay per cent. The average of 27 samples was 101 per cent, with maximum and minimum of 108 per cent and 92 per cent. An unusually high proportion of 2/3 of the samples, had C.E.C. values higher than the clay per cent. It may be that there is a slightly more montmorillonitic clay in this area, than in previous areas of survey.

4.34 pH

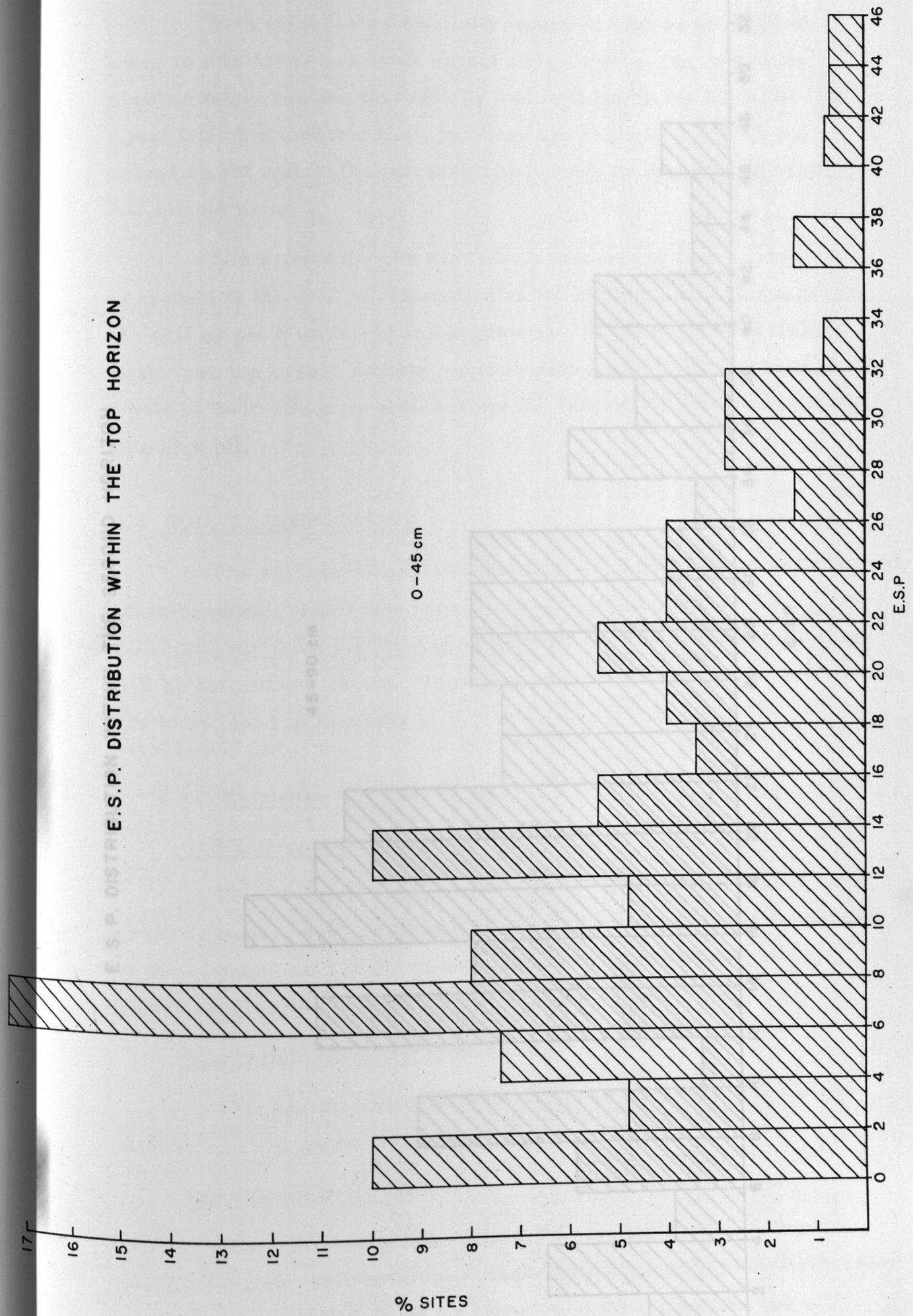
The test was carried out on the soil paste, and at 1:5 dilution, on the 'natural-horizon' samples from pits.

There is very little difference in values, either with depth or between sites, although there is usually a slight decrease in the lower horizons, possibly associated with slightly higher salinity. The correlation between E.C. and pH paste is indefinite however, due to an insufficiently wide range of values, and differences in the horizon depths of sites.

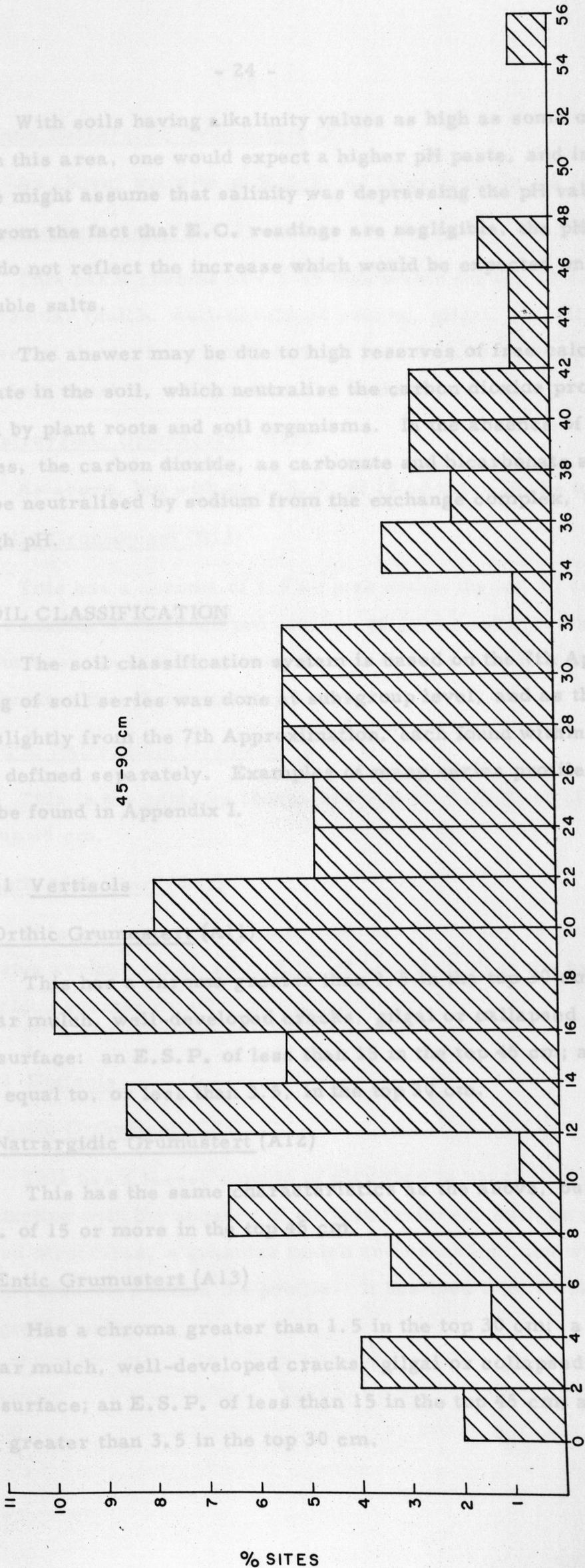
The pH paste is greater than 8.0 in only 3 cases, with a lower limit of 7.5, and an average value of 7.8. The pH 1:5 ranges from 7.9 to 8.8, with an average of 8.4.

Fig. 4.

E.S.P. DISTRIBUTION WITHIN THE TOP HORIZON



E.S.P. DISTRIBUTION WITHIN THE SECOND HORIZON



With soils having alkalinity values as high as some of the sites in this area, one would expect a higher pH. In its absence might assume that salinity was depressing the pH value. Apart from the fact that E.C. readings are negligible, these values do not reflect the increase which would be expected from leaching out soluble salts.

The answer may be due to high reserves of calcium carbonate in the soil, which neutralise the acidity produced in the soil by plant roots and soil organisms. These reserves, the carbon dioxide, as carbonate ions, would be neutralised by sodium from the exchange complex, resulting in a high pH.

4.4 SOIL CLASSIFICATION

The soil classification is based on an approximation. Mapping of soil series was done. The series differ slightly from the 7th Approx. The series will be defined separately. Examples are to be found in Appendix I.

4.41 Vertisols

Orthic Grumusol

This has the same characteristics as the Orthic Grumusol with an E.S.P. of 15 or more in the top 30 cm and a colour equal to, or greater than, 3.5 in the top 30 cm.

Natragidic Grumusol (A2)

This has the same characteristics as the Natragidic Grumusol with an E.S.P. of 15 or more in the top 30 cm and a colour equal to, or greater than, 3.5 in the top 30 cm.

Entic Grumusol (A13)

Has a chroma greater than 1.5 in the top 30 cm, granular mulch, well-developed cracks, and structures at the surface; an E.S.P. of less than 15 in the top 30 cm and a colour greater than 3.5 in the top 30 cm.

With soils having alkalinity values as high as some of the sites in this area, one would expect a higher pH paste, and in its absence might assume that salinity was depressing the pH value. Apart from the fact that E.C. readings are negligible, the pH 1:5 values do not reflect the increase which would be expected on leaching out soluble salts.

The answer may be due to high reserves of free calcium carbonate in the soil, which neutralise the carbon dioxide produced in the soil by plant roots and soil organisms. In the absence of these reserves, the carbon dioxide, as carbonate and bicarbonate anions, would be neutralised by sodium from the exchange complex, resulting in a high pH.

4.4 SOIL CLASSIFICATION

The soil classification system is based on the 7th Approximation. Mapping of soil series was done at sub-group level, and as these series differ slightly from the 7th Approximation, each found within the area will be defined separately. Examples of many series profile descriptions are to be found in Appendix I.

4.41 Vertisols

Orthic Grumustert (A11)

This has a chroma greater than 1.5 in the top 30 cm; a loose granular mulch, well-developed cracks, gilgai or collapsed structures, at the surface; an E.S.P. of less than 15 in the top 45 cm; and a colour equal to, or less than 3.5, in the top 30 cm.

Natrargidic Grumustert (A12)

This has the same characteristics as the above, but with an E.S.P. of 15 or more in the top 45 cm.

Entic Grumustert (A13)

Has a chroma greater than 1.5 in the top 30 cm; a loose granular mulch, well-developed cracks, gilgai or collapsed-structures, at the surface; an E.S.P. of less than 15 in the top 45 cm; and a colour greater than 3.5 in the top 30 cm.

Entic Natrargidic Grumustert (A14)

As above, but with an E.S.P. of 15 or more in the top 45 cm.

Orthic Grumaquert (B11)

This has a chroma of 1.5 or less within the top 30 cm; a loose granular mulch, well-developed cracks, gilgai, or collapsed structures at the surface; an E.S.P. of less than 15 in the top 45 cm; and a colour equal to, or less than 3.5 in the top 30 cm.

Natrargidic Grumaquert (B12)

As above, but with an E.S.P. of 15 or more in the top 45 cm.

Entic Grumaquert (B13)

This has a chroma of 1.5 or less within the top 30 cm; a loose granular mulch, well-developed cracks, gilgai or collapsed structures at the surface; an E.S.P. of less than 15 in the top 45 cm; and a colour greater than 3.5 in the top 30 cm.

Entic Natrargidic Grumaquert (B14)

This is the same as above, but with an E.S.P. of 15 or more in the top 45 cm.

Entic Mazustert (A23)

This has a chroma greater than 1.5 in the top 30 cm; a platy or massive surface crust; an E.S.P. of less than 15 in the top 45 cm; and a colour greater than 3.5 in the top 30 cm.

4.42 Entisols

Vertic Orthustent (C23)

This has a lesser amount of clay than is usual in a Vertisol in conjunction with the absence of surface features, such as gilgai, collapsed structures, a granular mulch and cracking; and with a poorer developed structure within the profile. It has less than 15 per cent exchangeable sodium.

4.43 Classification of the Area

Each site was classified at sub-group level, in order to characterise each site more definitely than is usual in an exploratory survey. This was possible, as mapping could not be carried out under such an arbitrary system.

Over 70 per cent of the sites are orthic or natrargidic grumusterts, and the immature entic soils are uncommon. The distribution is shown below:

TABLE 4.41

A11	A12	A13	A14	B11	B12	B13	B14	A23	C23
48.7%	22.6%	8%	4.7%	9.3%	5.1%	0.4%	0.4%	0.4%	0.4%

Difficulties occasionally arise as to whether a soil has a "grum" or a "maz" surface. The principal definitive feature of the "grum" is the loose granular mulch, which is rarely present in such a form as to leave no room for doubt. It is often thin, being the result of a broken up rain-crust, and often not granular, but fine and medium sub-angular blocky of variable strength. If the surface is undisturbed since the preceding rainy season, a rain-crust will be present. In conjunction with this, there are usually cracks, gilgai, or other holes and depressions, termed here, collapsed structures. If any of these are present, the soil has been classified as "grum". Only if the surface is flat and hard, without massive cracking or any surface disturbances, has it been termed "maz". This occurred at only one site throughout the area, and was probably fairly local. Such sites were usually avoided in case they turned out to be sandy.

Another difficulty arose over the classification of a site as a mazustert or vertic orthustent. The mazusterts usually owe their compactness to increased amounts of sand in the top horizon. This usually brings about a deterioration in the typical Vertisol structure, and verges on the Entisol. This is complicated by the fact that a vertic orthustent must have over 40 per cent expanding lattice clay, while a Vertisol can have only 35 per cent. In this area only one vertic orthustent was classified. Comparing this with the entic mazustert it is seen that the entisol has a lower clay percentage, and poorer profile structure than the mazustert, though having a more vertisolic surface, with cracks and gilgai.

TABLE 4.42

Order	Sub-Order	Great Group	Sub-Group	Mapping Symbol
			Orthic Grumusterts	A11
		Grumusterts A1	Natrargidic Grumusterts	A12
			Entic Grumusterts	A13
			Entic Natrargidic Grumusterts	A14
A Usterts				
			Orthic Mazusterts	A21
		Mazusterts A2	Natrargidic Mazusterts	A22
			Entic Mazusterts	A23
			Entic Natrargidic Mazusterts	A24
Vertisols				
			Orthic Grumaquerts	B11
		Grumaquerts B1	Natrargidic Grumaquerts	B12
			Entic Grumaquerts	B13
			Entic Natrargidic Grumaquerts	B14
			Orthic Mazaquerts	B21
		Mazaquerts B2	Natrargidic Mazaquerts	B22
			Entic Mazaquerts	B23
			Entic Natrargidic Mazaquerts	B24
			Orthic Psammustents	C11
		Psammustents C1	Orthustentic Psammustents	C12
Entisols	C Ustents			
			Orthic Orthustents	C21
			Natrargidic Orthustents	C22
			Vertic Orthustents	C23
			Vertic Natrargidic Orthustents	C24

The classification was according to the U. S. Bureau of Reclamation standards, adjusted where necessary for satisfactory application under Sudan conditions, and has been discussed fully in previous reports.

CHAPTER 5

LAND CLASSIFICATION

5.1 OBJECTIVES OF THE CLASSIFICATION

This survey differed from all previous work done in the Sudan, in that it was on a broad exploratory basis, without photography, proper access to the area, or accurate maps, and with very little time available. On this basis, the usual form of land-classification procedure, based on analytical data from sites, in conjunction with photo-interpretation of the area, is impossible. Instead a system of "site classification" was adopted, with a land class on the lines of a semi-detailed survey accorded to each site, but not being applicable to anywhere but the immediate surroundings.

Recommending land for further investigation on the basis of such a classification is a hazardous business. Any area recommended would include much land not surveyed, the assumption being that a high percentage of sites with potentialities of a high order, situated along traverses through an area, would be sufficient to justify recommending the rest of that area for further investigation. Previous surveys in the Sudan do not encourage optimism in this belief, and it is possible that unsurveyed land lying between 'good' traverses may well turn out to be poor.

In the event, the 'site-classification' proved to be much more consistent than was expected, and it was possible to delineate an area, with a reasonable expectation that a sufficiently large area of irrigable land will be found, on further investigation.

5.2 LAND CLASS STANDARDS

The classification was according to the U.S. Bureau of Reclamation standards, adjusted where necessary for satisfactory application under Sudan conditions, and has been discussed fully in previous reports.

The Bureau of Reclamation capability classes are numbered from 1 to 6. The higher the number, the lower is the capability rating. The first three classes, 1, 2 and 3, are considered arable with progressively increasing limitations on their use and/or with increasing costs of reclamation and management. Class 4 is land suited only to special uses. Class 5 is land needing further investigation, and Class 6 is permanently non-arable.

5.3 CLASSIFICATION OF THE AREA

Table 5.44 shows the classification system used.

The classification distribution of the whole area is shown below.

TABLE 5.3

2	31	3a	3a1	4a	6a	6a/2	6a/4a	6a/3s
22.6%	0.4%	28.7%	0.4%	4.7%	24%	14.1%	4.7%	0.4%

It can be seen that class 6a/2 i.e. those with top horizon E.S.P. of less than 15, and second horizon of more than 25, accounts for a considerable number of sites. As these land-class ratings do not constitute mapping units in this area, increased definition of a site in this way is advantageous.

5.4 RECOMMENDATIONS

The sites which have been accepted as being indicative of good land for the purposes of this survey are those with classifications of 2, 31, 3a, 3a1, 4a, 6a/2 and 6a/3s. The only ones which are considered to be on poor land are 6a and 6a/4a.

5.41 Land Recommended for Semi-Detailed Soil Survey

The right bank Rahad lands are arable at all 28 sites and appear to be a southward extension of the good lands of areas 3c and 3 c extension. The lands are gently sloping towards the river and there are no serious limitations of drainage or topography. It is expected that the percentage of irrigable land will be as high as that in area 3c extension. This would justify the immediate carrying out of a semi-detailed soil and land classification survey of the 360,000 feddans of land between the Rahad siphon and Jebel el Fau without the necessity of first carrying out a reconnaissance soil and land class survey.

The distribution of sites within this area is as follows:

Table 5.41 Percentage Distribution of Land Classes

Rahad East Bank.

Land Class	No. of Sites	% of Sites
2	8	29
3a	18	64
4a	<u>2</u>	7
	<u>28</u>	

The lands east of Khor Aqaliyin and south of Khor Kenana (about 140,000 feddans) have been examined systematically along the link canal trace. The distribution of sites in the area is given in Table 5.42. Most sites are arable and one could guess that about three quarters of this block is suitable for irrigation. Because of the narrowness of this block and the fact that it was examined over its whole length, it would be quite reasonable to carry out a semi-detailed soil and land classification survey here without first carrying out a reconnaissance survey.

Table 5.42 Percentage Distribution of Land Classes East of Khor Aqaliyin.

Land Class	No. of Sites	% of Sites
2	13	65
3a	4	20
3a1	1	5
6a/2	1	5
6a	1	5
	<hr style="width: 100px; margin-left: auto; margin-right: 0;"/> 20	

Total area recommended for semi-detailed soil survey is approximately 500,000 feddans.

5.42 Land Recommended for Reconnaissance Survey

The lands between Rahad and Dinder (1,360,000 feddans), where access is difficult, have been examined only around the edges extension of area 2a across the Khor Aqaliyin. On the basis of the

of very large blocks of land, the interiors of which were not crossed by the field party nor were air photographs available. In fact, the whole area has been scanned only once or twice from the air, as on 14/2/1965. This is the old flood plain of the two rivers, extensively cut by effluent channels and parts of which are subject to seasonal flood spill from the Rahad towards the Dinder. The soil analyses show that there is a very widespread alkalinity problem throughout this whole vast area. One could generalise and speculate that this is an extension southwards of the alkali lands of area 3b. Perhaps the whole area between Rahad and Dinder was originally subject to seasonal flooding and subsequent evaporation of shallow lakes because of blocked drainage.

Table 5.43 Distribution of Land Classes

The above discussion, showing that these lands suffer from topographic, drainage and soils limitations, indicates that it is necessary to proceed with caution in evaluating them. Obviously the next step should be a reconnaissance type soil and land classification survey carried out along trace lines evenly spaced over the whole area between Rahad and Dinder. This is the most economical approach because it is quite possible that as little as one quarter of the area may be suitable for irrigation development. Semi-detailed soil and land classification surveys could then be carried out on suitably located blocks of good land found by the reconnaissance survey.

The lands between Dinder, Khor Aqaliyin and Khor Kenana have been examined only around the fringes. No examination was made across the centre of this large block of land. This is higher land than the Rahad-Dinder flood plain and may be considered an extension of area 2a across the Khor Aqaliyin. On the basis of the

TABLE 5.44

Physical and Chemical Standards for Land Classes in the Clay Plains South of Khartoum.

good quality land in area 2a and the generally favourable soil analyses from 18 sites around the edges of this block, one would surmise that about three quarters of it will eventually prove to be arable. It would, however, be desirable to first carry out a reconnaissance soil and land classification survey along trace lines before embarking on a semi-detailed survey of selected areas. This would involve very little extra effort because the reconnaissance traces could then be incorporated into any future semi-detailed soil survey.

The total area recommended for reconnaissance soil survey is around 1,850,000 feddans and the distribution of land classes for this area is as follows:-

Table 5.43 Distribution of Land Classes

Area Recommended for Reconnaissance Survey.

Land Class	No. of Sites	% of Sites
2	13	13
31	1	1
3a	21	20
4a	5	5
6a	35	34
6a/2	20	19
6a/4a	7	7
6a/3s	1	1
	<u>103</u>	

TABLE 5.44

Physical and Chemical Standards for Land Classes in the Clay Plains South of Khartoum.

LAND CLASS	SAMPLE DEPTH	CLAY CONTENT	E.C.	E.S.P.
2	0- 45 cm	exceeds 50%	less than 4	less than 15
	45- 90 cm	not limiting	" " 5.3	" " 15
	90-150 cm	" "	" " 8	not limiting
31	0- 45 cm	35 - 50 %	less than 4	less than 15
	45- 90 cm	not limiting	" " 5.3	" " 15
	90-150 cm	" "	" " 8	not limiting
3a	0- 45 cm	exceeds 50%	less than 4	less than 15
	45- 90 cm	not limiting	" " 5.3	15 - 25
	90-150 cm	" "	" " 8	not limiting
3al	0- 45 cm	35 - 50%	less than 4	less than 15
	45- 90 cm	not limiting	" " 5.3	15 - 25
	90-150 cm	" "	" " 8	not limiting
3s	0- 45 cm	exceeds 50%	4 - 5.3	less than 15
	45- 90 cm	not limiting	and/or 5.3 - 8	" " 15
	90-150 cm	" "	and/or 8 - 12	not limiting
3sl	0- 45 cm	35 - 50%	4 - 5.3	less than 15
	45- 90 cm	not limiting	and/or 5.3 - 8	" " 15
	90-150 cm	" "	and/or 8 - 12	not limiting
3as	0- 45 cm	exceeds 50%	4 - 5.3	less than 15
	45- 90 cm	not limiting	and/or 5.3 - 8	15 - 25
	90-150 cm	" "	and/or 8 - 12	not limiting
3asl	0- 45 cm	35 - 50%	4 - 5.3	less than 15
	45- 90 cm	not limiting	and/or 5.3 - 8	15 - 25
	90-150 cm	" "	and/or 8 - 12	not limiting
4a	0- 45 cm	exceeds 50%	less than 5.3	15 - 20
	45- 90 cm	not limiting	" " 8	less than 25
	90-150 cm	" "	" " 12	not limiting
41	0- 45 cm	5 - 35%	less than 5.3	less than 15
	45- 90 cm	not limiting	" " 8	" " 20
	90-150 cm	" "	less than 12	not limiting

Pit

7134

Sloping slightly eastwards.

TABLE 5.44 (Cont.)

LAND CLASS	SAMPLE DEPTH	CLAY CONTENT	E.C.	E.S.P.
4a1	0- 45 cm	35 - 50%	less than 5.3	15 - 20
	45- 90 cm	not limiting	" " 8.0	less than 25
	90-150 cm	not limiting	less than 12.0	not limiting
6a	0- 45 cm	exceeds 5%	less than 5.3	exceeds 15 and/or
	45- 90 cm	not limiting	" " 8	exceeds 20
	90-150 cm	" "	" " 12	not limiting
6s	0- 45 cm	exceeds 5%	exceeds 5.3 and/or	less than 20
	45- 90 cm	not limiting	exceeds 8 and/or	" " 25
	90-150 cm	" "	exceeds 12	not limiting
6as	0- 45 cm	exceeds 5%	exceeds 5.3 and/or	exceeds 15 and/or
	45- 90 cm	not limiting	exceeds 8	exceeds 20
	90-150 cm	" "	exceeds 12	not limiting
61	0- 45 cm	less than 5%	not limiting	not limiting
	45- 90 cm	not limiting	" "	" "
	90-150 cm	" "	" "	" "

140-200 cm

5Y 3/4-4/4. Clay. Slightly moist. Very firm. Massive. Occasional fine cracks. No roots. 15 per cent calcium carbonate concretions, forming a calcareous network.

Classification

Orthic Grumusert.

Pit

7134

Topography

Sloping slightly eastwards.

Cultivation and

Bottom of a shallow depression.

Land Use and

Nil.

Vegetation

Acacia seyal and Balanites aegyptiaca, 30/feddan

Surface

Uneven. Frequent collapsed structures. Rain crust 4-5 cm thick. Frequent shells. Occasional patches of Cymbopogon giganteum.

Profile Description

0- 46 cm

Slightly uneven. Abundant large cracks 8 cm
10YR 3/2. Clay. Dry and very hard at the top becoming very slightly moist and very firm lower down. Moderate coarse sub-angular blocky.

Profile Description

0- 65 cm

2.5Y 3/2-4/2. Clay. Dry. Extremely hard. Strong coarse sub-angular blocky. Large vertical cracks 3-4 cm diameter running to the bottom. Frequent roots. Abundant small calcium carbonate concretions. Occasional shell fragments.

46-140 cm

10YR 3/2. Clay. Slightly moist. Very firm. Weak coarse sub-angular blocky. Frequent vertical cracks to the top of the next horizon. Occasional horizontal cracks. Occasional roots. Frequent small calcium carbonate concretions. Occasional larger ones lower down.

65- 80 cm

5Y 3/4-4/4. Clay. Slightly moist. Very firm. Massive. Occasional fine cracks. No roots. 15 per cent calcium carbonate concretions, forming a calcareous network.

140-200 cm

2.5Y 3/2 at the top becoming 2.5Y 4/3 at the bottom. Clay. Moist. Very firm. Massive. Occasional slickensides at the top. Occasional roots. Calcium carbonate increasing to 5-7 per cent below 140 cm.

Classification

Orthic Grumustert.

Classification

Orthic Grumustert.

<u>Pit</u>	7156
<u>Topography</u>	Bottom of a shallow depression.
<u>Cultivation and land use</u>	Nil.
<u>Vegetation</u>	<u>Acacia fistula</u> , <u>Acacia seyal</u> , <u>Balanites aegyptiaca</u> <u>Acacia campybacantha</u> , 20/feddan. Occasional patches of <u>Cymbopogon giganteum</u> .
<u>Surface</u>	Slightly uneven. Abundant large cracks 8 cm diameter forming blocks 40 cm diameter.
<u>Profile Description</u>	Blocks 30-40 cm diameter. Loose, fine sub-angular blocky matrix.
0- 65 cm	2.5Y 3/2-4/2. Clay. Dry. Extremely hard. Strong coarse sub-angular blocky. Large vertical cracks, 3-4 cm diameter running to the bottom. Few fine cracks. Drying gives an angular blocky microstructure. Occasional roots. Frequent quartz grains. Traces of calcium carbonate.
65- 80 cm	2.5Y 3/2. Clay. Moist. Very firm. Moderate coarse angular blocky. Small 30° slickensides along the cracks, which decrease with depth.
80-200 cm	Occasional roots. No vertical cracks. Traces of calcium carbonate. 2.5Y 3/2 at the top becoming 2.5Y 4/2 at the bottom. Clay. Moist. Very firm. Massive. Occasional slickensides at the top. Occasional roots. Calcium carbonate increasing to 5-7 per cent below 140 cm.
<u>Classification</u>	Orthic Grumusert. Slightly moist. Very firm. Massive with occasional large vertical cracks, drying out to weak, coarse sub-angular blocky. Frequent large slickensides at the bottom, inclined at 50°. Calcium carbonate concretions increasing to 2-3 per cent at the bottom. Occasional shell fragments.
<u>Classification</u>	Orthic Grumusert.

<u>Pit</u>	7175
<u>Topography</u>	Flat.
<u>Cultivation and Land Use</u>	Rough grazing.
<u>Vegetation</u>	<u>Acacia seyal</u> , <u>Acacia mellifera</u> , <u>Acacia fistula</u> 15/feddan. <u>Rottboellia exaltata</u> , <u>Ocimum basilicum</u> , <u>Sorghum purpureo-sericeum</u> and <u>Cymbopogon giganteum</u> .
<u>Surface</u>	Level. Abundant large cracks 8 cm diameter. Blocks 30-40 cm diameter. Loose, fine sub-angular blocky mulch.
<u>Profile Description</u>	
0- 52 cm	2.5Y 3/2-10YR 3/2. Clay. Dry and extremely hard at the top, becoming very slightly moist and very firm lower down. Moderate coarse sub-angular to angular blocky. Abundant cracks, with large vertical ones to the bottom of the horizon. Occasional roots. Frequent shell fragments and very small calcium carbonate concretions.
52- 75 cm	2.5Y 3/2 - 10YR 3/2. Clay. Slightly moist. Very firm. Moderate, fine and medium angular blocky, formed by small slickensides. Abundant fine cracks. Occasional roots. Frequent shell fragments, and very small calcium carbonate concretions.
75-200 cm	10YR 3/1 - 3/2 grading into 10YR 3/2 - 4/2 at the bottom. Sandy clay. Slightly moist. Very firm. Massive with occasional large vertical cracks, drying out to weak, coarse sub-angular blocky. Frequent large slickensides at the bottom, inclined at 50°. Calcium carbonate concretions increasing to 2-3 per cent at the bottom. Occasional shell fragments.
<u>Classification</u>	Orthic Grumustert.

<u>Pit</u>	7214
<u>Topography</u>	7193
<u>Cultivation and Land Use</u>	Sloping from grassland plain towards a khor.
<u>Vegetation</u>	Rough grazing. Patches of <u>Sorghum vulgare</u> (dura). Rough grazing. Patches of <u>Sesamum indicum</u> . Occasional small <u>Acacia senegal</u> . Dense <u>Ischaemum afrum</u> and <u>Cymbopogon giganteum</u> .
<u>Surface</u>	Uneven. Heavily cracked. Loose sub-angular blocky mulch.
<u>Profile Description</u>	
<u>Profile Description</u>	
0- 65 cm	10YR 3/2. Clay. Dry. Extremely firm.
0- 90 cm	10YR 3/2 - 2.5Y 3/2. Clay. Dry and extremely hard at the top. Slightly moist and extremely firm below. Moderate coarse sub-angular blocky. Abundant vertical cracks of up to 10 cm diameter. Abundant fine cracks. Frequent roots. There is a tendency to break up into angular blocky fragments at the bottom, due to the presence of slickensides. Occasional small calcium carbonate concretions and shell fragments.
65-125 cm	
90-200 cm	10YR 3/2 - 2.5Y 3/2. Clay. Slightly moist. Extremely firm. Massive. Occasional cracks and roots. Tendency around the pit to form weak sub-angular blocky structures, and to become less massive towards the bottom. 1-2 per cent finely divided calcium carbonate concretions.
125-200 cm	
<u>Classification</u>	Natrargidic Grumustert.
<u>Classification</u>	Natrargidic Grumustert.

<u>Pit</u>	7214
<u>Topography</u>	Flat
<u>Cultivation and Land Use</u>	Rough grazing. Patches of <u>Sorghum vulgare</u> (dura)
<u>Vegetation</u>	<u>Acacia mellifera</u> , <u>Balanites aegyptiaca</u> , <u>Acacia seyal</u> , <u>Acacia senegal</u> , <u>Cadaba rotundifolia</u> , 5/feddan.
<u>Surface</u>	<u>Sorghum purpureo-sericeum</u> and <u>Ischaemum afrum</u> .
<u>Surface</u>	Heavily cracked. Mulched by trampling. recent rain.
<u>Profile Description</u>	
0- 65 cm	10YR 3/2. Clay. Dry. Extremely hard. Strong coarse sub-angular blocky. Abundant vertical cracks to the bottom of the horizon. Frequent horizontal cracks. Occasional roots. Beginnings of slickensides formation at the bottom, forming strong fine-medium, angular blocky peds. Abundant very small calcium carbonate concretions.
63- 80 cm	
65-125 cm	10YR 3/2 - 2.5Y 3/2, with tongues of 10YR 3/1 towards the bottom. Clay. Slightly moist. Very firm. Massive, drying out to weak coarse sub-angular blocky. Occasional cracks. No roots. Traces of calcium carbonate.
80-130 cm	
125-200 cm	10YR 3/1 with tongueing down from above. Clay. Slightly moist. Very firm. Massive. No cracks or roots. 2 per cent small calcium carbonate concretions.
130-200 cm	
<u>Classification</u>	Natrargidic Grumustert Calcium carbonate at the top, decreasing with depth.
<u>Classification</u>	Natrargidic Grumustert.

<u>Pit</u>	7224
<u>Topography</u>	Flat plain near the river.
<u>Cultivation and Land Use</u>	Small patches of <u>Sorghum vulgare</u> (dura)
<u>Vegetation</u>	Fairly dense <u>Sorghum purpureo-sericeum</u> and occasional <u>Cymbopogon giganteum</u> .
<u>Surface</u>	Frequent cracks. Loose sub-angular blocky mulch in parts. Rain crust formed after recent rain.
<u>Profile Description</u>	over a thin granular mulch. Occasional small calcium carbonate concretions and shells.
0- 63 cm	10YR 3/2 - 2.5Y 3/2. Clay. Dry and extremely hard at the top. Very slightly moist and very firm below.
<u>Profile Description</u>	Moderate, coarse sub-angular blocky, with fine incipient platiness. Frequent vertical cracks 5 cm diameter and occasional horizontal ones. Frequent fine roots. Frequent very small calcium carbonate concretions.
63- 80 cm	2.5Y 3/2-10YR 3/2; with tonguing up of 10YR 3/1. Clay. Very slightly moist. Very firm. Abundant small slickensides along the cracks in all directions, forming angular blocky fragments. Occasional roots. Traces of calcium carbonate.
80-130 cm	10YR 3/1. Clay. Very slightly moist. Very firm. Massive to weak, coarse sub-angular blocky.
135-200 cm	Occasional cracks. Few roots. Calcium carbonate increasing to 2-3 per cent at the bottom.
130-200 cm	10YR 3/2. Clay. Very slightly moist. Very firm. Massive. No cracks or roots. 2-3 per cent Calcium carbonate at the top, decreasing with depth.
<u>Classification</u>	Natrargidic Grumustert.

<u>Pit</u>	7225
<u>Topography</u>	Flat plain near the river.
<u>Cultivation and Land Use</u>	Rough grazing.
<u>Vegetation</u>	<u>Acacia seyal</u> , <u>Capparis decidua</u> , <u>Acacia nubica</u> , <u>Balanites aegyptiaca</u> , 8/feddan. Clumps of <u>Cymbopogon nervatus</u> .
<u>Surface</u>	Occasional cracks. Recently formed rain crust over a thin granular mulch. Occasional small calcium carbonate concretions and shells.
<u>Profile Description</u>	
0- 65 cm	10YR 3/2. Clay. Very slightly moist. Very firm. Moderate coarse sub-angular blocky. Cracks poorly defined. Roots frequent. Occasional small calcium carbonate concretions. Occasional sand lenses.
65-185 cm	10YR 3/2 ^h . Clay. Very slightly moist. Very firm. Probably massive. Cracking on drying into fine and medium sub-angular and angular blocky. Less massive at the bottom. Occasional cracks and roots. Frequent sand deposits. Calcium carbonate concretions increasing to 3 per cent at the bottom.
140-200 cm	
185-200 cm	10YR 4/2. Sandy-clay. Slightly moist, becoming wet at the bottom due to recent rain. Soft. Structureless. No cracks or roots. Occasional calcium carbonate concretions at the top.
<u>Classification</u>	
<u>Classification</u>	Orthic Grumustert.

Pit 7233

Topography Undulating

Cultivation and Land Use Patches of Sesamum indicum (simsim) Sesamum

Vegetation Acacia seyal, Balanites aegyptiaca 20/feddan,
Vegetation Cymbopogon nervatus, Rottboellia exaltata, gyptiaca,
Ischaemum afrum. feddan, and one Calotropus

Surface Broken up rain-crust. Loose fine and medium imum
Surface sub-angular blocky mulch. Occasional shell
fragments. racks. Loose rain crust over a thin loose
sub-angular blocky mulch. Occasional small calcium
carbonate concretions.

Profile Description

0- 90 cm 10YR 4/2-3/3. Clay. Dry. Very hard. Strong
Profile Description coarse sub-angular blocky. Frequent vertical
0- 48 cm cracks of 5 cm diameter. Incipient platiness
down to 40 cm. Occasional roots. Occasional hard.
shell fragments. b-angular blocky. Frequent

90-140 cm 10YR 3/3 with 10YR 3/2 mottles at the bottom.
Clay. Very slightly moist. Very firm. Weak
coarse sub-angular blocky around vertical cracks
extending from above. Occasional clay skins and
small slickensides. Shell fragments rare.

140-200 cm 10YR 3/2. Clay. Very slightly moist, becoming
moist at the bottom. Extremely firm. Massive.
No cracks. Occasional roots. Occasional large
slickensides. Traces of calcium carbonate.
rare. Occasional shell fragments. Occasional very
fine sand lenses. Traces of calcium carbonate
towards the bottom.

Classification Orthic Grumustert.

Classification Entic Natrargidic Grumustert

Pit 7242

Topography Flat.

Cultivation and Land Use Slightly undulating
Patches of Sorghum vulgare (dura) and Sesamum indicum (simsim). Rough grazing.

Vegetation Acacia seyal. Acacia fistula. Balanites aegyptiaca, Acacia nubica, 10/feddan, and one Calotropus procera. Occasional Sorghum sp. (addar). Ocimum basilicum and Ischaemum afrum.

Surface Description Frequent cracks. Loose rain crust over a thin loose sub-angular blocky mulch. Occasional small calcium carbonate concretions.

Profile Description

0- 38 cm 10YR 4/2.-2.5Y 4/2 gradually darkening to 10YR 3/2 - 2.5Y 3/2. Clay, Dry. Extremely hard. Strong coarse sub-angular blocky. Frequent vertical cracks, and a well-developed fine laminar structure within blocks. Small incipient slickensides at the bottom. Roots rare. Occasional small calcium carbonate concretions. Occasional shell fragments.

38- 70 cm 10YR 3/2 - 2.5Y 3/2. Clay. Slightly moist. Extremely firm. Weak coarse sub-angular blocky. No cracks but an abundance of small slickensides, which become less numerous towards the bottom. Roots rare. Occasional shell fragments. Occasional very fine sand lenses. Traces of calcium carbonate towards the bottom.

70-200 cm

48-200 cm

Classification Entic Natrargidic Grumustert

<u>Pit</u>	7243
<u>Topography</u>	Slightly undulating
<u>Cultivation and Land Use</u>	Rough grazing.
<u>Vegetation</u>	<u>Acacia mellifera</u> , <u>Acacia seyal</u> , occasional <u>Cadaba rotundifolia</u> 5/feddan. <u>Sorghum purpureosericeum</u> .
<u>Surface</u>	Abundant large cracks. Rain crust in places.
<u>Profile Description</u>	
0- 38 cm	10YR 3/2-3/1. Clay. Dry. Extremely hard. Moderate- strong coarse sub-angular blocky. Frequent vertical cracks, better developed than the horizontal ones. Incipient platiness in parts. Frequent roots. Frequent very small calcium carbonate deposits.
38- 70 cm	10YR 3/2. Clay. Very slightly moist. Very firm. Weak coarse sub-angular blocky. Frequent fine cracks. Occasional roots. Traces of calcium carbonate.
70-200 cm	10YR 3/1-2/1. Clay. Slightly moist. Extremely firm. Massive. No cracks or roots. Occasional calcium carbonate deposits throughout.
<u>Classification</u>	Natrargidic Grumaquert.

Sample No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Excb. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
54	0-45	5	19	76	1.45	74	1.50	10.9	14.4	A11	3a
55	45-90	32	7	61	2.20	76	2.10	12.3	20.1		
56	0-45	25	12	63	1.80	69	1.73	12.3	19.5	A12	6a/3a
57	45-90	22	17	61	3.30	66	2.80	24.4	40.0		
58	0-45	0	12	88	0.34	73	0.18	1.8	2.0	A11	2
59	45-90	8	11	81	3.20	64	2.60	11.4	14.1		
60	0-45	25	17	58	0.80	73	0.64	4.2	7.2	A11	2
61	45-90	27	22	51	5.20	64	3.40	7.0	13.7		
62	0-45	15	14	71	2.0	71	1.50	6.5	9.2	B11	3a
63	45-90	10	14	76	1.80	72	1.42	13.0	17.1		
64	0-45	2	15	83	0.55	74	0.37	2.0	2.4	A11	3a
65	45-90	17	17	66	1.72	69	1.40	12.2	18.5		
66	0-45	5	12	83	0.24	83	0.11	0.7	0.8	A11	2
67							1.1	6.1	8.3		
68									1.6	A13	2
69								1.8	2.5		
70	0-45	13	19	68	0.19	52	0.10	0.7	1.0	A11	2
71	45-90	13	19	68	0.30	43	0.16	1.8	2.6		
72	0-45	32	15	53	0.19	42	0.10	0.3	0.6	A13	2
73	45-90	35	12	53	0.20	59	0.15	0.2	0.4		
74	0-45	30	12	58	0.24	42	0.10	0.7	1.2	A23	2
75	45-90	32	24	44	0.26	47	0.12	0.7	1.6		
76	0-45	22	15	63	0.22	46	0.10	1.1	1.7	A13	2
77	45-90	25	9	66	0.32	48	0.12	3.1	4.7		
78	0-45	27	15	58	0.22	51	0.10	0.7	1.2	A11	2
79	45-90	22	15	63	0.28	47	0.12	0.7	1.1		
80	0-45	12	20	68	0.24	61	0.15	1.0	1.8	A11	2
81	45-90	20	30	50	0.40	58	0.30	6.1	12.2		
85	0-45	37	10	53	3.0	59	2.22	13.0	24.6	B12	6a
86	45-90	22	12	66	2.66	65	2.20	13.0	19.7		

APPENDIX I

(a) Soil profile descriptions at 10 pits

(b) Analytical data from 151 sites sampled at fixed depth and from 10 pits sampled by natural horizons

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7121	70154	0-45	5	19	76	1.45	74	1.50	10.9	14.4	A11	3a
	55	45-90	32	7	61	2.20	76	2.10	12.3	20.1		
7122	56	0-45	25	12	63	1.80	69	1.73	12.3	19.5	A12	6a/4a
	57	45-90	22	17	61	3.30	66	2.80	24.4	40.0		
7123	58	0-45	0	12	88	0.34	73	0.18	1.8	2.0	A11	2
	59	45-90	8	11	81	3.20	64	2.60	11.4	14.1		
7124	60	0-45	25	17	58	0.80	73	0.64	4.2	7.2	A11	2
	61	45-90	27	22	51	5.20	64	3.40	7.0	13.7		
7125	62	0-45	15	14	71	2.0	71	1.50	6.5	9.2	B11	3a
	63	45-90	10	14	76	1.80	72	1.42	13.0	17.1		
7126	64	0-45	2	15	83	0.55	74	0.37	2.0	2.4	A11	3a
	65	45-90	17	17	66	1.72	69	1.40	12.2	18.5		
7127	66	0-45	5	12	83	0.24	83	0.11	0.7	0.8	A11	2
	67	45-90	15	12	73	1.70	67	1.1	6.1	8.3		
7128	68	0-45	12	17	71	0.20	62	0.10	1.1	1.6	A13	2
	69	45-90	12	15	73	0.28	60	0.15	1.8	2.5		
7129	70	0-45	13	19	68	0.19	52	0.10	0.7	1.0	A11	2
	71	45-90	13	19	68	0.30	43	0.16	1.8	2.6		
7130	72	0-45	32	15	53	0.19	42	0.10	0.3	0.6	A13	2
	73	45-90	35	12	53	0.20	59	0.15	0.2	0.4		
7131	74	0-45	30	12	58	0.24	42	0.10	0.7	1.2	A23	2
	75	45-90	32	24	44	0.26	47	0.12	0.7	1.6		
7132	76	0-45	22	15	63	0.22	46	0.10	1.1	1.7	A13	2
	77	45-90	25	9	66	0.32	48	0.12	3.1	4.7		
7133	78	0-45	27	15	58	0.22	51	0.10	0.7	1.2	A11	2
	79	45-90	22	15	63	0.28	47	0.12	0.7	1.1		
7134	80	0-45	12	20	68	0.24	61	0.15	1.0	1.5	A11	2
	81	45-90	20	30	50	0.40	58	0.30	6.1	12.2		
7135	85	0-45	37	10	53	3.0	59	2.22	13.0	24.6	B12	6a
	86	45-90	22	12	66	2.66	65	2.20	13.0	19.7		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7136	70187	0-45	7	15	78	0.34	58	0.14	1.1	1.4	A11	3a
	88	45-90	22	15	63	2.80	53	1.90	11.3	17.9		
7137	89	0-45	15	17	68	1.70	62	1.17	5.6	8.2	A11	2
	90	45-90	26	13	61	2.80	60	2.20	9.0	14.8		
7138	91	0-45	18	16	66	0.26	55	0.10	0.7	1.1	A11	2
	92	45-90	28	14	58	2.60	62	2.00	7.6	13.1		
7139	93	0-45	13	16	71	0.22	61	0.15	0.6	0.8	A11	2
	94	45-90	18	14	68	2.70	58	1.94	8.9	13.1		
7140	95	0-45	16	18	66	0.20	55	0.10	0.7	1.1	A11	2
	96	45-90	16	16	68	0.28	54	0.14	2.3	3.4		
7141	97	0-45	31	18	51	4.60	59	3.80	12.2	23.9	A12	6a
	98	45-90	15	14	71	1.80	65	1.46	9.7	13.7		
7142	99	0-45	20	17	63	2.60	64	1.92	6.1	9.7	B11	2
	70200	45-90	12	15	73	1.05	65	0.89	10.7	14.6		
7143	201	0-45	22	20	58	0.60	68	0.51	6.7	11.6	B13	6a/2
	202	45-90	32	10	58	0.54	76	0.27	18.1	31.2		
7144	203	0-45	42	12	46	0.22	55	0.10	1.5	3.3	A11/C23	3a1
	204	45-90	30	12	58	2.60	62	1.86	10.9	18.8		
7145	205	0-45	15	14	71	0.60	61	0.33	4.5	6.3	A11	3a
	206	45-90	25	14	61	3.60	69	3.10	14.9	24.4		
7146	207	0-45	5	12	83	0.28	72	0.18	3.0	3.6	A11	6a/2
	208	45-90	15	12	73	2.10	70	1.74	20.7	28.4		
7147	209	0-45	30	14	56	0.75	63	0.48	6.7	12.0	B11	2
	210	45-90	12	15	73	1.70	69	1.30	9.9	13.6		
7148	211	0-45	20	14	66	1.58	64	0.95	3.0	4.5	B11	2
	212	45-90	25	17	58	4.0	60	2.90	5.1	8.8		
7149	213	0-45	2	15	83	0.30	71	0.18	4.6	5.5	A11	3a
	214	45-90	17	15	68	3.0	66	2.30	14.9	21.9		
7150	215	0-45	21	13	66	3.40	66	2.60	11.4	17.3	A12	6a/4a
	216	45-90	31	11	58	1.90	56	1.34	14.7	25.4		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
151	70217	0-45	11	16	73	1.80	57	1.3	10.7	14.6	A13	6a/2
	18	45-90	11	13	76	1.70	66	1.34	19.1	25.2		
152	19	0-45	18	16	66	1.30	70	1.12	12.1	18.4	A12	6a/4a
	20	45-90	26	16	58	4.50	71	4.2	18.2	31.4		
153	21	0-45	16	13	71	0.40	82	0.41	5.6	7.9	B11	3a
	22	45-90	21	13	66	2.60	65	2.20	13.8	20.9		
154	23	0-45	3	14	83	0.28	87	0.22	6.6	7.9	A11	3a
	24	45-90	16	16	68	0.70	83	0.73	12.9	19.0		
155	25	0-45	8	24	68	0.40	74	0.28	4.5	6.6	A13	3a
	26	45-90	21	18	61	2.60	68	2.10	12.3	20.2		
156	27	0-45	11	13	76	0.26	66	0.17	4.6	6.0	A11	3a
	28	45-90	8	26	66	1.54	56	0.83	12.0	18.2		
157	31	0-45	16	16	68	1.60	91	1.71	9.1	13.4	A11	3a
	32	45-90	13	19	68	0.90	80	0.80	15.2	22.4		
158	33	0-45	16	16	68	3.0	77	3.00	19.4	28.5	A12	6a
	34	45-90	16	23	61	0.70	67	0.42	6.8	11.2		
159	35	0-45	8	26	66	1.50	72	1.17	8.8	13.3	A11	6a/2
	36	45-90	21	13	66	2.20	63	1.74	19.9	30.2		
160	37	0-45	11	16	73	1.05	75	0.76	7.6	10.4	B11	3a
	38	45-90	23	16	61	2.80	64	2.20	13.0	21.3		
161	39	0-45	33	13	54	1.3	55	1.00	23.8	44.1	A12	6a
	40	45-90	33	16	51	0.65	64	0.48	3.5	6.9		
162	41	0-45	8	11	81	0.31	87	0.33	4.1	5.1	A11	3a
	42	45-90	28	16	56	3.0	66	2.60	11.8	21.1		
163	43	0-45	3	16	81	0.3	74	0.37	6.0	7.4	B11	6a/2
	44	45-90	38	13	49	4.2	62	3.50	12.5	25.5		
164	45	0-45	20	16	64	0.95	67	1.00	7.8	12.2	A11	6a/2
	46	45-90	28	11	61	1.9	71	1.95	33.6	55.1		
165	47	0-45	28	13	59	0.95	74	0.93	4.6	7.8	B11	3a
	48	45-90	33	16	51	1.30	62	1.25	9.5	18.6		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7166	7024	0-45	8	13	79	0.32	75	0.47	5.9	7.5	A11	6a/2
	50	45-90	20	16	64	2.2	62	2.40	25.6	40.0		
7167	51	0-45	3	16	81	0.4	83	0.83	6.8	8.4	A11	3a
	52	45-90	25	11	64	0.66	65	0.65	10.9	17.0		
7168	53	0-45	15	14	71	0.93	71	0.90	6.3	8.9	A11	2
	54	45-90	25	11	64	1.60	75	1.50	8.1	12.6		
7169	55	0-45	18	13	69	2.10	79	1.90	23.7	34.5	A12	6a
	56	45-90	68	8	24	1.60	35	0.88	5.5	22.9		
7170	57	0-45	10	16	74	1.20	77	1.17	10.0	13.5	A11	2
	58	45-90	68	11	21	0.65	36	0.31	2.5	11.9		
7171	59	0-45	13	13	74	1.10	78	0.97	5.8	7.8	A11	2
	60	45-90	33	13	54	1.70	58	1.30	6.3	11.7		
7172	61	0-45	23	13	64	1.0	64	0.80	3.6	5.6	A11	3a
	62	45-90	38	11	51	0.72	64	0.64	9.0	17.6		
7173	63	0-45	13	16	71	1.80	65	1.64	11.6	16.4	A12	4a
	64	45-90	65	9	26	0.95	36	0.54	3.9	15.0		
7174	65	0-45	3	16	81	0.50	77	0.54	6.7	8.3	A11	2
	66	45-90	40	14	46	0.66	63	0.56	2.2	4.8		
7175	67	0-45	63	16	21	1.3	59	1.03	4.5	21.9	A11	2
	68	45-90	23	16	61	0.8	68	0.67	5.3	8.7		
7176	72	0-45	28	16	56	2.3	63	1.90	14.1	25.2	A12	6a
	73	45-90	18	18	64	2.4	61	2.0	14.4	22.5		
7177	74	0-45	3	16	81	0.48	58	0.44	10.0	12.4	A11	3a
	75	45-90	25	11	64	1.1	63	0.95	9.8			
7178	76	0-45	24	14	62	0.8	72	0.31	4.5	7.2	A11	6a/2
	77	45-90	54	9	37	2.1	51	1.50	17.7	47.8		
7179	78	0-45	8	13	79	0.97	77	0.87	7.5	9.5	A13	6a/2
	79	45-90	23	18	59	4.5	72	4.20	17.0	28.8		
7180	80	0-45	10	14	76	1.4	83	1.50	14.1	18.6	A12	4a
	81	45-90	33	13	54	1.8	62	1.40	10.2	18.9		
	14	0-45	15	11	74	0.36			12.0		A13	6a/2
	15	45-90	13	19	69	3.60			28.0			

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7181	70282	0-45	18	11	71	2.5	78	2.40	14.8	20.8	B12	6a
	83	45-90	35	11	54	1.8	67	1.50	12.1	22.4		
7182	84	0-45	5	11	84	0.42	74	0.03	12.77	15.2	A12	6a/4a
	85	45-90	18	13	69	2.40	75	2.30	27.7	40.2		
7183	86	0-45	23	13	64	2.2	71	1.90	12.9	20.2	A12	6a
	87	45-90	33	11	56	1.7	67	1.40	7.0	12.5		
7184	88	0-45	23	13	64	0.9	80	0.80	8.8	13.7	B11	3a
	89	45-90	15	14	71	1.7	97	2.03	11.97	16.9		
7185	90	0-45	18	11	71	1.5	58	1.15	30.0	42.3	A14	6a
	91	45-90	28	14	58	3.6	70	3.30	21.9	37.8		
7186	92	0-45	25	11	64	2.8	73	2.60	15.8	24.7	A12	6a
	93	45-90	33	11	56	2.1	70	2.10	20.7	37.0		
7187	94	0-45	18	13	69	0.7	73	0.73	10.1	14.7	A11	3a
	95	45-90	25	13	62	4.2	62	3.40	13.4	21.6		
7188	96	0-45	18	13	69	1.8	78	1.90	14.9	21.6	A12	6a
	97	45-90	23	13	64	3.4	77	3.70	17.1	26.7		
7189	98	0-45	15	14	71	0.44	83	0.04	3.96	5.6	A11	6a/3s
	99	45-90	40	14	46	5.60	61	4.30	11.3	24.6		
7190	70300	0-45	18	13	69	0.41	72	0.03	4.37	6.4	B11	6a/2
	1	45-90	28	12	60	4.50	68	4.30	18.5	30.8		
7191	2	0-45	8	16	76	1.30	77	1.35	9.4	12.4	A11	6a/2
	3	45-90	25	12	63	3.0	75	3.0	16.6	26.3		
7192	4	0-45	15	14	71	0.85	78	0.78	9.6	13.5	A11	6a/2
	5	45-90	25	11	64	4.4	68	3.90	26.5	41.4		
7193	6	0-45	28	13	59	4.9	95	4.50	9.1	15.4	A12	6a/4a
	7	45-90	28	12	60	4.7	71	4.30	22.1	36.9		
7194	10	0-45	28	11	61	2.8	68	2.60	20.2	33.2	A12	6a
	11	45-90	23	13	64	1.8	68	1.70	24.7	38.6		
7195	12	0-45	38	11	51	1.4	60	1.05	15.7	30.8	B14	6a
	13	45-90	28	11	61	2.2	64	1.75	19.4	31.8		
7196	14	0-45	15	11	74	0.38	77	0.29	8.9	12.0	A13	6a/2
	15	45-90	13	19	68	2.60	83	2.60	19.0	28.0		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7197	70316	0-45	30	14	56	3.60	63	2.90	21.1	37.7	A14	6a
	17	45-90	30	11	59	2.40	69	2.10	19.5	33.0		
7198	18	0-45	20	14	66	0.7	56	0.42	15.6	23.6	A12	6a
	19	45-90	30	14	56	2.6	64	2.20	17.8	31.8		
7199	20	0-45	15	14	71	1.6	70	1.60	16.4	23.1	A12	6a
	21	45-90	23	13	64	4.5	75	4.90	28.7	44.9		
7200	22	0-45	20	14	66	2.0	74	2.0	19.6	29.7	A12	6a
	23	45-90	25	14	61	2.6	80	2.60	15.8	26.0		
7201	24	0-45	30	14	56	0.44	71	0.03	7.17	12.8	B11	3a
	25	45-90	38	11	51	0.63	58	0.04	11.96	23.5		
7202	26	0-45	13	11	76	3.0	67	2.50	17.1	22.5	A12	6a
	27	45-90	20	16	64	2.4	77	2.40	11.6	18.1		
7203	28	0-45	20	11	69	2.4	74	2.20	15.8	22.8	A12	6a
	29	45-90	23	13	64	2.6	73	2.70	18.1	28.3		
7204	30	0-45	23	13	64	2.6	70	2.50	16.7	26.1	A12	6a
	31	45-90	25	14	61	3.6	75	3.60	14.8	24.3		
7205	32	0-45	28	11	61	1.5	75	1.30	13.1	21.5	A12	6a
	33	45-90	20	14	66	1.2	71	1.15	20.8	31.6		
7206	34	0-45	25	17	58	1.7	79	0.40	2.8	4.8	A11	3a
	35	45-90	23	17	60	3.8	77	2.80	9.2	15.3		
7207	36	0-45	23	11	66	2.6	73	2.50	16.3	24.7	A14	6a
	37	45-90	48	8	44	7.0	58	4.50	7.1	16.1		
7208	38	0-45	28	11	61	0.55	69	0.52	8.3	13.6	A11	6a/2
	39	45-90	20	14	66	2.40	72	2.30	18.1	27.5		
7209	40	0-45	15	14	71	0.38	74	0.28	4.5	6.3	A11	6a/2
	41	45-90	25	16	59	3.4	69	3.10	15.7	26.6		
7210	42	0-45	33	13	54	2.8	64	2.40	12.8	23.7	A12	6a
	43	45-90	30	14	56	2.9	58	2.30	11.7	20.8		
7211	44	0-45	15	14	71	0.72	69	0.52	22.7	32.0	B12	6a
	45	45-90	23	13	64	4.6	67	4.0	18.8	29.4		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
2127	0346	0-45	9	15	76	0.42	93	0.47	5.1	6.7	A11	3a
	47	45-90	34	10	56	1.90	73	1.70	9.5	17.0		
213	48	0-45	21	16	63	3.10	66	2.70	18.9	30.0	B12	6a
	49	45-90	19	25	56	3.20	80	3.40	14.6	26.1		
214	50	0-45	39	8	53	1.10	63	0.87	11.1	21.0	A12	6a
	51	45-90	29	13	58	5.2	82	6.30	27.3	47.0		
215	55	0-45	29	13	58	2.8	60	2.40	12.0	20.6	A12	6a
	56	45-90	19	Floc.		5.0	77	5.40	18.6			
216	57	0-45	31	13	56	1.2	130	1.96	14.8	26.5	B12	6a
	58	45-90	34	11	55	2.15	87	2.30	16.1	29.3		
217	59	0-45	31	11	58	1.40	69	1.50	17.7	30.5	B12	6a
	60	45-90	21	16	63	1.50	71	2.80	24.4	38.6		
218	61	0-45	19	18	63	3.60	85	4.70	17.7	28.1	A14	6a
	62	45-90	19	15	66	2.80	85	3.90	22.5	34.1		
219	63	0-45	21	16	63	1.35	89	1.84	23.4	37.2	A12	6a
	64	45-90	11	13	76	2.60	73	3.00	26.6	35.0		
220	65	0-45	21	13	66	1.75	74	1.86	14.5	22.0	A12	6a
	66	45-90	26	16	58	2.50	72	2.80	20.4	35.2		
221	67	0-45	19	13	68	1.70	74	1.85	10.1	14.9	B11	6a/2
	68	45-90	14	18	68	2.30	74	2.50	27.9	41.0		
222	69	0-45	31	16	53	1.50	66	1.32	9.9	18.7	B12	6a/4a
	70	45-90	34	13	53	1.85	67	1.80	22.2	42.0		
223	71	0-45	16	17	67	0.46	77	0.24	3.0	4.4	B11	2
	72	45-90	14	15	71	0.38	91	0.34	5.3	7.5		
224	73	0-45	14	13	73	1.45	70	1.70	15.9	21.8	A12	6a
	74	45-90	14	18	68	1.50	78	1.70	19.1	28.1		
225	78	0-45	16	13	71	0.43	84	0.48	5.1	7.2	A11	3a
	79	45-90	29	13	58	0.96	67	0.83	9.6	16.5		
226	83	0-45	16	13	71	1.70	71	1.50	22.5	31.5	A14	6a
	84	45-90	26	18	56	4.00	74	4.20	24.2	43.3		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
7227	70385	0-45	24	20	56	2.30	74	2.40	23.2	41.5	A12	6a
	86	45-90	41	11	48	5.00	60	4.60	22.6	47.1		
7228	87	0-45	6	16	78	0.40	83	0.52	10.7	13.7	A11	6a/2
	88	45-90	21	16	63	2.00	76	1.90	18.9	30.0		
7229	89	0-45	6	16	78	0.56	85	0.42	5.2	6.7	A11	2
	90	45-90	54	13	33	2.50	63	1.02	2.98	9.1		
7230	91	0-45	26	31	43	0.22	74	0.92	1.1	2.6	C23	31
	92	45-90	31	28	41	0.90	67	0.55	1.4	3.4		
7231	93	0-45	4	13	83	0.35	74	0.37	12.0	14.4	A11	3a
	94	45-90	19	14	67	1.75	72	1.44	10.6	15.8		
7232	95	0-45	4	18	78	0.52	78	0.54	13.5	17.3	A14	4a
	96	45-90	6	13	81	1.60	93	1.87	17.3	21.4		
7233	97	0-45	19	28	53	0.32	68	0.17	0.6	1.1	A11	6a/2
	98	45-90	36	13	51	2.90	65	2.40	13.6	26.6		
7234	70402	0-45	11	16	73	0.95	71	0.85	11.9	16.3	A12	4a
	3	45-90	16	16	68	2.20	74	2.20	16.2	23.8		
7235	4	0-45	6	16	78	0.37	87	0.43	6.0	7.7	A11	2
	5	45-90	4	15	81	0.65	81	0.59	7.4	9.1		
7236	6	0-45	4	13	83	0.25	81	0.21	1.0	1.2	A13	6a/2
	7	45-90	26	13	61	3.60	74	3.20	17.6	28.9		
7237	8	0-45	14	13	73	0.30	85	0.32	2.1	2.9	A13	2
	9	45-90	9	13	78	0.90	78	0.82	11.2	14.4		
7238	10	0-45	29	13	58	1.40	65	1.06	7.3	12.6	A11	6a/2
	11	45-90	21	18	61	2.10	77	2.10	21.9	36.0		
7239	12	0-45	26	13	61	0.38	75	0.37	8.0	13.1	A11	6a/2
	13	45-90	34	11	55	2.60	75	2.80	14.8	27.0		
7240	14	0-45	9	13	78	0.42	87	0.33	2.9	3.7	A11	3a
	15	45-90	34	8	58	1.80	71	1.42	12.2	21.0		
7241	16	0-45	31	13	56	2.00	56	1.05	10.5	18.8	A12	4a
	17	45-90	39	10	51	1.80	81	1.80	5.0	9.8		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
72427	0418	0-45	24	15	61	1.40	80	1.60	12.0	19.7	A14	6a/4a
	19	45-90	29	10	61	3.0	80	3.30	21.5	35.3		
7243	22	0-45	19	13	68	0.50	69	0.43	16.4	24.1	B12	6a
	23	45-90	29	13	58	2.60	69	2.40	18.4	31.7		
7244	27	0-45	5	13	82	0.36	90	0.67	3.7	4.5	A11	3a
	28	45-90	30	16	54	3.60	75	3.70	9.5	17.6		
7245	29	0-45	3	13	84	0.36	73	0.36	6.0	7.1	A11	3a
	30	45-90	35	11	54	3.60	63	2.90	11.5	21.3		
7246	31	0-45	3	13	84	0.35	77	0.38	6.8	8.1	A11	3a
	32	45-90	20	13	67	2.00	74	1.95	10.8	16.1		
7247	33	0-45	13	13	74	0.57	83	0.52	3.1	4.2	A11	3a
	34	45-90	20	13	67	1.90	80	1.90	10.9	16.3		
7248	35	0-45	15	11	74	1.15	75	0.95	6.6	8.9	A11	3a
	36	45-90	30	16	54	4.20	66	3.20	12.8	23.7		
7249	37	0-45	8	13	79	0.31	73	0.28	4.9	6.2	A11	2
	38	45-90	18	10	72	1.00	70	0.97	9.8	13.6		
7250	39	0-45	10	11	79	0.38	73	0.46	11.5	14.6	A11	3a
	40	45-90	28	13	59	4.40	74	3.90	9.7	16.4		
7251	41	0-45	8	10	82	0.38	75	0.38	3.6	4.4	A11	2
	42	45-90	8	11	81	0.44	78	0.40	5.6	6.9		
7252	43	0-45	18	10	72	0.95	75	0.85	8.3	11.5	A11	2
	44	45-90	20	13	67	1.25	72	1.10	8.5	12.7		
7253	45	0-45	23	13	64	1.10	66	0.90	8.3	13.0	A11	3a
	46	45-90	28	10	62	4.50	69	3.80	13.0	21.0		
7254	47	0-45	8	15	77	0.33	68	0.34	2.9	3.8	A11	2
	48	45-90	10	13	77	0.38	64	0.32	6.9	9.0		
7255	49	0-45	20	11	69	0.40	69	0.24	5.4	7.8	A13	2
	50	45-90	15	13	72	1.55	70	1.23	10.0	13.9		
7256	51	0-45	5	21	74	0.42	71	0.36	6.8	9.2	A11	2
	52	45-90	15	16	69	0.85	71	0.80	6.4	9.3		

Site No.	Sample 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	Land Class
			Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
257	70453	0-45	18	13	69	1.40	78	1.40	9.4	13.6	A11	3a
	54	45-90	18	13	69	1.65	73	1.45	12.1	17.6		
258	55	0-45	18	13	69	1.20	75	1.14	11.3	16.4	A12	4a
	56	45-90	20	13	67	1.75	80	2.0	9.2	13.7		
259	57	0-45	10	13	77	0.47	76	0.38	4.8	6.2	A11	3a
	58	45-90	25	13	62	1.90	61	1.40	12.2	19.7		
260	59	0-45	8	15	77	0.42	78	0.39	5.2	6.8	A11	3a
	60	45-90	10	11	79	1.02	79	1.0	13.0	16.4		
261	61	0-45	8	15	77	0.80	74	0.74	13.7	17.8	A12	4a
	62	45-90	13	10	77	1.45	75	1.30	14.7	19.1		
262	63	0-45	8	13	79	0.89	70	0.90	7.5	9.5	A11	3a
	64	45-90	13	13	74	1.22	72	1.0	14.2	19.2		
263	65	0-45	10	13	77	0.46	62	0.31	7.3	9.5	A11	3a
	66	45-90	15	11	74	1.30	72	1.10	13.7	18.5		
264	67	0-45	20	13	67	0.50	82	0.41	4.0	6.0	A11	3a
	68	45-90	13	13	74	1.40	71	1.15	13.2	17.8		
265	69	0-45	25	11	64	0.72	74	0.60	4.6	7.2	A11	3a
	70	45-90	28	15	57	1.85	62	1.40	9.0	15.8		
266	71	0-45	13	10	77	0.39	71	0.36	5.2	6.7	A11	3a
	72	45-90	18	10	72	2.50	70	2.30	14.5	20.0		
267	73	0-45	13	15	72	0.44	71	0.36	7.6	10.6	A11	3a
	74	45-90	13	20	67	1.55	70	1.40	15.4	23.0		
268	75	0-45	20	11	69	0.38	72	0.27	5.3	7.7	A11	2
	76	45-90	10	23	67	0.62	67	0.50	8.7	13.0		
269	77	0-45	13	13	74	0.48	75	0.38	6.8	9.2	A13	2
	78	45-90	10	18	72	0.89	75	0.75	9.6	13.3		
270	79	0-45	13	10	77	0.55	74	0.47	5.5	7.1	A11	3a
	80	45-90	13	10	77	1.10	73	0.92	11.9	15.4		
271	81	0-45	13	15	72	0.50	68	0.34	6.5	9.0	A13	3a
	82	45-90	10	13	77	0.69	67	0.60	13.0	16.9		

Site No.	Sample No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Sand		Silt 0.02-0.002 mm	Clay 0.002 mm	Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
							CS 2.0-0.2 mm	FS 0.2-0.02 mm						
7233	70399	0-90	8.18	7.62	0.32	71	13	30	19	58	0.18	1.4	61.5	
	70400	90-140	8.10	7.65	2.30	73	10	18	17	55	2.20	10.6	57.5	
	71	140-200	8.50	7.86	1.95	60	18	17	12	53	1.50	9.7	55.5	
7242	70420	0-48	8.05	7.57	2.20	78	2	16	14	68	2.10	9.9	66	
	21	48-200	8.80	8.25	0.82	62	22	6	14	58	0.78	12.0	59	
7243	70424	0-38	8.50	7.93	0.46	69	7	6	14	73	0.43	16.8	72.5	
	25	38-68	8.38	7.90	0.68	72	6	14	15	65	0.54	14.3	62.5	
	26	68-200	8.72	8.15	0.82	102	7	1	4	88	1.10	22.9	80	
7134	70182	0-46	7.92	7.72	0.5	65	4	11	20	65	0.16	0.2	70	
	83	46-140	8.38	7.62	0.77	67	6	12	17	65	0.5	3.5	70	
	84	140-200	8.46	8.0	0.58	64	7	13	28	52	0.4	2.8	55	
7156	70229	0-70	8.28	7.61	1.5	64	6	9	13	72	1.3	9.1	73	
	30	70-200	8.17	7.77	4.7	69	11	15	14	60	3.7	6.3	65	
	82	85-200	8.78	8.00	0.71	54	21	32	9	38	0.47	7.1	35	As per bore site.

Site No.	Sample 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 0.02-0.002 mm	Clay 0.002 mm				
							CS 2.0-0.2 mm	FS 0.2-0.02 mm						
7175	70269	0-52	8.00	7.61	4.10	65	12	13	10	65	7.2	10.4	62.5	As per bore site.
	70	52-75	8.52	7.74	1.90	73	9	11	12	68	1.9	15.7	71	
	71	75-200	8.20	7.65	7.80	52	33	17	10	40	5.6	12.8	42.5	
7193	70308	0-90	8.30	7.65	1.25	61	8	2	12	78	1.0	10.2	76	
	9	90-200	8.30	7.67	1.85	80	10	10	12	68	2.0	9.6	70	
7214	70352	0-65	8.28	7.65	2.10	70	16	14	12	58	2.0	11.2	60	
	53	65-125	8.80	8.02	0.68	76	6	24	15	55	0.77	8.0	57.5	
	54	125-200	8.59	7.88	3.10	60	16	12	14	58	2.50	11.9	60	
7224	70375	0-63	8.65	7.89	1.75	63	18	12	12	58	1.60	10.4	59	
	76	63-130	8.70	7.82	1.50	80	5	10	12	73	1.60	15.6	70	
	77	130-200	8.62	7.80	0.76	55	28	2	10	60	0.54	10.3	59	
7225	80	0-65	8.28	7.77	0.41	68	14	14	12	60	0.34	5.3	60	
	81	65-185	8.67	7.94	0.86	77	12	11	17	60	0.86	10.3	60	
	82	185-200	8.78	8.00	0.71	54	21	32	9	38	0.47	7.1	35	

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This report describes the exploratory engineering surveys which were carried out during the period March to May 1965 in the two areas.

The locations of the areas referred to above are shown on Figure 2 and the surveys are described in separate sections of the report.

OBJECTIVES OF THE EXPLORATORY SURVEYS(a) Guneid Area

- (i) The main objective of the survey was to demarcate for semi-detailed soil survey the areas which can be commanded by extension of the gravity irrigation supply from the Rahad Project.
- (ii) To survey the part of the Guneid Link Canal, some 15 to 20 kilometres in length, which traverses a ridge of high ground between the Rahad Project and the extension areas.

(b) Hawata Area

The objectives of the exploratory engineering survey in the Hawata area were :

- (i) To demarcate the extent of the land on the east bank of the River Bahad that can be commanded by gravity

1. INTRODUCTION

The proposed Rahad Project has a main canal taking off the River Rahad at Malek (lat. $13^{\circ}38'N$, long. $34^{\circ}32'E$) which supplies a net irrigable area of approximately 565,000 feddans, stretching from Tuneidba (lat. $13^{\circ}43'N$, long. $34^{\circ}23'E$) in the south to Wad Harras (lat. $14^{\circ}37'N$, long. $33^{\circ}37'E$) in the north, a distance of about 130 kilometres. In addition to the principal area between Tuneidba and Wad Harras supplied by the Project Main Canal further blocks of land can be made available for irrigation.

These possible extensions to the Project occur in two areas. In the north, in the vicinity of the Guneid Pump Scheme, and in the south, centred around the town of Hawata (lat. $13^{\circ}25'N$, long. $34^{\circ}48'E$).

This report describes the exploratory engineering surveys which were carried out during the period March to May 1965 in the two areas.

The locations of the areas referred to above are shown on Figure 2 and the surveys are described in separate sections of the report.

2. OBJECTIVES OF THE EXPLORATORY SURVEYS

(a) Guneid Area

- (i) The main objective of the survey was to demarcate for semi-detailed soil survey the areas which can be commanded by extension of the gravity irrigation supply from the Rahad Project.
- (ii) To survey the part of the Guneid Link Canal, some 15 to 20 kilometres in length, which traverses a ridge of high ground between the Rahad Project and the extension areas.

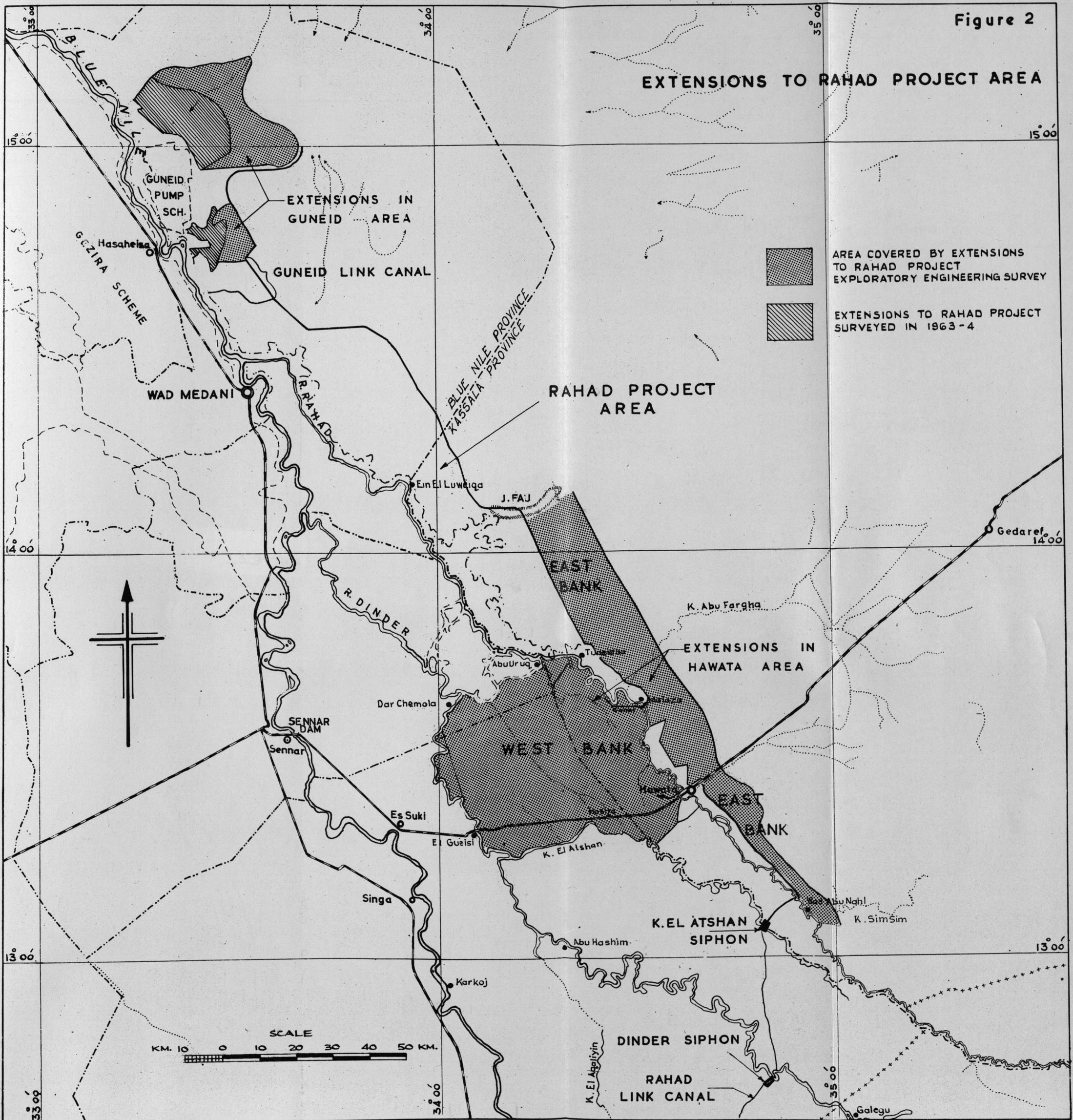
(b) Hawata Area

The objectives of the exploratory engineering survey in the Hawata area were :

- (i) To demarcate the extent of the land on the east bank of the River Rahad that can be commanded by gravity

Figure 2

EXTENSIONS TO RAHAD PROJECT AREA



supply from Roseires via the proposed Rahad Link Canal.

(ii) To locate possible pump sites and survey short lengths of pump canals on the east bank of the River Rahad just north of Khor Sim Sim and at any other sites along the gravity canal line where it appears that considerable advantage can be obtained by pumping.

(iii) To survey section lines along existing tracks and traces on the left bank of the River Rahad in the area bounded, in the south by the Khor el Atshan, in the west by the River Dinder and in the north by Khor el Zeraf. From these sections to determine the extent of the land that can be commanded by gravity from the Malek Barrage, and to assess the general suitability of the whole area for irrigation.

GUNEID AREA

3. MAPS AND AIR PHOTOGRAPHY

The Sudan Survey Department produce the following series of maps which cover or partially cover the area involved. The coverage includes the following series:

- (a) Scale 1:50,000
- (b) Scale 1:250,000
- (c) Scale 1:1,000,000

The 1:50,000 maps include near the Guneid Pump Scheme, contours derived from reconnaissance levelling. However these contours were limited and only touched the area involved in the northermost survey area and gave no idea of the extent of the land that was finally demarcated.

The air photography mosaics numbers 5, 6 and 7 of the Khartoum-Sennar Series (Area 3d) were prepared and produced by the Sudan Survey Department in 1963 at a scale of 1:50,000. Unfortunately this cover was limited to a small portion of the western edge of the area surveyed.

Similarly, the Khartoum-Sennar air photography flown by the

Sudan Survey Department and mosaics prepared by Huntings Surveys Limited early in 1963, only partially covers the potential irrigable area to the south east of Guneid.

Figure 3 gives an index to the map and air photographic cover.

4. DESCRIPTION OF AREAS DEMARCATED FOR SOIL SURVEY

This extension is shown on Plate 1. It comprises two separate areas both of which are adjacent to the existing Guneid Pump Scheme and for which the gross area exceeds 200,000 feddans.

The smaller area of about 45,000 feddans is situated due east of Rufa'a and southeast of the Guneid scheme. It is separated from the northern limit of the Rahad East Bank Project Area by 16 kilometres of high sandy ground which is unsuitable for development and out of command from the proposed gravity canal. The area contains a number of villages and almost all the land has "Terus" and is used for the cultivation of dura during the rains. The larger area is a compact block of about 170,000 feddans which is adjacent to the north-eastern boundary of the Guneid Scheme. It consists mainly of a cracking clay plain which is uniform in appearance and with very little relief. The area is wider and extends eastwards along the low ground associated with the Khor Wad Araki and the Wadi Merah forming two bulges on the eastern boundary. The area is bounded on the south side by the well-defined ridge of high ground which extends from Tambul, four kilometres east of the Guneid Scheme boundary to Tundub and Hasanab villages. High sandy ground also limits the area on the east and north sides and in the west the boundary is formed by a natural drainage line which extends north-westwards from the Guneid Scheme. Two parts of the extension are separated by ten kilometres of unsuitable land between Wad el Kabir and Tambul. Along this length more steeply sloping high ground approaches to within a few kilometres of the eastern boundary of the Guneid Scheme.

On Plate 1 the results of the semi-detailed soil survey carried out during 1963/64 are shown. The land classification covers 18,000 feddans in the southern and 78,000 feddans in the northern area. Of these areas 16,000 and 68,000 feddans in the southern

and northern areas were classified as usable irrigable lands (Class 2, 3 and 4 lands).

The remainder of the extension areas, 27,000 and 93,000 feddans respectively in south and north are being covered by semi-detailed soil survey which started in April 1965 and will be completed after the commencement of the 1965/66 season in October 1965.

Assuming that the additional area surveyed is not greatly inferior to the parts for which the results are already available, the gross area of usable irrigable land in the extension will be of the order of 150,000 feddans. This is expected to provide a project extension covering about 120,000 feddans net cultivable area.

5. FIELDWORK

5.1. North east of Guneid

To demarcate the extent of any suitable irrigable land to the north east of the Guneid Pump Scheme a number of reconnaissance sections were surveyed, using as a starting point Bench Mark No. 6 established by the Sudan Survey Department about 1 kilometre west of the village of Haddaf (lat. $15^{\circ}02'N$, long. $33^{\circ}26'E$).

These lines of levelling extended northwards through Abu Sham to Abu Horira and eastward to Hasanab and Khawalda. The location of these sections is given on Plate 1 and the longitudinal sections on Plates 2 to 4.

In addition to the current survey work in the area, additional data was available from a line of levels surveyed in 1962 by the Ministry of Irrigation and Hydro-electric Power. This line of levelling is shown on Plate 1 and it was found that the ground levels along this line tied in, within expected limits, to those obtained from the present survey.

5.2 South east of Guneid

Since the 1:50,000 scale maps produced by the Sudan Survey Department included reconnaissance contouring over the greater part of this area, no additional levelling was done and the reconnaissance

was limited to ground inspection trips around the area.

5.3 Guneid Link Canal

A preliminary alignment for the Guneid Link Canal, which offtakes from the Project Main Canal at Km. 162 near the village of Wad Harras, was made on the reconnaissance contour plans.

Levelling, tied into the Sudan Survey Department beaconing of the area, was carried out along the suggested alignment for sixteen kilometres to a point near the village of Belalab (lat. $14^{\circ}45'N$, long $33^{\circ}30'E$) and cross sections were taken at each kilometre to ensure the line followed was the most economical. The final alignment followed very closely the preliminary one, but it was discovered that the reconnaissance levelling had failed to show the saddle between the high ground situated each side of the canal route near Km. 9. The route traverses an area of cracking clay with occasional areas of sandy loam. A sketch map of the link canal route and a longitudinal section are given on Plate 5. The maximum cut at Km. 9.2 on the link canal is approximately eleven metres. It is considered unlikely that much rock will be encountered in the excavation of the link canal.

Beyond Km. 16 (water level 413.2) near the village of El La'ota (lat. $14^{\circ}45'N$, long. $33^{\circ}31'E$) the proposed canal route follows the eastern perimeter of the southern Guneid extension, then the ridge of high ground, northward to the vicinity of Tambul (water level 410.7). Still following the high ground, the alignment here turns east to Tundub and Hasanab proceeding thence around the boundary of the northern extension to Borida, Abu Sham and finally Abu Horira in the north (water level 405.0).

HAWATA AREA

6. MAPS AND AIR PHOTOGRAPHY

Figure 4 shows the map and photographic cover relevant to this area.

The uncountoured map cover was, with the exception of the 1:50,000 series, prepared and produced by the Sudan Survey Department. The 1:50,000 maps were prepared by Sir. M. MacDonald

and Partners by enlarging the existing maps and with some additional information from the air photography. The map cover includes the following :-

- (a) Scale 1:50,000
- (b) Scale 1:100,000
- (c) Scale 1:250,000

Also Sheet No. 55 of the 1:1,000,000 series includes the surveyed areas.

The air photography includes two separate series, one the River Rahad and the other the Suki-Bunzuga series, both flown in connection with the Roseires Soil Survey. The mosaics for both areas were produced and prepared by the Sudan Survey Department and the River Rahad series covers all of the area surveyed on the east bank of the river except for about thirty kilometres in the southernmost part.

Of the surveyed area on the west bank of the River Rahad the eastern third is covered by the River Rahad series of mosaics and a small area in the vicinity of El Gueisi by the Suki-Bunzuga series. Approximately half of the area has no air photographic cover.

7. DESCRIPTION OF AREAS DEMARCATED FOR SOIL SURVEY

7.1 East Bank Area

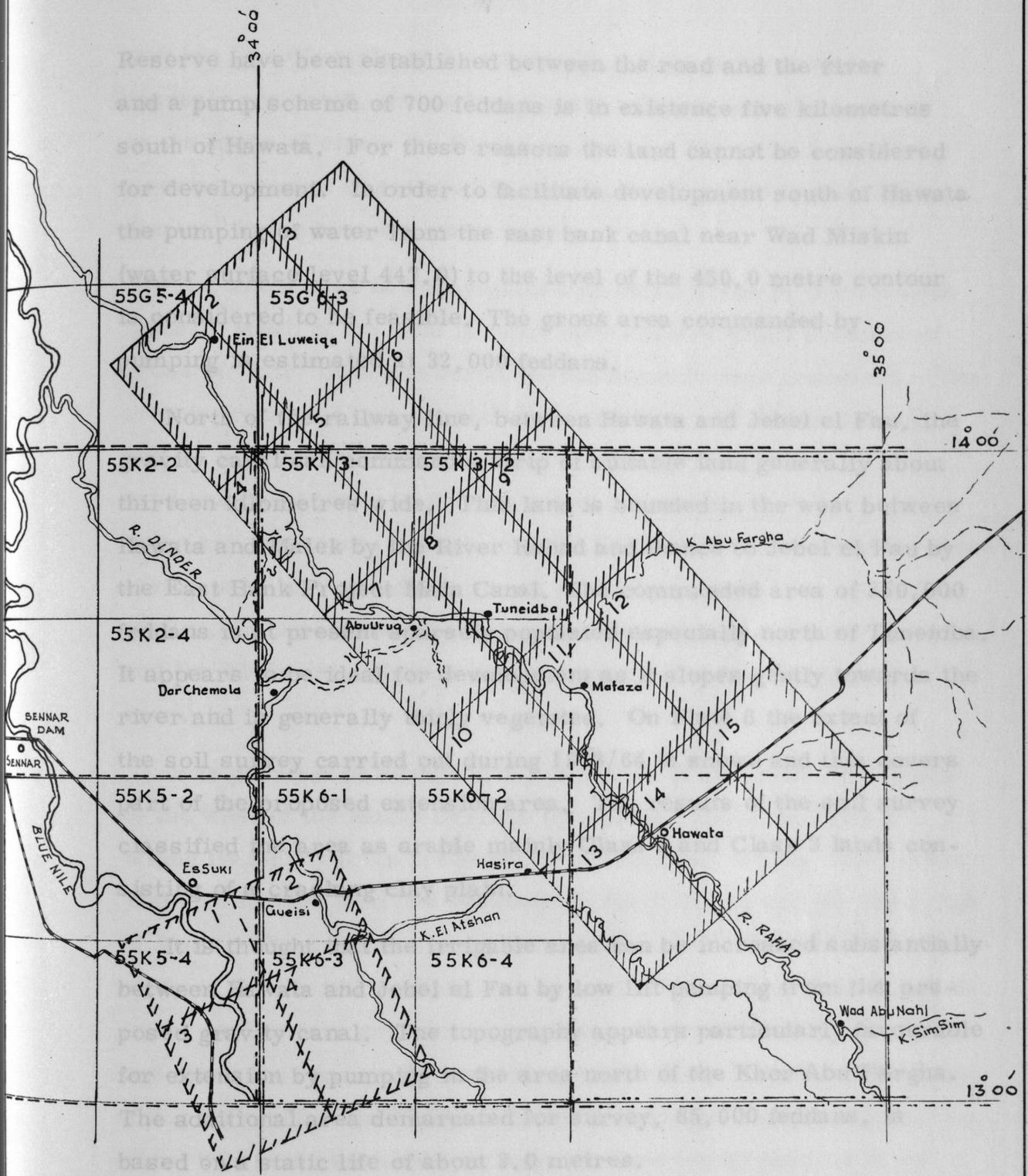
The land demarcated on the east bank of the River Rahad and shown on Plate 6 comprises two separate areas:

- (i) An area of 240,000 feddans which can be commanded by a gravity canal on the east bank flowing from Wad Miskin to Jebel el Fau.
- (ii) An area of 85,000 feddans between Wad Miskin and Jebel el Fau commanded by pumping water from the east bank canal.

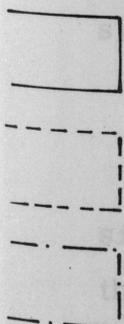
The area south of Hawata which would be commanded by gravity is of little value, being a strip no more than five kilometres wide and adjacent to the River Rahad. This land is undulating and dissected by numerous drainage channels and much of it is subject to periodic flooding from the Rahad. Considerable areas of Forest

EXTENSIONS IN HAWATA AREA MAP & PHOTOGRAPHIC COVER

Figure 4



MAP COVER

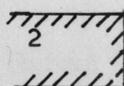


SCALE 1: 50,000

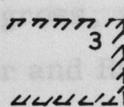
SCALE 1: 100,000

SCALE 1: 250,000

PHOTOGRAPHIC COVER

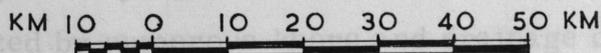


ROSEIRES SOIL SURVEY
RIVER RAHAD



ROSEIRES SOIL SURVEY
SUKI BUNZUGA

SCALE



Reserve have been established between the road and the river and a pump scheme of 700 feddans is in existence five kilometres south of Hawata. For these reasons the land cannot be considered for development. In order to facilitate development south of Hawata the pumping of water from the east bank canal near Wad Miskin (water surface level 447.0) to the level of the 450.0 metre contour is considered to be feasible. The gross area commanded by pumping is estimated at 32,000 feddans.

North of the railway line, between Hawata and Jebel el Fau, the gravity canal can command a strip of suitable land generally about thirteen kilometres wide. This land is bounded in the west between Hawata and Malek by the River Rahad and thence to Jebel el Fau by the East Bank Project Main Canal. The commanded area of 250,000 feddans is at present sparsely populated especially north of Tuneidba. It appears to be ideal for development as it slopes gently towards the river and is generally thinly vegetated. On Plate 6 the extent of the soil survey carried out during 1963/64 is shown and this covers part of the proposed extension area. The results of the soil survey classified the area as arable mainly Class 2 and Class 3 lands consisting of a cracking clay plain.

It is thought that the irrigable area can be increased substantially between Hawata and Jebel el Fau by low lift pumping from the proposed gravity canal. The topography appears particularly favourable for extension by pumping in the area north of the Khor Abu Fargha. The additional area demarcated for survey, 85,000 feddans, is based on a static life of about 3.0 metres.

Hawata, with its railway access, is the main centre on the Rahad east bank and would, with the development of the area, assume considerable importance especially as an outlet for produce.

7.2 West Bank Area

This area of 600,000 feddans gross, shown on Plate 6, is situated between the rivers Dinder and Rahad and is bounded in the south by the Khor el Atshan and in the north by the Khor el Zeraf. The land is generally flat at an elevation of between 425 and 435 metres but is dissected by numerous khors and drainage channels. The general slope of the land is to fall from the south-east near Hawata

towards Dar Chemola in the northwest. Most of the area is sparsely populated, the majority of the villages being situated on the banks of either the Dinder or Rahad. There is, however, a certain amount of seasonal habitation which relies on rain-filled "hafirs" in the area for water supply.

The whole area is a clay plain with small areas of thick acacia forest. Much of the area is more open country which consists of areas of "kitr" bush and scrub alternating with open grassland. The area is traversed by a graded earth road from El Hasira railway station to Umm Darraga and Dar Chemola, but this road is little used and in places is badly overgrown. In the north of the area there are few roads; a track from El Eteifa to Dar Chemola and three rarely used tracks radiating from Umm Darraga to Khor el Atshan station, El Gueisi and El Eteifa. The main Sennar-Gedaref railway and the El Gueisi - Hawata road, cross the southern edge of the area.

It is possible to command a gross area of about 25,000 feddans to the west of the Malek Barrage by a canal, shown on Plate 6 taking its supply from upstream of the barrage, holding level 429.0. The commanded land lies between the River Rahad and the Khor Tab el Mara. The estimate of the commanded area is based on an office study of the air photography and on the limited survey data obtained in the exploratory engineering survey. This included two sections, one along the road on the west bank of the River Rahad and the other along the track from El Eteifa to Umm Darraga. It appears that the canal will be a carrier for at least the first ten kilometres of its length.

8. FIELDWORK

8.1 East Bank Area

On the east bank of the River Rahad between Wad Miskin (lat. $13^{\circ}10'N$, long. $34^{\circ}54'E$) and Jebel el Fau (lat. $14^{\circ}09'N$, long. $34^{\circ}18'E$) eight cross sections were levelled to determine the extent of the land that could be irrigated from a canal built on the east bank obtaining its supply from the proposed siphon at Wad Miskin. The location of these sections is shown on Plate 6. In addition a

short canal line was surveyed at Umm Shaar near Khor Sim Sim.

In the 1963/64 field season levelling had been completed by the Consultant from Khor Sim Sim (lat. $13^{\circ}05'N$, long. $34^{\circ}58'E$) in the south along the road to Tuneidba (lat. $13^{\circ}43'N$, long $34^{\circ}23'E$) in the north.

From this longitudinal section of the road, cross sections of the River Rahad had been completed in the same field season. The benchmarks established during that survey proved invaluable for the completion of six of the eight east bank cross sections. The two northernmost cross sections on the plain south of Jebel el Fau were tied into benchmarks established by the Sudan Survey Department for the beaconing of the Rahad Project Area in 1964.

A plan at scale 1/150,000 with reconnaissance contours at five metre intervals provided useful information on the area south of the Sennar-Gedaref railway line on the east bank.

The sections surveyed are numbered 3c/R1 to 3c/R8 and are shown on Plates 7 to 9.

8.2 West Bank Area

Levelling on the west bank of the River Rahad was restricted by the time available in the field but had to be sufficient to give the general lie of the land and to indicate as far as possible, whether irrigation development is feasible.

The sections actually levelled were numbered 3c/L1 to 3c/L6 and totalled some one hundred and fifty kilometres, the majority following existing tracks and traces, the only exception being a section levelled from Umm Darraga in an easterly direction.

The location of the sections is shown on Plate 6 and the longitudinal sections on Plates 10 to 13.

P.C. Pump Channel near Umm Sharr

G.L.C. Guneid Link Canal Survey

- (1) Bench mark on north wall of railway culvert, 300m. west of Khor el Atshan Station.
- (2) S.R. Bench Mark at Khor el Atshan Station
- (3) S.R. Bench Mark at El Rasra Station
- (4) S.R. Bench Mark at Hawala Station
- (5) S.R. Pile Bench Mark
- (6) S.S.D. Cylinder Bench Mark.

APPENDIX IBench Mark Values in Metres

Based on the zero of the Khartoum Gauge, assumed as 360.00 metres above M.S.L. at Alexandria.

Notation

M : Concrete Bench Mark
S.G. : Angle Iron Bench Mark

B. M.	Reduced Level	Location	B. M.	Reduced Level	Location
M10	398.30	3d/5	M477	425.06	3c/L4
M11	399.03	3d/5	M480	425.69	3c/L4
M23	413.23	G. L. C.	M523	416.60	G. L. C.
M50	425.65	3c/L3	M580	434.02	3c/R6
M106	408.57	3d/14	M586	426.94	3c/L3
M113	423.65	3c/L4	M587	434.84	3c/R3
M115	428.68	3c/L5	SG. 68	408.86	3d/6
M120	427.76	3c/L5	SG. 74	403.38	3d/6
M126	440.25	3c/R6	SG. 82	409.35	3d/8
M130	426.20	3c/L1	SG. 84	410.54	3d/9
M131	427.87	3c/L3	SG. 87	401.08	3d/7
M133	426.74	3c/L3	SG. 88	408.10	3d/7
M141	433.19	3c/L1	SG. 89	400.51	3d/6
M144	431.70	3c/L1	SG. 90	410.19	3d/13
M168	434.59	3c/L1	SG. 91	401.51	3d/6
M169	426.91	3c/L4	SG94	406.74	3d/7
M255	432.26	3c/L1	SG. 95	405.37	3d/7
M282	436.74	3c/R6	SG. 96	408.80	3d/7
M283	423.75	3c/L4	SG. 97	453.16	3c/R1
M294	432.90	3c/L1	SG. 98	403.40	3d/9
M310	452.85	P. C.	R250*	423.44	3c/L4
M373	407.96	3d/7	CS. 13*	409.51	3d/10
M413	429.79	3c/L5	M2 *	428.42	3c/R8
M435	425.98	3c/L3	454	428.61	3c/L5 (1)
M450	413.84	G. L. C.	10029	431.071	3c/L6 (2)
M458	417.04	G. L. C.	10033	433.171	3c/L1 (3)
M462	420.65	G. L. C.	10038	441.102	3c/R2 (4)
M474	429.30	3c/L5	B17	429.29	3c/L6 (5)
M476	432.90	3c/L1	PBM6	397.81	3d/5 (6)

* Angle Iron Bench Marks

P.C. Pump Channel near Umm Sharr

G. L. C. Guneid Link Canal Survey

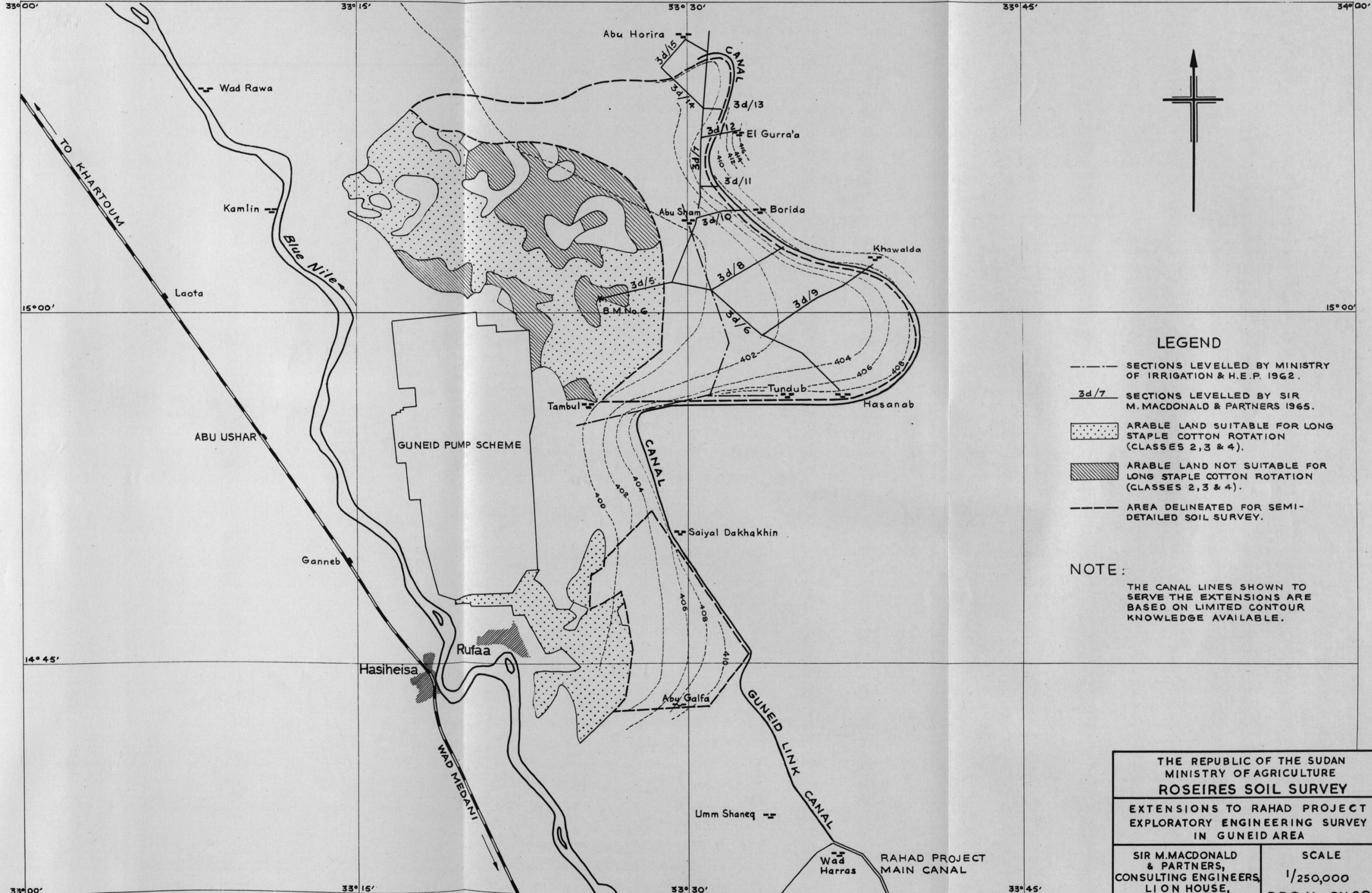
- (1) Bench mark on north wall of railway culvert, 300m. west of Khor el Atshan Station.
- (2) S.R. Bench Mark at Khor el Atshan Station
- (3) S.R. Bench Mark at El Hasira Station
- (4) S.R. Bench Mark at Hawata Station
- (5) S.R. Pile Bench Mark
- (6) S.S.D. Cylinder Bench Mark.

SCALE

1/250,000

DRG No. SU.200

DATE JULY 1955

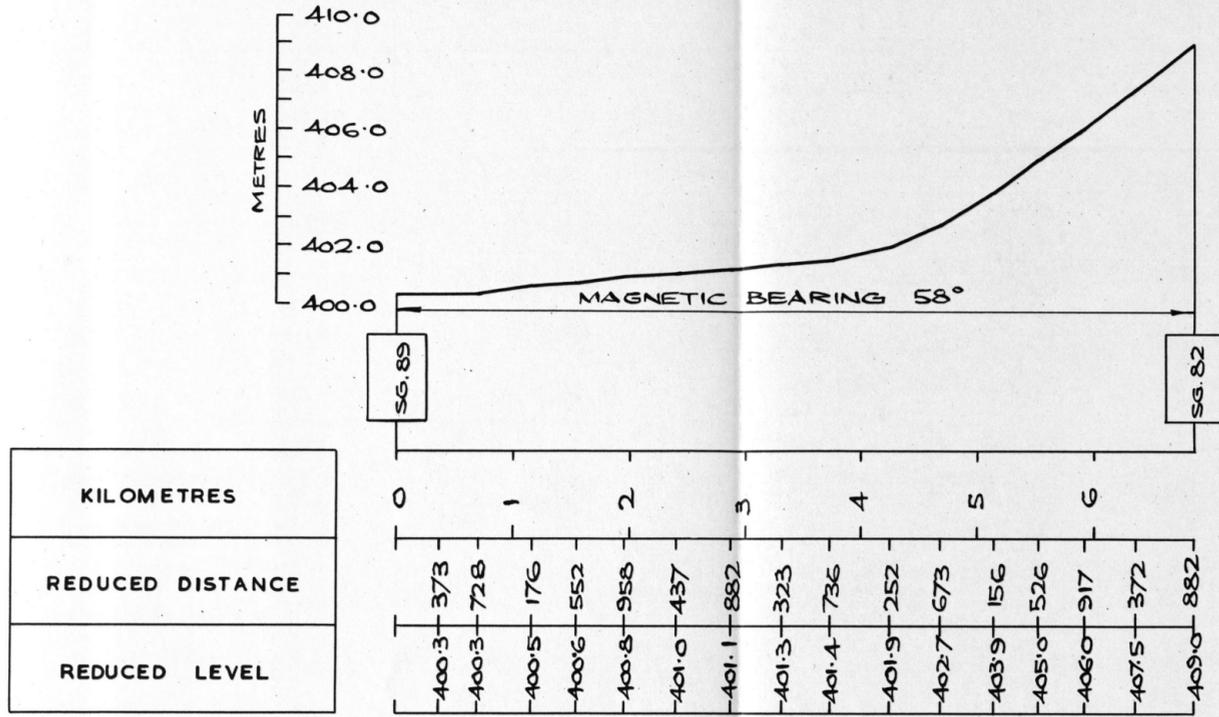


LEGEND

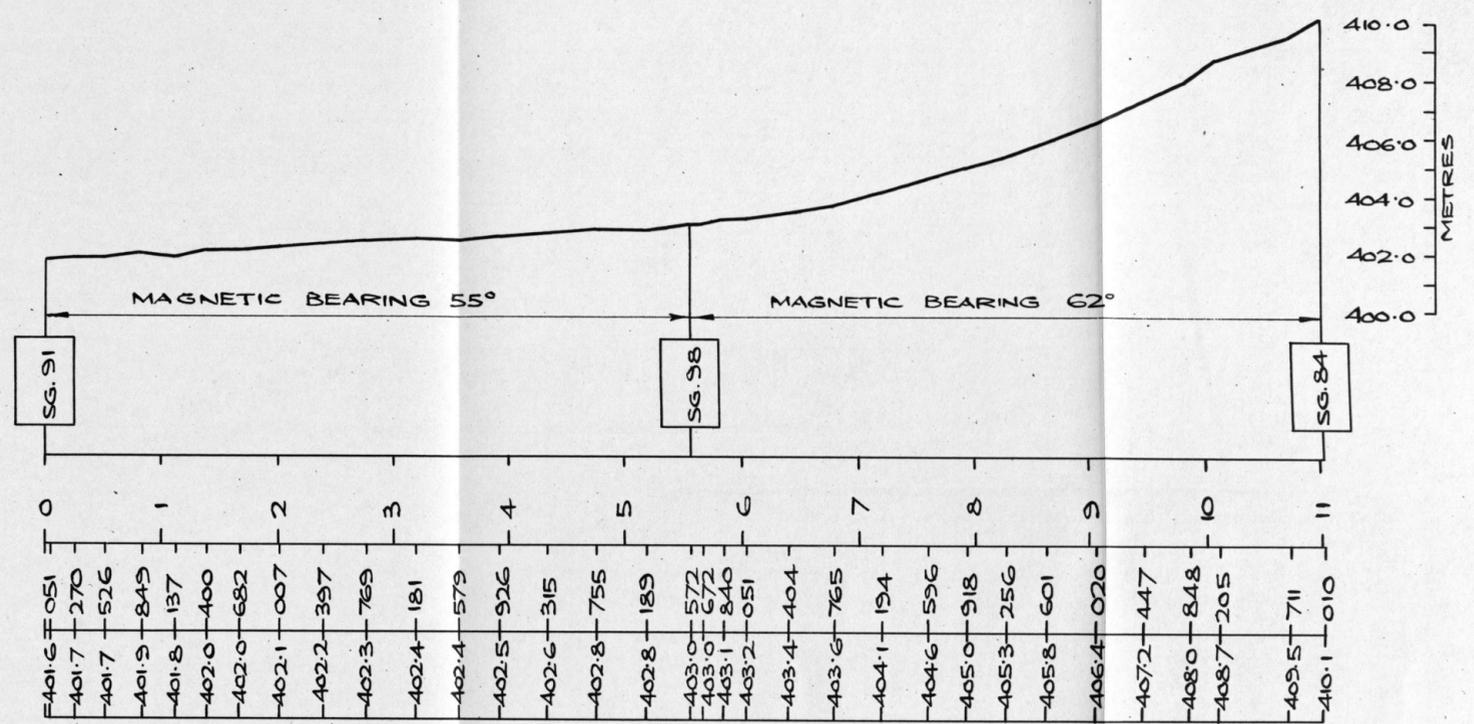
- SECTIONS LEVELLED BY MINISTRY OF IRRIGATION & H.E.P. 1962.
- 3d/7 SECTIONS LEVELLED BY SIR M. MACDONALD & PARTNERS 1965.
- [Dotted pattern] ARABLE LAND SUITABLE FOR LONG STAPLE COTTON ROTATION (CLASSES 2, 3 & 4).
- [Diagonal hatching] ARABLE LAND NOT SUITABLE FOR LONG STAPLE COTTON ROTATION (CLASSES 2, 3 & 4).
- - - AREA DELINEATED FOR SEMI-DETAILED SOIL SURVEY.

NOTE:
 THE CANAL LINES SHOWN TO SERVE THE EXTENSIONS ARE BASED ON LIMITED CONTOUR KNOWLEDGE AVAILABLE.

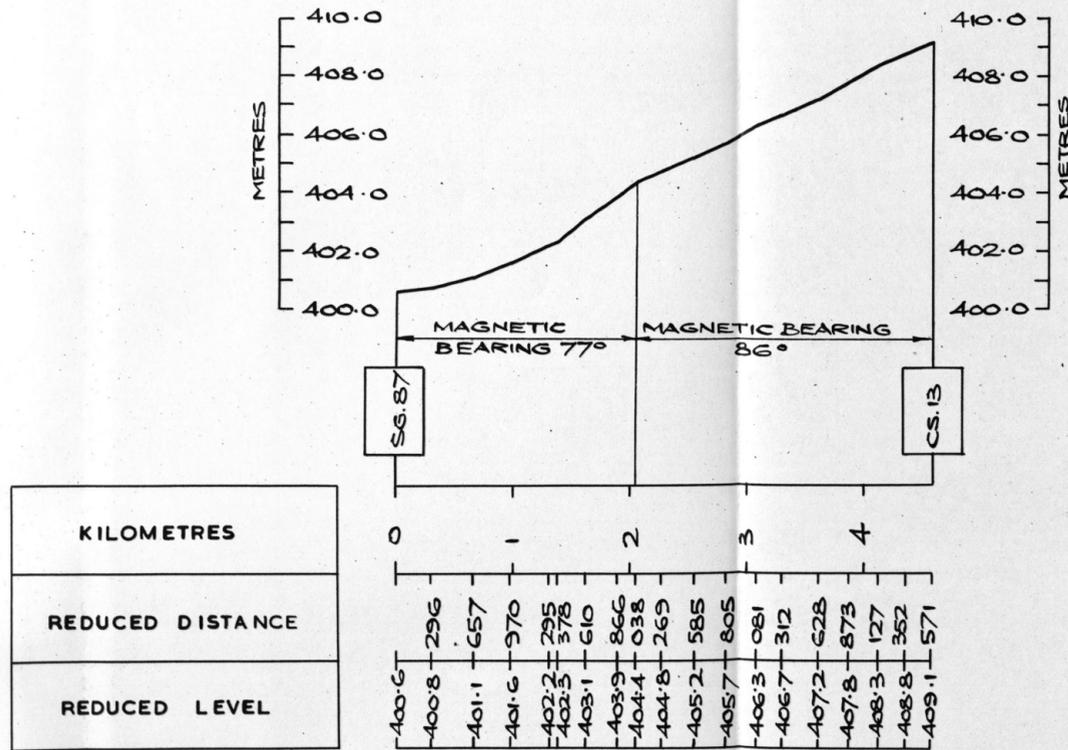
THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT EXPLORATORY ENGINEERING SURVEY IN GUNEID AREA	
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON W.C.I.	SCALE 1/250,000 DRG. No. SU.200 DATE JULY 1965



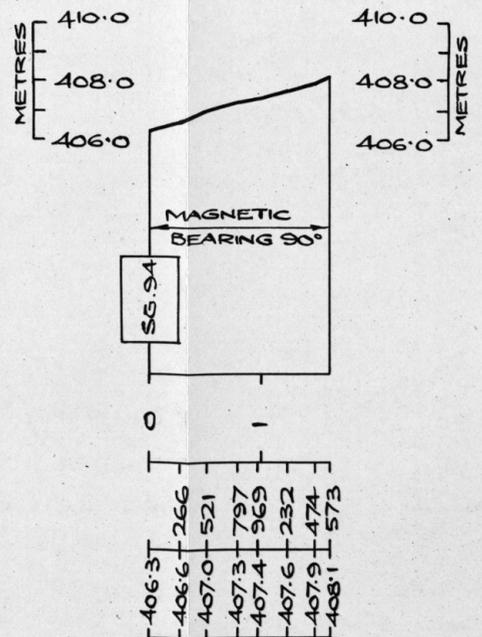
3D/8



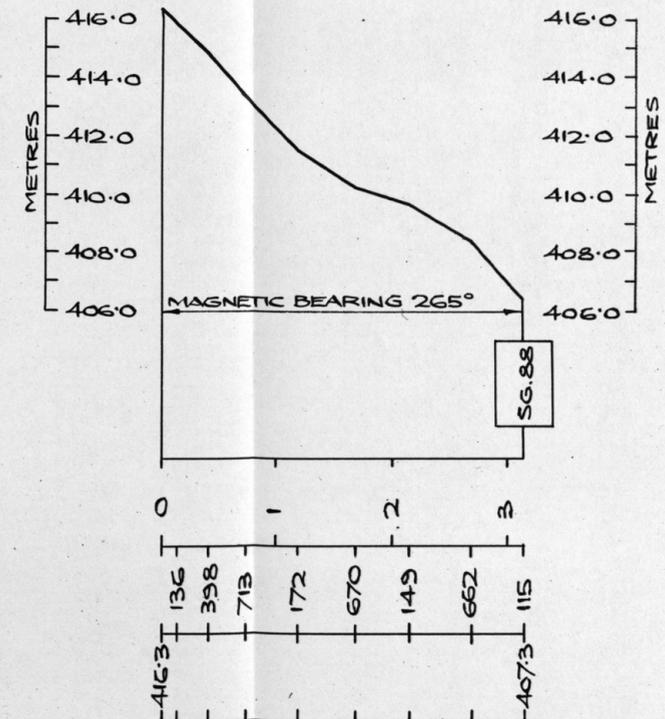
3D/9



3D/10



3D/11



3D/12

THE REPUBLIC OF THE SUDAN
 MINISTRY OF AGRICULTURE
ROSEIRE'S SOIL SURVEY

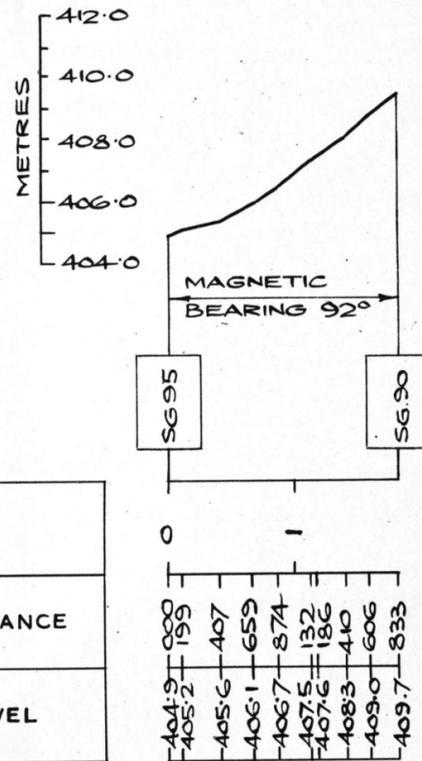
EXTENSIONS TO RAHAD PROJECT
 LONGITUDINAL SECTIONS IN
 GUNEID AREA (SHEET 2)

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

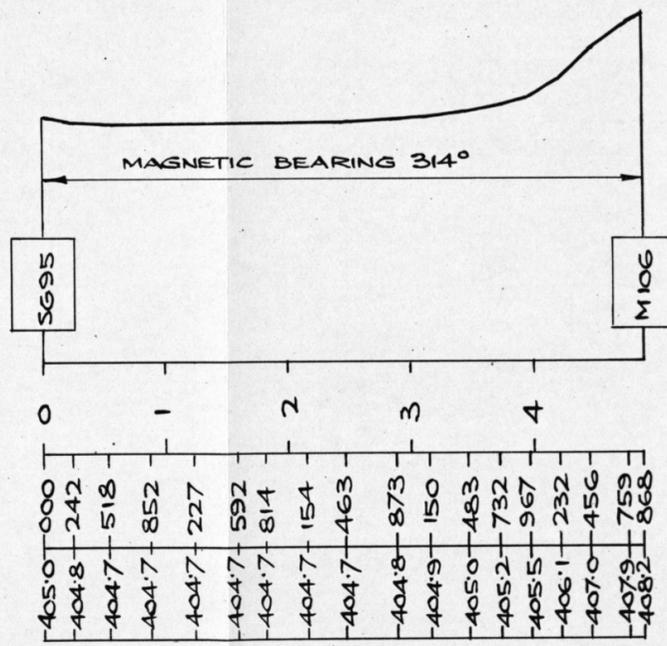
SCALES
 AS SHOWN

DRG. No. SU.202
 DATE. JULY 1965

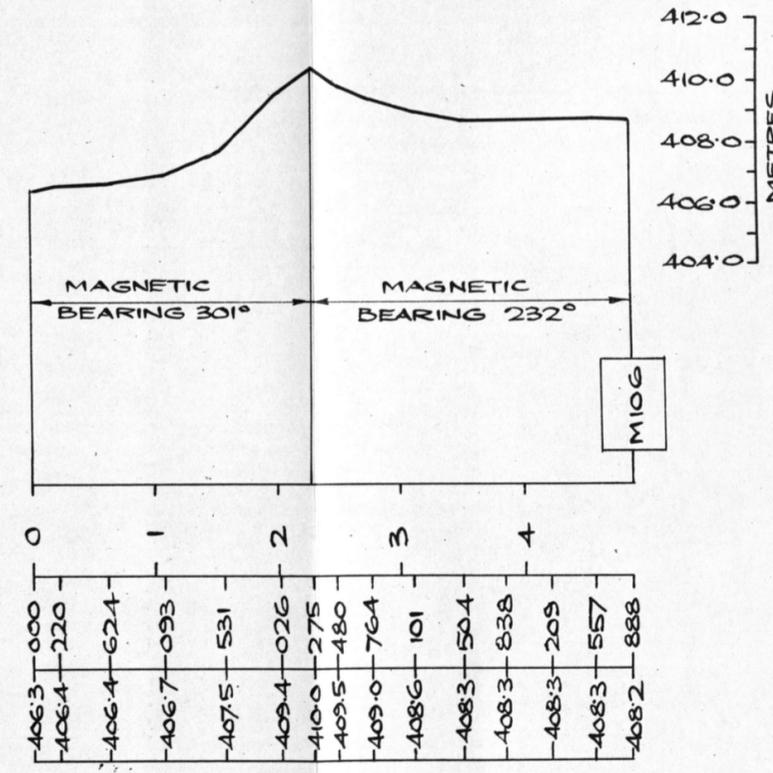
KILOMETRES
REDUCED DISTANCE
REDUCED LEVEL



3D/13

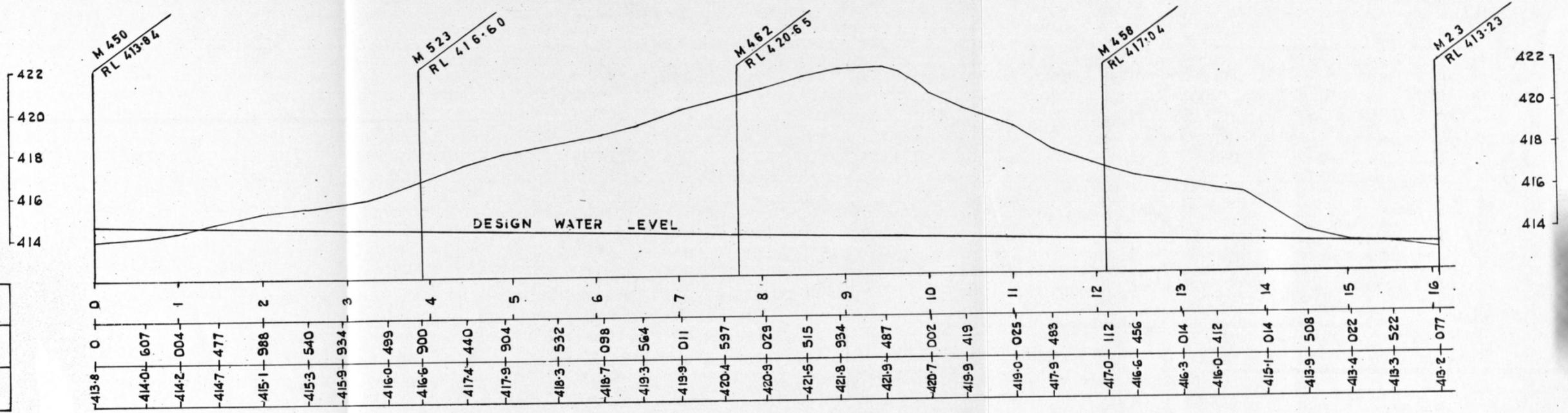


3D/14

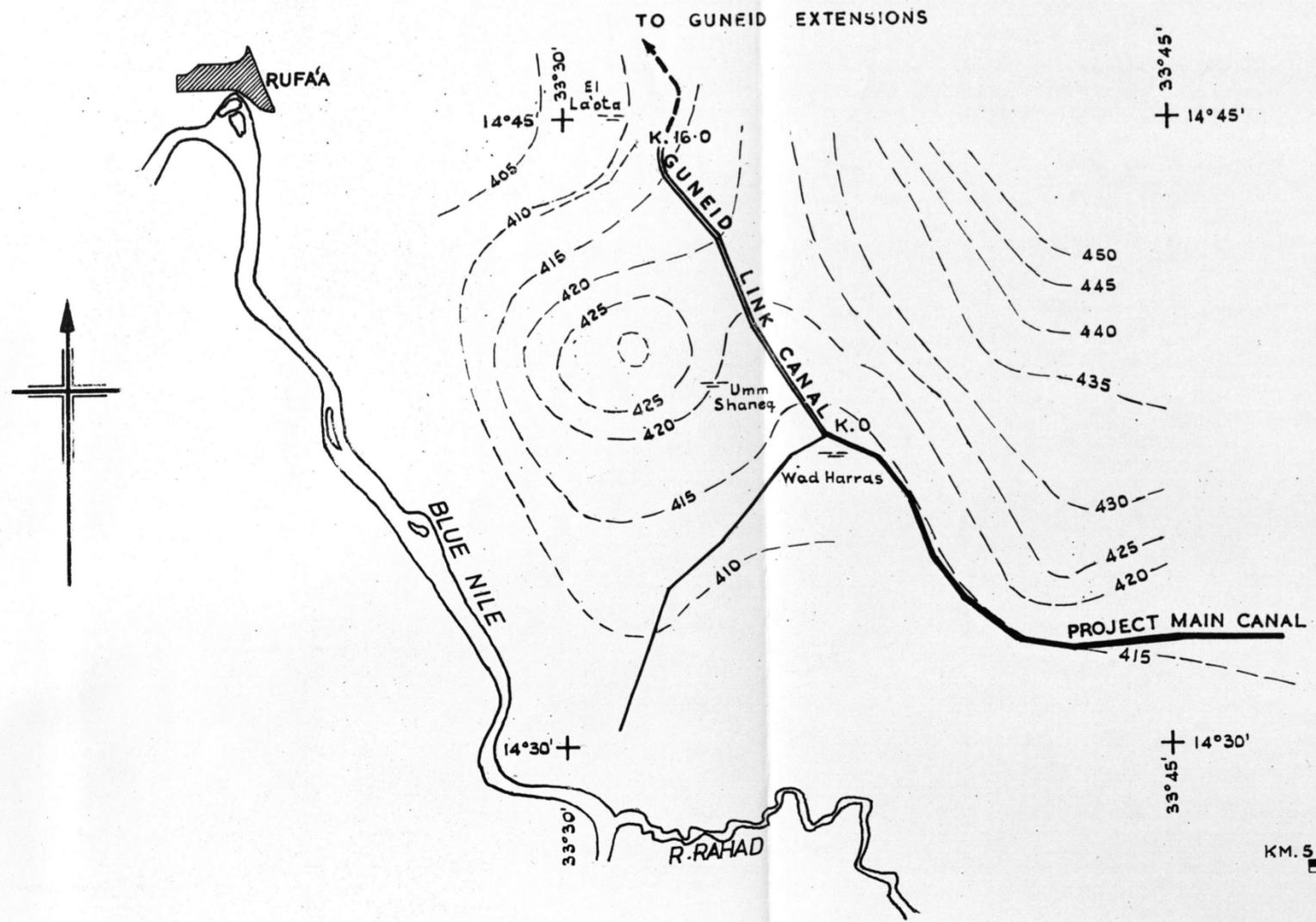


3D/15

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT LONGITUDINAL SECTIONS IN GUNEID AREA (SHEET 3)	
SIR M.MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON W.C.1.	SCALES AS SHOWN DRG.No.SU.203 DATE: JULY 1965



KILOMETRES
REDUCED DISTANCE
REDUCED LEVEL

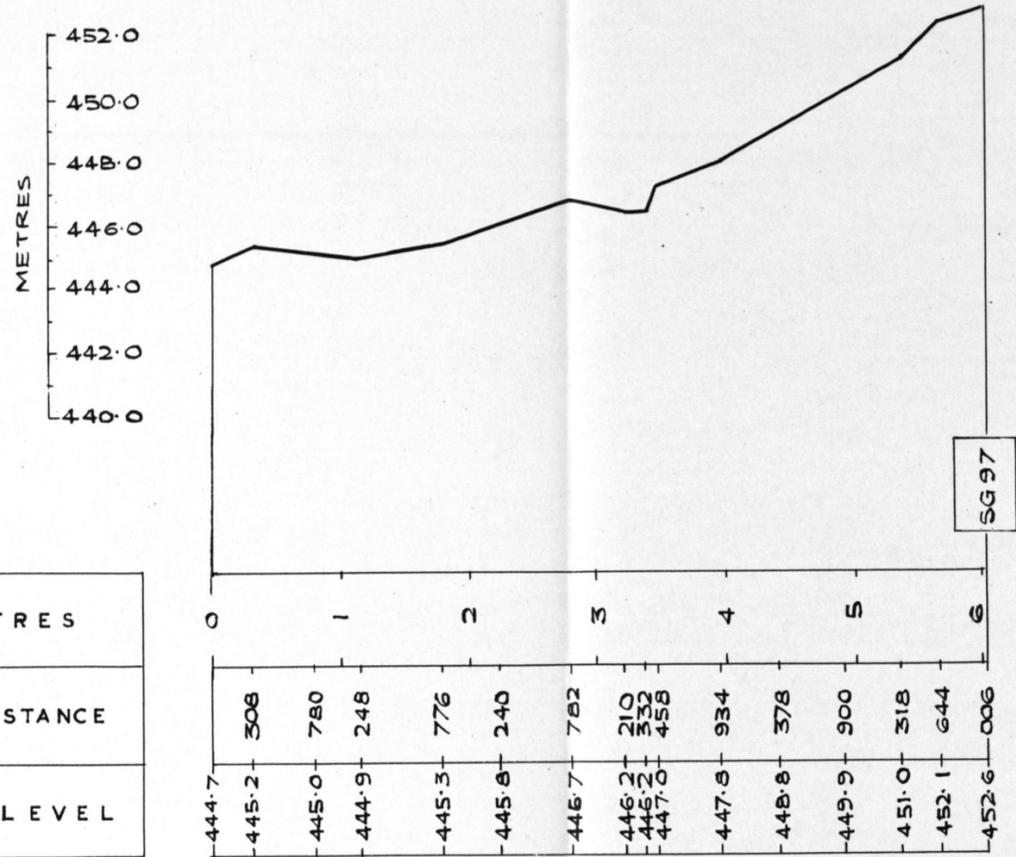


NOTES.

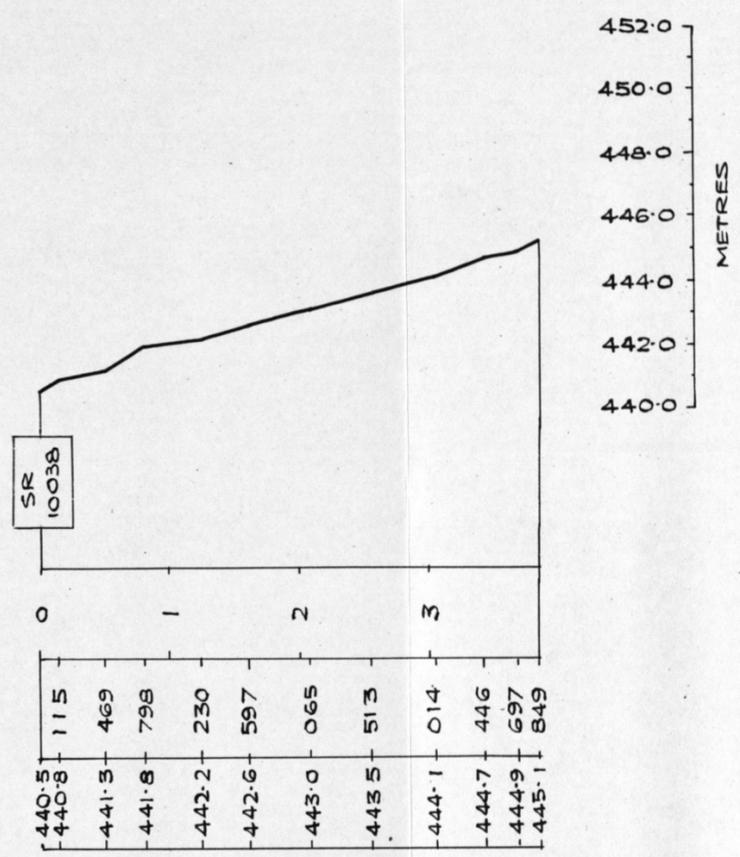
- GUNEID LINK CANAL OFFTAKES AT APPROX. K. 162 ON PROJECT MAIN CANAL
- DESIGN DIMENSIONS
 DESIGN CAPACITY : Q = 31 CUMECs
 WATER SURFACE WIDTH: $W_s = 4.0 Q^{0.75}$ APPROX.
 BEDWIDTH : B = 10.7 M
 DESIGN WATER DEPTH : D = 2.9 M
 WATER SURFACE SLOPE : S = 7.9 CM/KM

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT GUNEID LINK CANAL	
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON W.C.1.	SCALES AS SHOWN DRG. No. SU.204 DATE: JULY 1965

KILOMETRES
REDUCED DISTANCE
REDUCED LEVEL

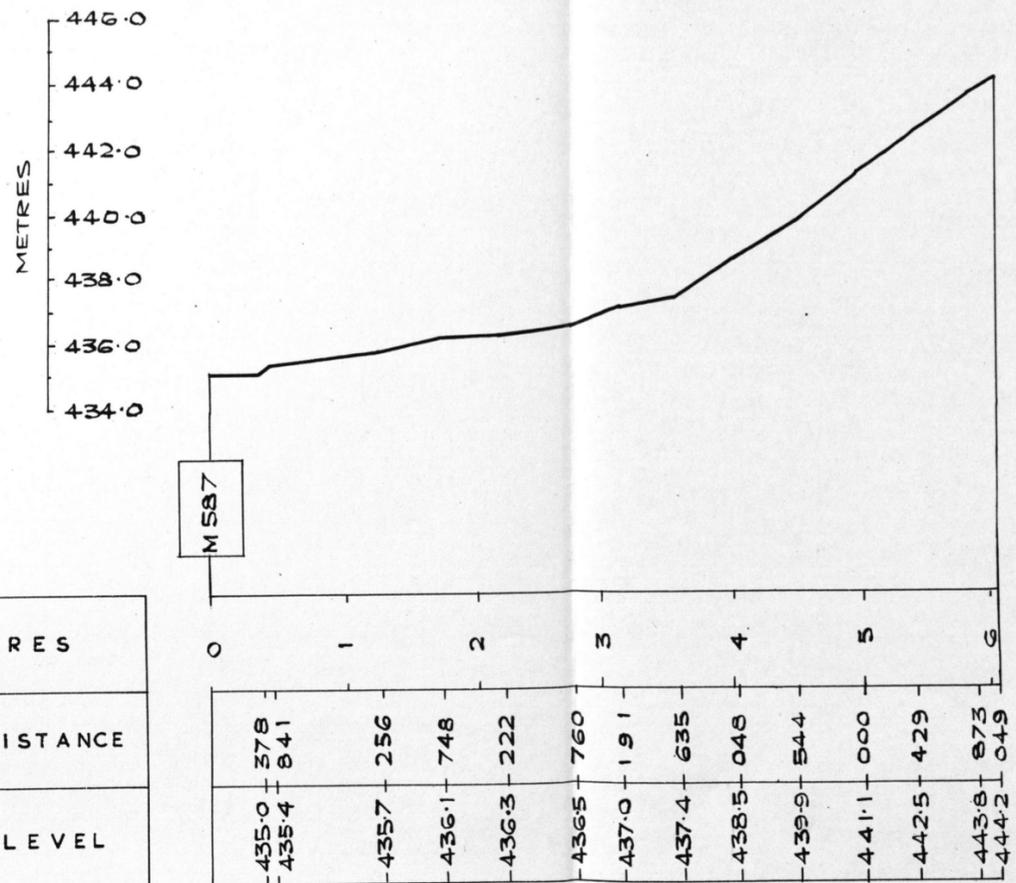


3C/R1

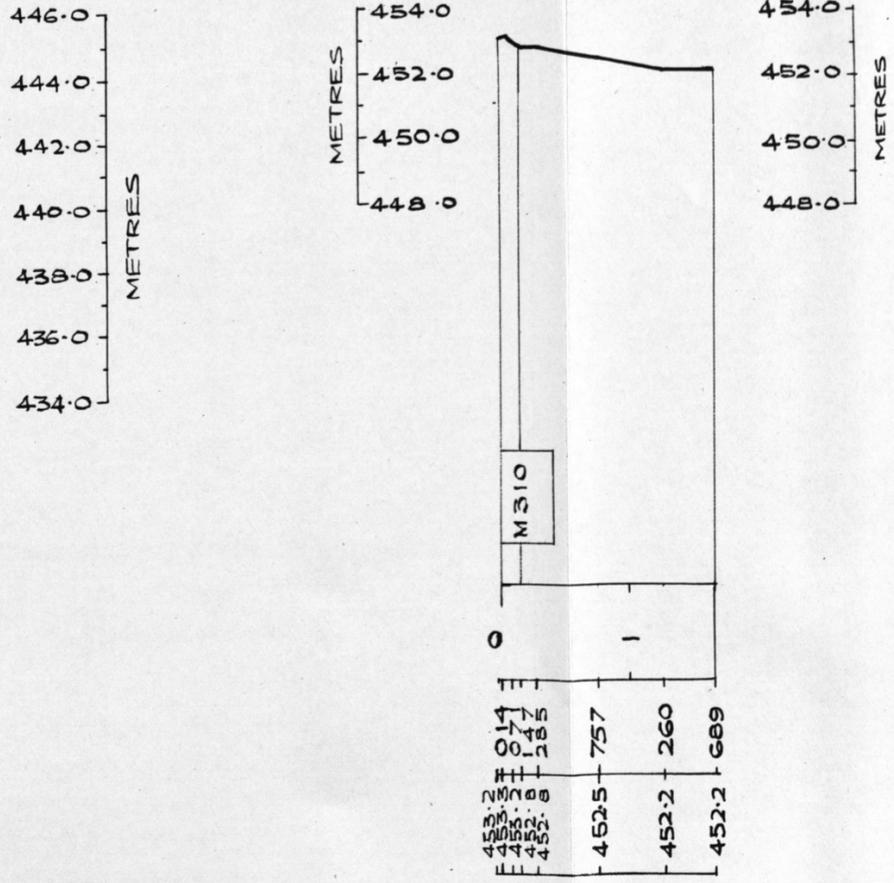


3C/R2

KILOMETRES
REDUCED DISTANCE
REDUCED LEVEL



3C/R3

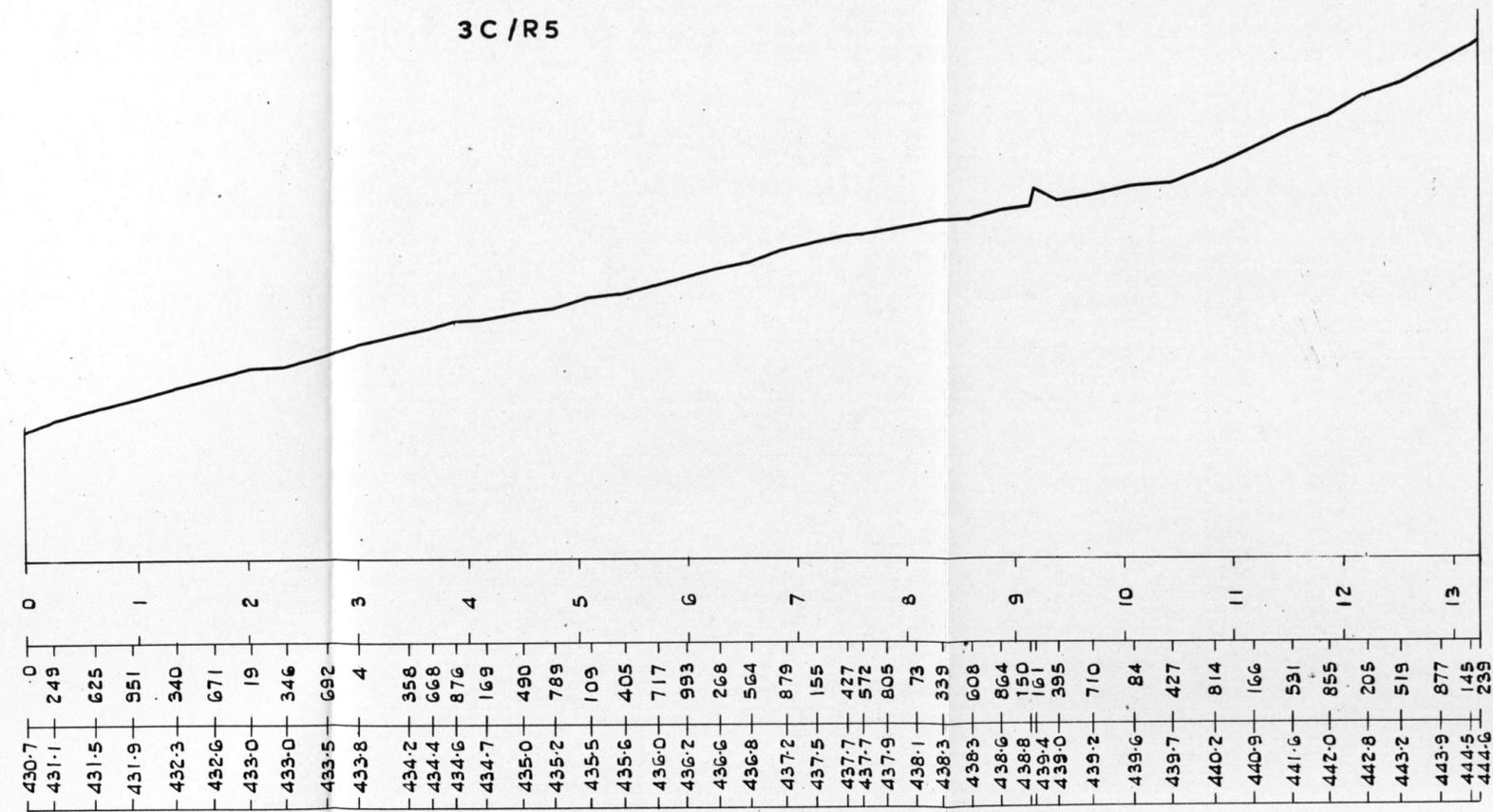
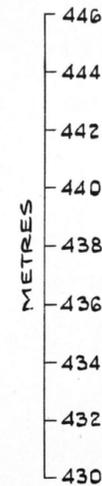
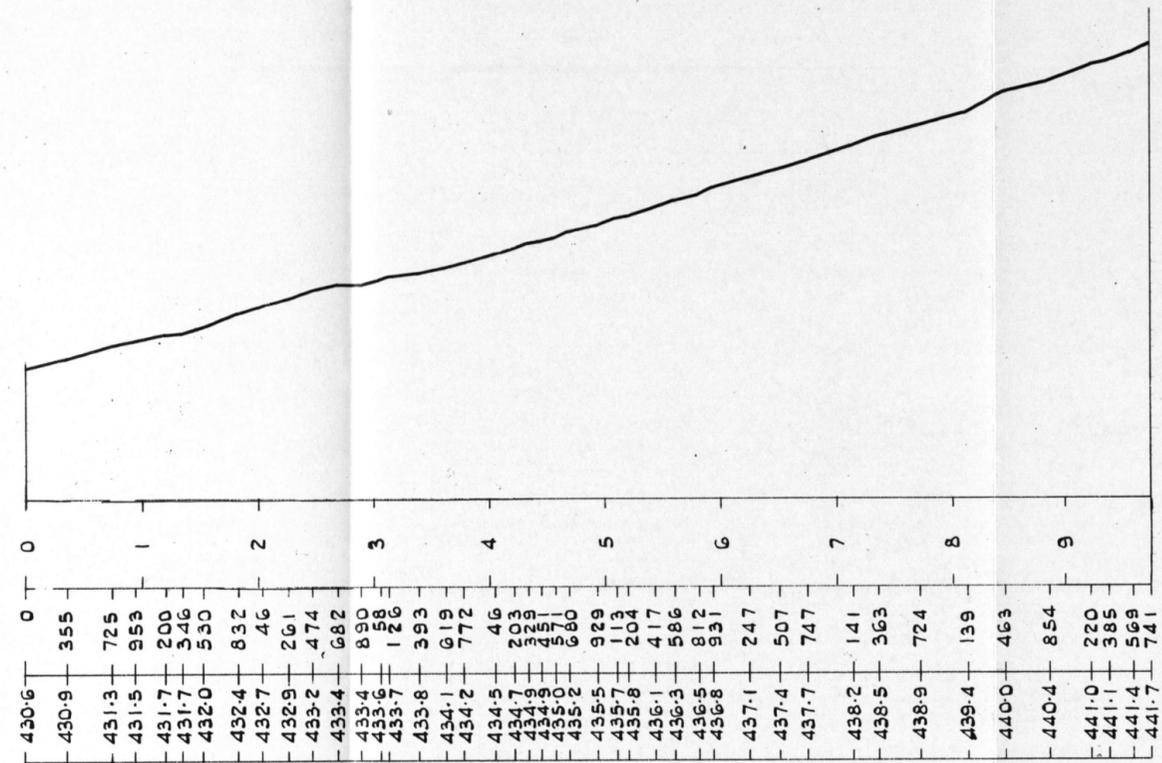
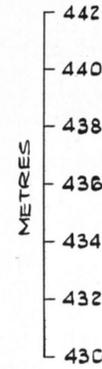


PUMP CHANNEL AT UMM SHAAR

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT LONGITUDINAL SECTIONS IN HAWATA AREA (SHEET 1)	
SIR M. MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON W.C.1.	SCALES AS SHOWN DRG. No. SU.206 DATE. JULY 1965

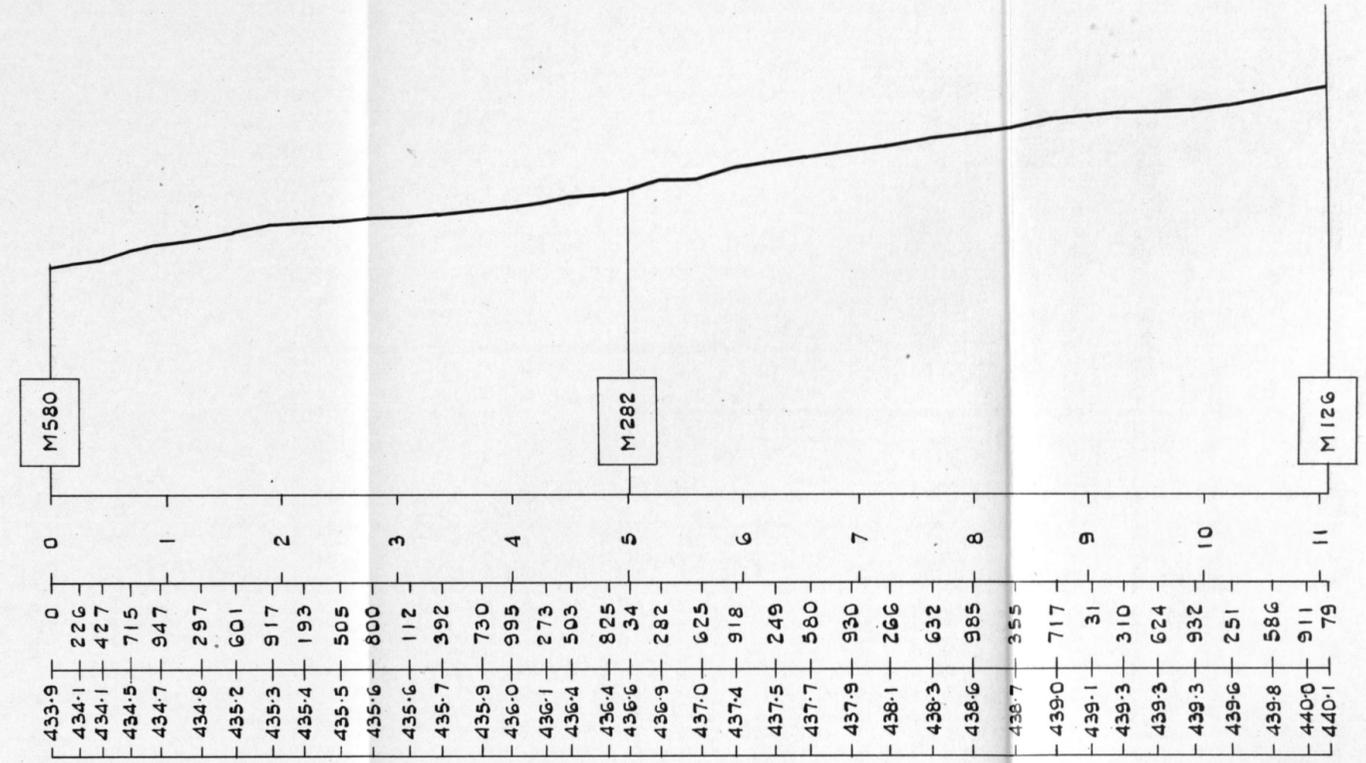
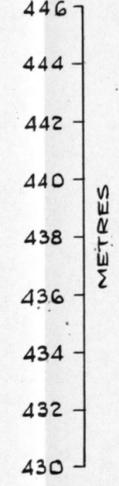
KILOMETRES
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KILOMETRES
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3C/R4

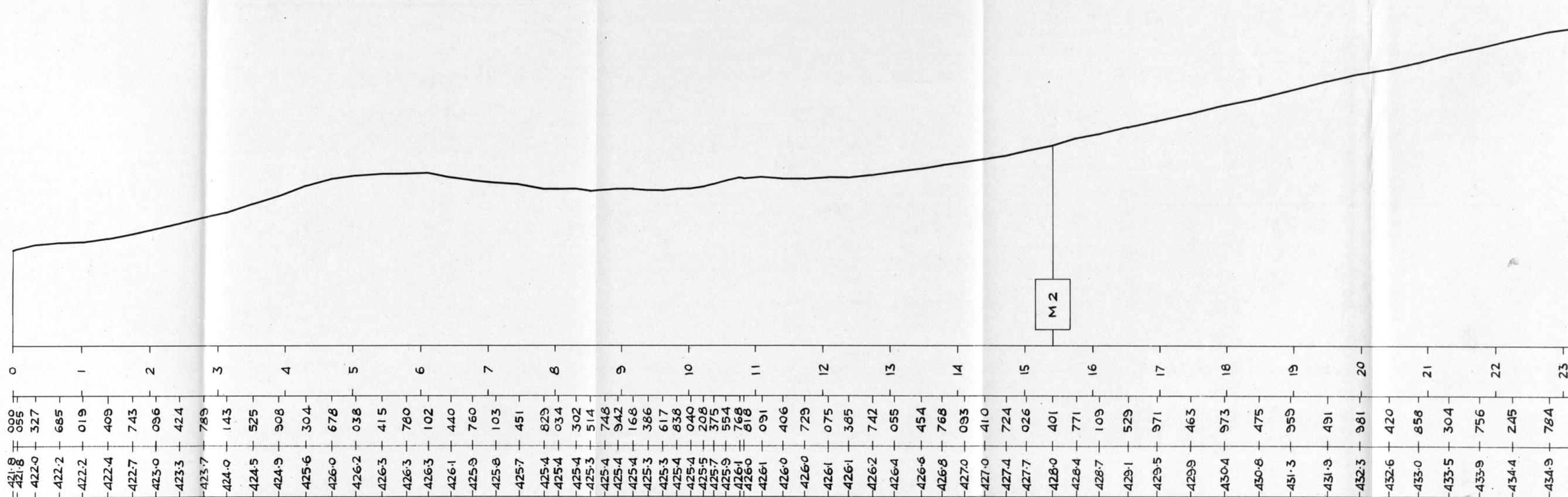
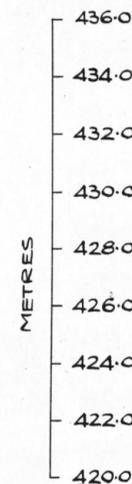
3C/R5



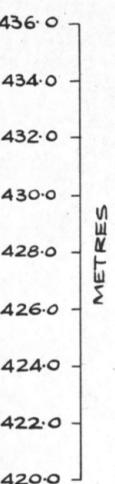
3C/R6

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT LONGITUDINAL SECTIONS IN HAWATA AREA. (SHEET 2)	
SIR M MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON W.C.1.	SCALES AS SHOWN DRG. No. SU 207 DATE: JULY 1965

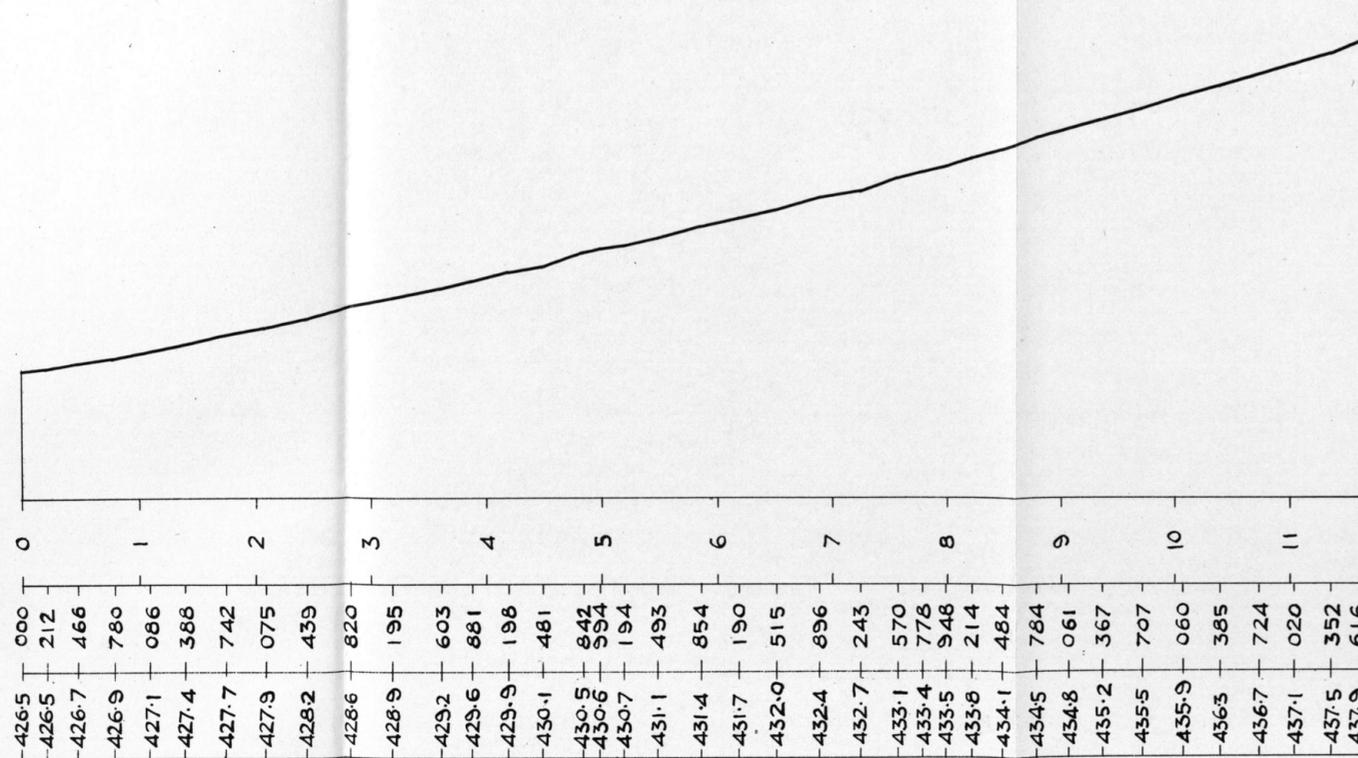
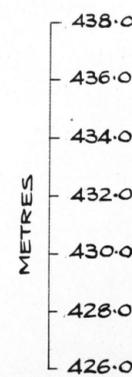
KILOMETRES
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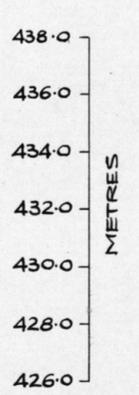
REDUCED DISTANCE	REDUCED LEVEL
000	421.8
005	421.8
327	422.0
685	422.2
019	422.2
409	422.4
743	422.7
096	423.0
424	423.3
789	423.7
143	424.0
525	424.5
908	424.9
304	425.6
678	426.0
038	426.2
415	426.3
780	426.3
102	426.3
440	426.1
760	425.9
103	425.8
451	425.7
829	425.4
034	425.4
302	425.4
514	425.3
748	425.4
942	425.4
168	425.4
386	425.3
617	425.3
838	425.4
040	425.4
208	425.5
375	425.7
554	425.9
768	426.1
618	426.0
091	426.1
406	426.0
729	426.0
075	426.1
385	426.1
742	426.2
055	426.4
454	426.6
768	426.8
093	427.0
410	427.0
724	427.4
026	427.7
401	428.0
771	428.4
109	428.7
529	429.1
971	429.5
463	429.9
973	430.4
475	430.8
969	431.3
491	431.9
981	432.3
420	432.6
858	433.0
304	433.5
756	433.9
245	434.4
784	434.9
165	435.1



KILOMETRES
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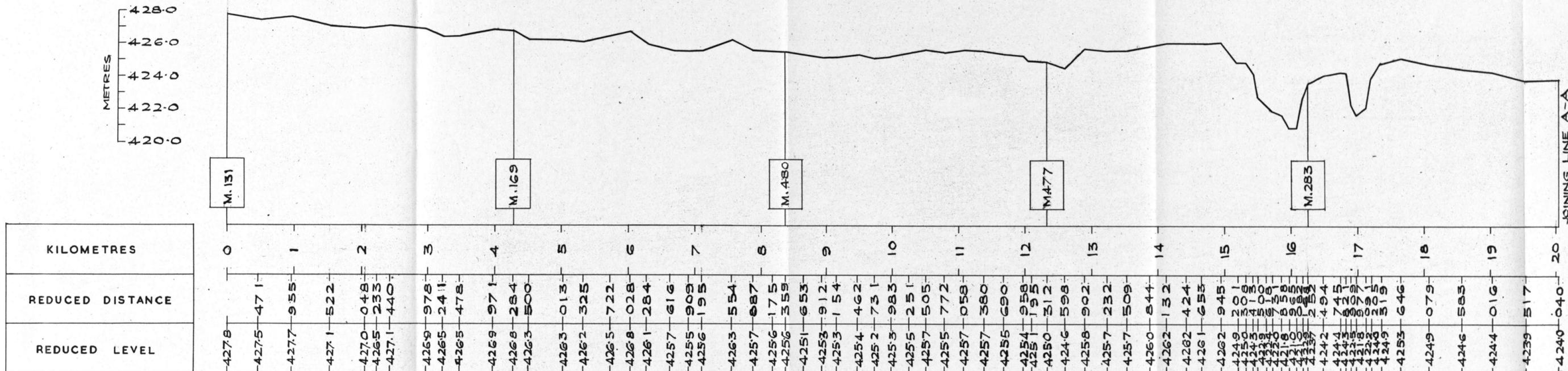
REDUCED DISTANCE	REDUCED LEVEL
000	426.5
212	426.5
466	426.7
780	426.9
086	427.1
388	427.4
742	427.7
075	427.9
439	428.2
820	428.6
195	428.9
603	429.2
881	429.6
198	429.9
481	430.1
842	430.5
594	430.6
194	430.7
493	431.1
854	431.4
190	431.7
515	432.0
896	432.4
243	432.7
570	433.1
778	433.4
948	433.5
214	433.8
484	434.1
784	434.5
061	434.8
367	435.2
707	435.5
060	435.9
385	436.3
724	436.7
020	437.1
352	437.5
616	437.9
657	438.3



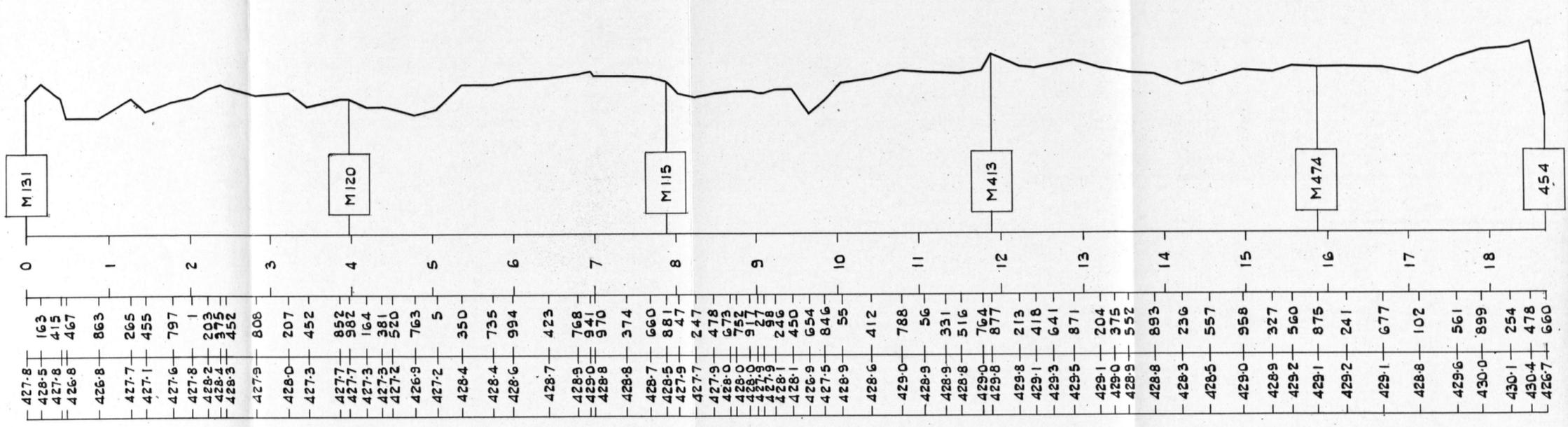
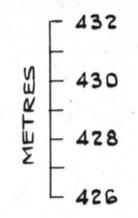
3C/R8

3C/R7

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE POSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT LONGITUDINAL SECTIONS IN HAWATA AREA (SHEET 3)	
SIR M. MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON W.C.1.	SCALES AS SHOWN DRG. No. SU.208 DATE: JULY 1965

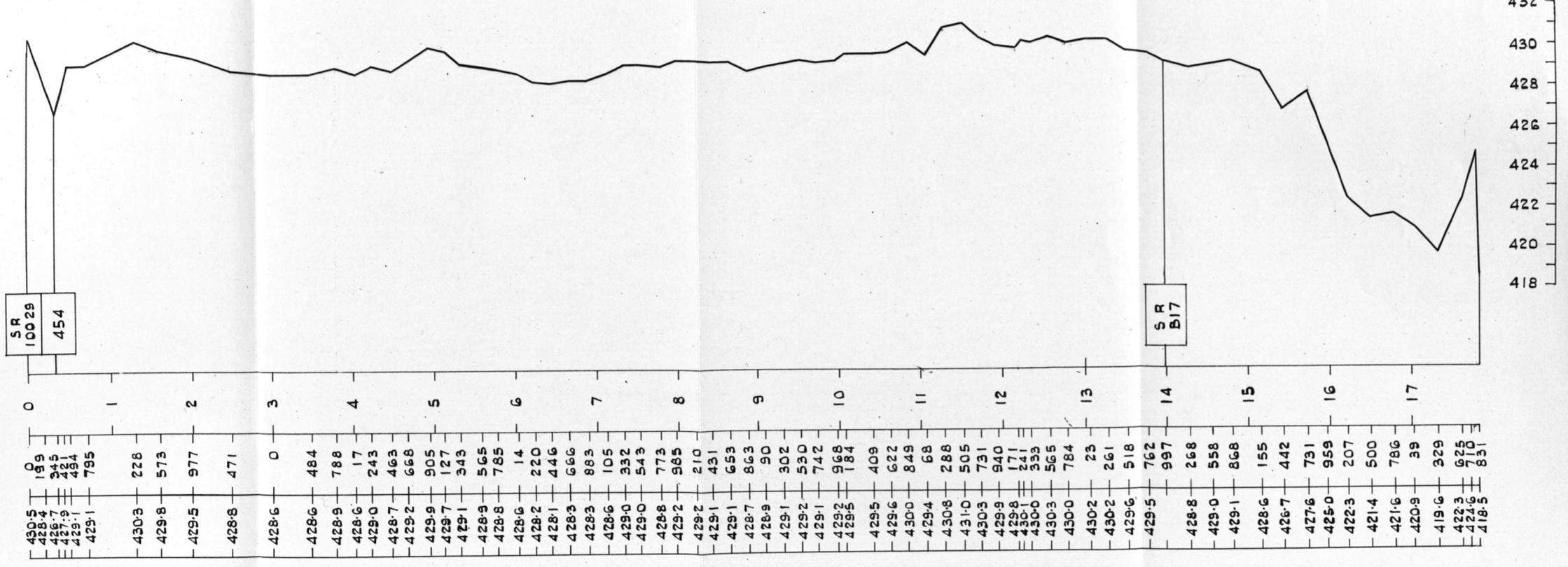
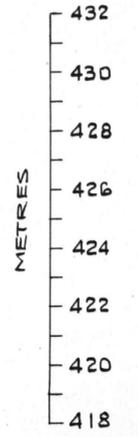


KILOMETRES
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3 C / L 5

KILOMETRES
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3 C / L 6

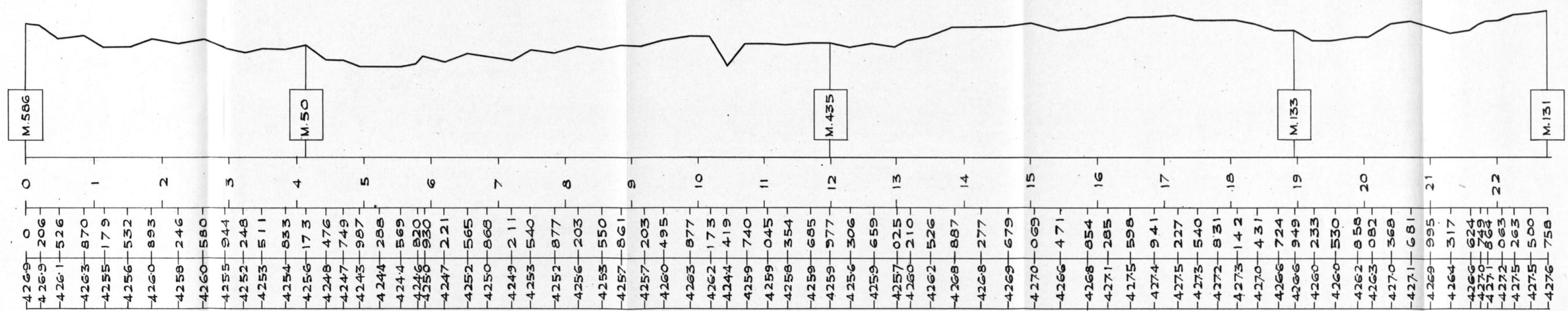
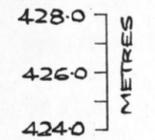
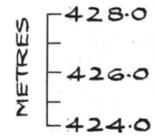
THE REPUBLIC OF THE SUDAN
 MINISTRY OF AGRICULTURE
ROSEIRES SOIL SURVEY

EXTENSIONS TO RAHAD PROJECT
 LONGITUDINAL SECTIONS IN
 HAWATA AREA (SHEET 6)

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

SCALES
 AS SHOWN

DRG. No. SU.211
 DATE: JULY 1965



KILOMETRES	REDUCED DISTANCE	REDUCED LEVEL
0	0	4269
	206	4269
	526	4261
1	870	4263
	179	4255
	532	4256
	893	4260
2	246	4258
	580	4260
3	944	4255
	248	4252
	511	4253
	833	4254
4	173	4256
	476	4248
	749	4247
5	987	4243
	288	4244
	569	4244
	820	4246
6	930	4256
	221	4247
	565	4252
	868	4250
7	211	4249
	540	4253
	877	4252
8	203	4256
	550	4253
	861	4257
9	203	4257
	495	4260
	877	4263
10	173	4262
	419	4244
	740	4259
11	045	4259
	354	4258
	685	4259
	977	4259
12	306	4256
	659	4259
	025	4257
13	210	4260
	526	4262
	887	4268
14	277	4268
	679	4269
15	069	4270
	471	4266
	854	4268
16	285	4271
	598	4275
	941	4274
17	227	4275
	540	4273
	831	4272
18	142	4273
	431	4270
	724	4266
	949	4266
19	233	4260
	530	4260
	858	4262
20	082	4263
	368	4270
	681	4271
21	995	4269
	317	4264
	624	4266
	749	4270
	863	4271
22	063	4272
	263	4275
	500	4275
	758	4276

3C/L3

THE REPUBLIC OF THE SUDAN MINISTRY OF AGRICULTURE ROSEIRES SOIL SURVEY	
EXTENSIONS TO RAHAD PROJECT LONGITUDINAL SECTIONS IN HAWATA AREA (SHEET 7)	
SIR M MACDONALD & PARTNERS CONSULTING ENGINEERS LION HOUSE RED LION STREET LONDON W.C.1.	SCALES AS SHOWN DRG. No. SU.212 DATE: JULY 1965