SOMALI DEMOCRATIC REPUBLIC
NATIONAL RANGE AGENCY

NORTHERN RANGELAND DEVELOPMENT PROJECT

REPORT ON SOILS IN THE PROJECT AREA

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CONTENTS

FIGURES

MAPS

TABLES

1. INTRODUCTION

A reconnaissance soils survey of the Northern Rangelands Project area was carried out in June and July 1979 by A. R. Griffin and the results of this survey are presented in his report "A praisal of Geology and Soils in Project Area". Agronomic aspects of he Project were covered in a report "Agronomic Factors Relevant to Fodder Production Units" by A. D. McKay, following his visit to the area in October to December 1980. This report covers aspects of soil relevant to the agronomy of the Project Area.

More detailed studies were undertaken between September 1980 and June 1981. These studies included auger and trial pit investigation in the field. Laboratory work was undertaken in the National Range Agency offices in Burao on samples of soil obtained from the various sites of the Project. Laboratory equipment was available to perform Atterberg Limit, moisture content, soil compaction, particle size distribution and in-situ density tests.

The major rock types of the area are limestone and anhydrite. The limestones typically form mountainous and hilly areas and the anhydrites typically produce flat plains topography. Where the two rock types are interbedded cone shaped hills, mesas and buttes are commonly found. A greater variety of rock types occur along the northern edge of the project area in the coastal range including sandstones, granites and gneisses. In the Project Area the general dip of the rocks is 3^{o} to 4^{o} in a southerly direction thou small local variations do occur. Faults dissect the area with a gene east west or east-south-east west-north-west trend producing persistent scarp features on the landscape. The geomorphology of the area is that of a typical semi-arid region having rocky hills dissected by steep sided valleys with alluvial fans where the water flow reaches flatter ground.

There are two main types of soil in the area. Pale coloured gypsic silts or silty clays are derived from underlying anhydrite deposits. Light red loam calcareous sandy silts or silty sands are derived from limestone deposits and may overlie the limestone rocks of origin or may overlie anhydrite and limestone rocks as transported alluvial material. Gypsic material is much less often found to have been transported any significant distance by water.

A third type of soil is found in the Bokh Haud part of the Project Area where dark red sands, silts and clays with calcareous gravel are found in a broad valley which has been the scene of large scale deposition of material possibly from sandstone and limestone hills to the north-east of Hargeisa.

The gypsic soils are often thin and cemented, the calcareous soils are generally deeper. The Bokh Haud soils are in excess of 4m deep in the areas investigated but may be interrupted by calcrete or gravel layers. Limestone derived soils have various advantages over gypsic soils for the purposes of fodder production. These include greater depth, more suitable texture, better drainage and the avoidance of accumulation of salts in the upper layers. A gypsum content of more than 50% in the soils is likely to have a deleterious effect on crop yield. It is also considered that limestone derived soil provides a better material for the construction of bunds and other earthworks, having greater cohesion and resistance to erosion and solution than gypsic material. In some areas alluvial mixing of calcareous and gypsic material has occured to produce soils with intermediate characteristics.

2. ORGANISATION OF SOILS INVESTIGATION

The investigation of the soils of the Project Area was performed from a base at the N.R.A. offices in Burao. At these offices there was a one room soils laboratory with equipment which enabled certain basic soils tests to be carried out.

Tests undertaken in the laboratory were:

i) Moisture content

ii) Atterberg Limits

iii) Particle size distribution (wet and dry sieve and hydrometer sedimentation).

iv) 2.5 kg rammer compaction test.

Tests undertaken in the field were:

i) in-situ densities by sand replacement

ii) water quality tests (pH, conductivity, hardness, alkalinity, chloride, sulphate, nitrate, ammonia and phosphorous). Some of these were done in the laboratory, others in the field.

For the purposes of field reconnaissance a hand auger was used to obtain samples of soil and to estimate the depth of soil available for plant growth or for excavation. A back-hoe excavator was available to use at one site only, Qaalin Dheere, for the excavation of trial pits. Small trial pits were dug with hand tools at various sites.

Work was in various ways limited by the non-availability of trial pit excavating plant for most of the project period. The hand auger proved to be a useful tool but was not able to penetrate gravelly soil or well cemented soil.

In the laboratory the equipment was adequate for the number of tests that were carried out. The main limiting factor on the volume of laboratory work performed was the lack of suitable local assistance. No counterpart was provided though a few individuals showed some interest in the workings of the laboratory. None of the laboratory testing work load was taken by any local employee. The quantities of standard vessels and containers in the laboratory proved in general to be adequate but in a few cases limited the number of tests that could be performed at any one time.

A Landrover was available for soils fieldwork, petrol supplies permitting.

3. FIELD AND LABORATORY INVESTIGATIONS

3.1 General

The following sites were visited by the soils engineer, R.C. Tuck between September 1980 and June 1981:-

1. Fiqishinni
2. Qaalindheere
3. Gal Shiikh
4. Gambara
5. Yufleh
6. Gaba Gabo
7. Odweina
8. Goita
9. Hadaftimo and Tug Dhurcood
10. Dur Cad
11. Cabdi Dheere
12. Qurac Kudle
13. Gorayaood and Ceek Ballah
14. Warta Faarax Geedi
15. Xambaree
16. Rimaaleyse
17. Geel Wanaaje

Records of auger holes and trial pits from these sites are included in Appendix 'A'. Only the more important auger holes are noted in this report as many more were drilled principally in order to establish site boundaries.

Records abstracted from the earlier report by A.R. Griffin are at Appendix C.

Soil samples were taken from Goita, Qaalindheere, Gal Shiikh, Hadaftimo, Fiqishinni, Gambara, Dur Cad and Warta Faarax Geedi for the purposes of laboratory testing. All the test results, both from field and laboratory, are presented in Appendix 'B'.

3.2 Field Investigations

Hand auger holes were drilled at all sites to ascertain soil depth and nature. The observations made contributed to the overall assessment of the individual sites outlined in the site descriptions in Chapter 5.

Trial pits were excavated at two sites. At Goita two pits were excavated by hand to augment hand auger information. At Qaalindheere fifteen trial pits were excavated by machine along the line of the proposed irrigation canals.

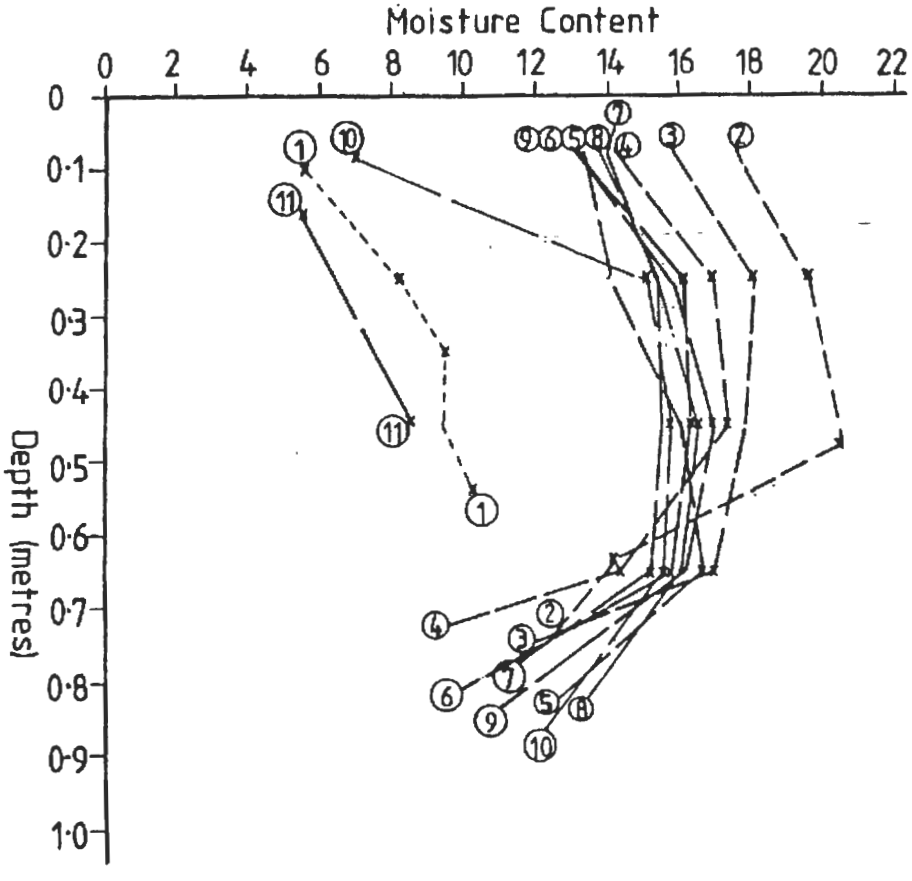
A series of in-situ dry density measurements were made at Goita site. The method used was the Sand Replacement Method (B.S. 1377 1975). Densities of natural ground, uncompacted bund and compacted bund were measured during the dry season, and again, after the rainy season, on the uncompacted bund material. Compaction was carried out by a Fiat 8B Dozer making many passes over layers of soil some 200 to 300mm in thickness. The table below shows the results.

Date	Material	Average wet soil density Mg/m^3	Average moisture content %	Average d density Mg/m^3
21/2/81	Natural Ground	1.56	2.2	1.53
21/2/81	Uncompacted Bund	1.46	2.6	1.42
21/2/81	Compacted Bund	1.46	2.8	1.42
25/5/81	Uncompacted Bund	1.23	5.4	1.17

Table 3.1 In Situ Density at Goita

Two tests were performed at Goita to investigate the behaviour of water applied to the soil. On 2nd December 1980 water was applied to a depth of 200mm in a small basin approximately four square metres in area. Auger holes were then drilled in the basin at intervals for a period of two months. The decrease in water content with time is shown in Fig. 1 as a series of profiles of water content against depth. The ground surface of the test basin was not vegetated. On 21st February 1981 a basin approximately $3.7m^2$ was filled to a depth of 180mm in 20 minutes. The rate of infiltration from the end of filling for 30 minutes was 128mm/hr and then 86mm/hr for the next hour (Ref. Fig. 2).

In addition to these tests some observations were made at Goita of the moisture content at the end of the rainy season. An auger hole was drilled on 25th May 1981 in a basin behind a bund on line 37 which was approximately halfway down the bunded area. The moisture content was 15% throughout the profile to a depth of 2M. On 26th May 1981 two auger holes were drilled at bund line 12 which is near the major source of water for the site in the north of the area. One auger hole drilled inside a bund basin showed a moisture content between 20% and 25% to a depth of 2m. The other hole was drilled outside a bund basin and showed a moisture content of about 10% to a depth of 0.5m The ground was too dry and hard to auger to greater depth. The date of the most recent rains before the auger holes were excavated was 9th May, except for a light shower on the 17th.



INFILTRATION TEST 1

Moisture Content v. Depth in area flooded to depth of 200mm on 2/12/80

Date of sampling

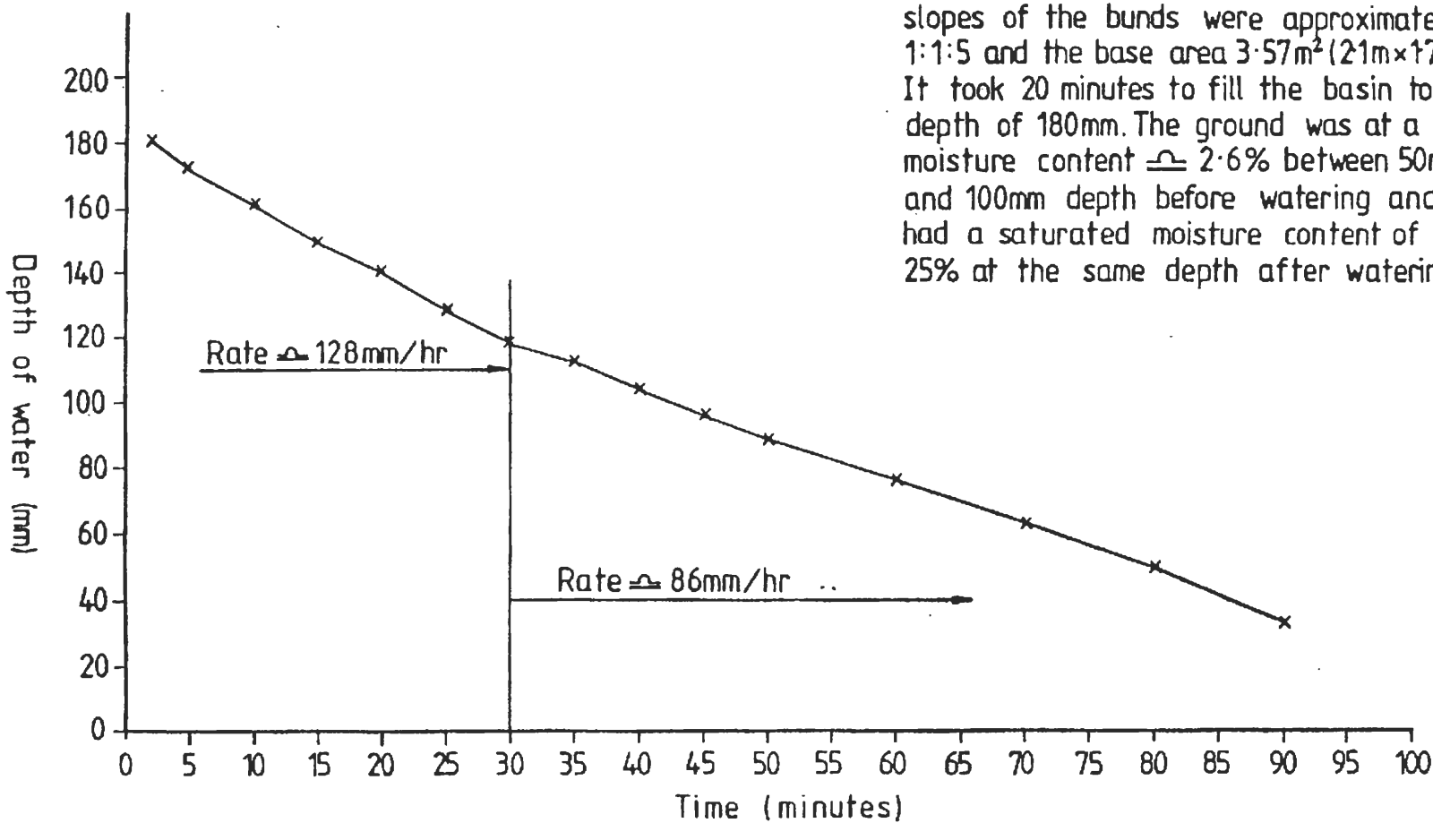
① 2/12/80 ---------
② 4/12/80 — — — —
③ 6/12/80 — — — —
④ 8/12/80 — — —
⑤ 15/12/80 — — —
⑥ 23/12/80 — — -
⑦ 31/12/80 ——— ———
⑧ 7/1/81 ——— ——
⑨ 17/1/81 ——— ——
⑩ 3/2/81 ——— —
⑪ 3/2/81 (Outside wetted area)

①	0·1 5·7	0·25 8·2	0·35 9·5	0·45 9·4	0·55 10·4	m %
②	0·1 17·9	0·25 19·6	0·47 20·6	0·63 19·3	0·73 12·6	m %
③	0·07 15·8	0·25 18·1	0·45 18·6	0·65 17·1	0·75 12·0	m %
④	0·07 14·1	0·25 17·0	0·45 17·4	0·65 14·4	0·72 9·9	m %
⑤	0·07 13·2	0·25 14·1	0·45 16·0	0·65 16·7	0·82 12·7	m %
⑥	0·07 13·1	0·25 15·7	0·45 17·1	0·65 16·1	0·77 10·8	m %
⑦	0·07 14·0	0·25 15·4	0·45 15·8	0·65 15·4	0·77 11·2	m %
⑧	0·07 13·8	0·25 15·7	0·45 16·5	0·65 16·1	0·82 13·4	m %
⑨	0·07 13·0	0·25 15·4	0·45 16·1	0·65 15·4	0·82 11·5	m %
⑩	0·07 6·9	0·25 15·0	0·45 15·8	0·65 15·6	0·85 12·5	m %
⑪	0·18 5·6	0·43 8·3				m %

FIGURE 1

NOTE

Bunds were pushed up to provide a small basin for an infiltration test. The side slopes of the bunds were approximately 1:1·5 and the base area 3·57m² (2·1m×1·7m) It took 20 minutes to fill the basin to a depth of 180mm. The ground was at a moisture content ≙ 2·6% between 50mm and 100mm depth before watering and had a saturated moisture content of 25% at the same depth after watering.



GOITA F.P.V. - INFILTRATION TEST 2

21/2/81 R.L.

FIGURE. 2

3.3 Laboratory Tests

Both wet and dry sieve methods were used to obtain particle size distribution of soil samples from six of the sites. Sedimentation methods were used to ascertain the proportions of silt and clay in the samples. The tests were performed in accordance with BS 1377 1975 Tests 7(A), (B) and (D). The grading curves are given in Appendix B.

Atterberg Limit Tests were performed on samples from seven sites in accordance with BS 1377 1975 Tests 2(A) and 3 using the cone penetrometer method for liquid limit determination. 2.5Kg Rammer compaction tests were performed on samples from three sites BS 1377 1975 Test 12. A large number of moisture content tests were also performed (ref. Section 3.2) in accordance with BS 1377 1975 Test 1(A). The results of all these tests are given in Appendix B.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Hydrology - Infiltration and Runoff

Section 3.3 of the Hydrology Report gives details of Infiltration Tests and a Runoff Study upon which the design of the various sites of the Project have been based. As a result of the spray and ring infiltrometer tests an infiltration rate for stored surface water of 100mm/hr was inferred. The assumption was supported by the data from the basin infiltration test (Ref. Section 3.2 of this report) carried out at Goita where an initial rate of 128mm/hr was measured falling to 86mm/hr after about 30 minutes. (Fig. 2, page 7).

No conclusions can be added to those in the Hydrology Report concerning runoff except that wide variations can exist within individual catchments as well as between catchment areas. Descriptions of catchment areas are included in Chapter 5 of this report.

4.2 Agronomy

The Report on Agronomic Factors Relevant to Fodder Production Units by A.D. McKay presents conclusions on aspects of soils affecting agronomy. In particular such factors as soil erosion, runoff, crop requirements and depth of storage are dealt with.

With regard to depth of storage, McKay states that for a design maximum retention level of 200mm of water behind bunds such a quantity can be absorbed in a soil depth of approximately 1 metre and represents a month's requirement for maximum growth. The basin infiltration test (Ref. Fig. 1 and Section 3.2) at Goita supports the view that a single application of 200mm of water will raise the moisture content of about 1m of soil to a value around 20%. This value is thought to be near the Field Capacity of the Goita soil. It was shown by the auger holes drilled at Goita after the rainy season (also Ref. Section 3.2) that repeated applications of water were able to increase the moisture content of the soil to in excess of 2m depth.

McKay also presents the agronomic arguments against forming level basins behind bunds. The contrary view, which has been adopted by the consultant, is set out in their Final Report, section 9.7.

4.3 Engineering and Engineering Materials

The Construction Manual sets out the general guidelines for bund construction, excavation for channels and ponds, embankment compaction, quarrying, production of graded stone, design of filter material and aggregates for concrete production.

It is not considered practical to compact bunds and this will mean that initially they will be vulnerable to erosion and animal damage. Grassing and stabilisation should occur over a period of time.

Where excavations for channels or stockwater ponds are necessary it is anticipated that at many sites cemented sub-soils may require loosening by ripping as soil cementation to varying degrees occurs widely throughout the region.

Embankments that are intended to retain water for a period of time or likely to be subject to erosion should be constructed with compacted soil. From the number of laboratory compaction tests performed it appears that a moisture content of about 18 to 20% is required to achieve the maximum dry density of typical soils of the area. For the greater part of the year most soils in the area have natural moisture contents of less than 10%. As demonstrated at Goita (Ref. Section 3.2) it is unlikely that such dry soils will respond to compactive effort in their natural moisture state. The recommended method of compaction is given in the Construction Manual.

The method of production of graded stone for use as fine and coarse aggregate for concrete, granular backfill, filter material and gabion stone is outlined in the Construction Manual. It is considered that tug beds will form an important source of material together with stony ridges and borrow pits in alluvial

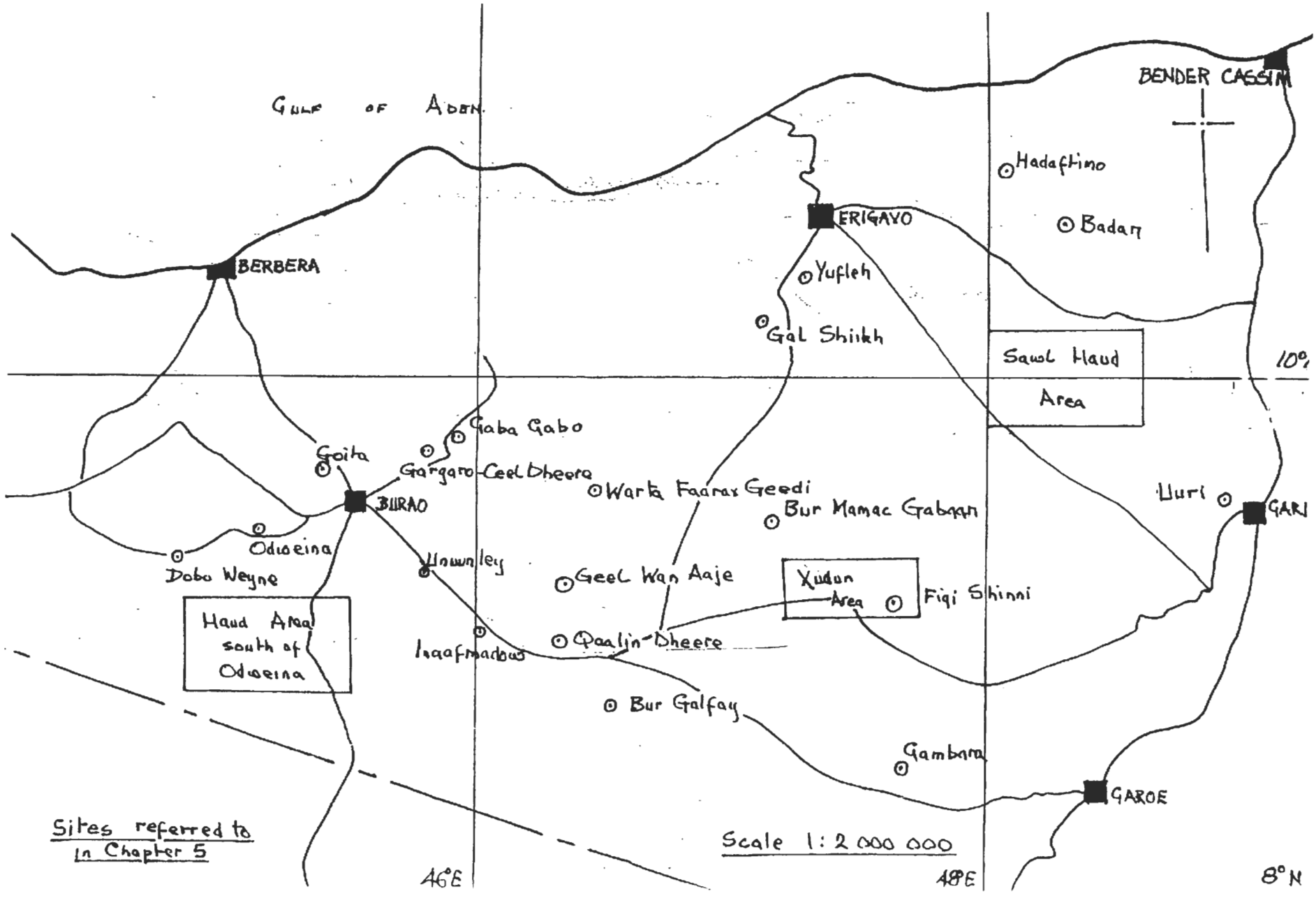
fans or other natrual accumulations of coarse material. Material should in general only be considered if it is of limestone origin, both for quarrying and collection of natural accumulations.

The Construction Manual also sets out the method of design of filter material for use at water retaining structures. Grading curves for the soils occurring at the relevant sites such as those included in Appendix B can be used in conjunction with the method set out to specify the type of filter required for a particular location.

Limestone hills should provide the main source of all materials for use in construction work at the recommended sites. In all cases some limestone material is within fairly easy reach of the sites.

Section 3.4 of Appraisal of Geology and Soils in Project Area by A.R. Griffin presents observations and conclusions on the soil properties of the two major types of soil found in the area, limestone derived and anhydrite derived (gypsic). Subsequent observations have in general supported these initial conclusions. In general the gypsic soils are fine grained, have low plasticities and lack true cohesion. While very soft and weak when wet they become brittle and crumbly when dry. Gypsic soils will be susceptible to scour, erosion and solution, will have negligible shrinking and swelling properties, low shear strengths and low compacted maximum densities. Limestone derived soil shows greater cohesion and resistance to erosion and solution than gypsic material.

These differences are illustrated by the results of some laboratory tests on samples of soil from three sites, Gal Shiikh, Hadaftimo and Fiqishinni. These samples represented limestone derived, anhydrite derived and mixed origin soils respectively. Samples from Gal Shiikh were shown by Atterberg Limit Tests to fall into the range of clays of medium plasticity and a particle size analysis showed the material to be a sandy silt with a little clay (the relative proportions being 40%. 45% and 15% respectively). A sample from Fiqishinni had a much lower plasticity though still falling in the same classification as the Gal Shiikh samples. In contrast the gypsic soil samples from Hadaftimo proved to be non-plastic but a particle size analysis showed the material to be 20% clay, 55% silt and 25% sand.


GULF OF ADEN
BENDER CASSIM
Hadaftimo
Badan
ERIGAVO
BERBERA
Yufleh
Gal Shikh
Sawl Haud Area
10°
Gaba Gabo
Goita
Gargaro-Ceel Dheere
BURAO
Warta Faarax Geedi
Bur Mamac Gabaan
Uuri
GARI
Odweina
Dobo Weyne
Unwnley
Geel Wan Aaje
Xudun Area
Figi Shinni
Haud Area south of Odweina
Isaafmadow
Qaalin-Dheere
Bur Galfay
Gambara
GAROE
Sites referred to in Chapter 5
Scale 1:2 000 000
46°E
48°E
8°N

5. SITE DESCRIPTIONS

5. 1. FIQISHINNI

This site lies about 15 km east of Xudun and is centred on map reference 8788E 1006N on sheet NC-38-108.

The site is bounded by limestone hills to the north and south but in the catchment area to the east there are areas of anhydrite bedrock. These anhydrite beds occur in the northern part of the catchment and form the low hills which ring the northern upper catchment. The hills which form the southern boundary to the catchment area are mainly limestone.

The catchment of Tug Baadho iyo Kayaxa and its tributary tugs occupies an area of approximately 90 km^2. The limestone hills and slopes on the southern side and the anhydrite hills and slopes on the northern side surround a central area which was formerly an area of deposition of alluvial material but is now being dissected and eroded by numerous gullies several metres deep. These gullies join the main tug before reaching the area of the site.

The tug flows out onto the site area and has deposited its material over a wide plain, the flow of water is presently concentrated in two rill flow areas running parallel to the northern and southern boundary hills.

As a result of the mixture of alluvial material from anhydrite and limestone rocks the soils of the site area are, in general, pale coloured silts with little cohesion. The gravel content of the soils is generally low and the soils of suitable depth for fodder production except in limited areas (Ref. 3.5.3 of A D McKay's Report "Agronomic Factors relevant to Fodder Production Units").

5. 2. QAALIN DHEERE

This site lies about 12 km north of Ainabo. Proposed diversion structures at the site lie at map reference 8659E 1000N on sheet NC-38-105.

The site is situated near the point where water from the limestone Buur Dhaab hills to the north-west reaches flatter anhydrite plains to the south-east. The soils of the site are formed from alluvial deposits from a rocky limestone catchment area of 118 km^2. The Qaalin Dheere tug forms the south western boundary of the site area and in places the banks of the tug show up to 4m of the alluvial deposits. Some gravel beds can be expected in the alluvial deposits in this area as it is very likely that tugs emerging from the hills have changed course during the time the deposits have been laid down.

The proximity of the site to low limestone hills to the north has meant that there is some gravel derived from

these hills in the soil. Anger holes drilled at the site often encountered gravel and were prevented from penetrating further. A series of fifteen trial pits showed that although gravel does occur and cementation of the soil increases with depth, there is in excess of 2m of a predominantly silt and sand soil over the majority of the site.

5.3. GAL SHIIKH

This site lies some 4 km north-west of Gal Shiikh village which is about 18 km north of Ceel Afweyn on sheet NC-38-71. Water is to be diverted from tug Gurya San at map reference 8739E, 1115N.

The two main tugs which flow into the site area are Tug Dhaax with a catchment area of 44 km^2 and Tug Gurya San with a catchment area of 16 km^2. Both catchments are characterised by an upper reach of gently sloping sparsely vegetated land leading to steep bare rock slopes, which feed run-off into a network of channels deeply incised into the soils of the connecting valleys. Waters from Tug Gurya San have caused extensive gullying to the north west of the site and have formed a deeply incised channel cutting through the plain to run out in the east through a wooded area.

The hills which bound the north-east side of the site are limestone and those to the south-east, south-west and north-west are anhydrite. The limestone scarp which bounds the north-east side is guided by a fault and it is likely that anhydrites underlay the alluvium of the site and are a continuation of the rocks of the gently sloping anhydrite hills to the south-west of the site area.

The tugs flowing into the site area have deposited limestone alluvial material to depths in excess of 5m. There is a very marked change in soil type at the south-western edge of the site, where the alluvial limestone soil meets the shallow gypsum soils of the anhydrite slopes. The soils of the site area are mostly gravel free calcareous sandy silts with a little clay. A very few gravel beds can be seen in the incised tug banks but these should prove to be no obstruction to construction or rooting.

5.4. GAMBARA

This area is about 25 km north-east of Las Anod along the Chinese Road. The site is centred on map reference 8786E 0952N on sheet NC-38-132. Two tugs flow into the area, Goblay and Doryare, and have catchments of 300 km^2 and 150 km^2 respectively.

The rocks of the catchment areas are flat interbedded anhydrites and limestones, the anhydrite being the

dominant rock type. The catchments consist of a series of broad, fairly flat basins with surrounding steep sided hills. The steep hill sides are poorly vegetated rock and scree slopes where s the broad basins are more vegetated with gullies and channels incised into the alluvial deposits.

The soils of the site area are underlain by anhydrite rocks and are themselves formed of a mixture of anhydrite and limestone derived material. The soils are generally silts and sands with some clay and gravel in some areas. Established grass areas can cause an increase in clay content of the soil by slowing water flow and causing deposition of fines in the grass area and this appears to have happened in the well grassed areas of this site. Gravel and gypsic cementation of the soil may restrict the growth of vegetation in parts of the site outside the well grassed areas.

5. 5. YUFLEH

This site lies about 6 km south-east of Yufleh village, which is about 30 km south-west of Erigaro. The site is centred on map reference 8746E 1146N on sheet NC-38-59.

The hills surrounding the site are both of limestone and anhydrite. The upper catchment is an area of sparsely vegetated gypsic soils on gentle slopes. Nearer the site the limestone slopes are steeper and more rocky.

The site can be divided into two areas. The lower area lies below the outflow of the main tug, Tug Hareer , and is a large plain of deposition. The upper area of the site is fed by material from the adjacent hills, which are mostly limestone but contain some anhydrites.

The soils of the site are mainly calcareous in character but contain some limited areas of gypsic soils, particularly in the upper area of the site. In general, except for areas adjacent to hillslopes, the soils are of good depth with low gravel contents.

5.6. GABA GABO

This site stretches from 4 to 12 km south of Gaba Gabo village (8598E 1084N) on sheet NC-38-80.

This site occupies a strip of land to the east of a range of limestone hills. There are no major watercourses entering the area but a series of minor flows from the hillside which bring limestone material into the site area. Adjacent to the steep rocky hillsides gravel and cobbles are predominant in the soil, further away from the hillsides, in general, the soil grain size is reduced. The rocky hill slopes and adjacent gravel slopes are sparsely vegetated with an increase in shrubs, trees and grass only occuring on the firmer soils of the site area.

This soil is a calcareous silt and sand. There are areas of gravel away from the hillside, as at the north end of the site. The site boundaries avoid the more gravelly areas.

5. 7. ODWEINA, DOBO WEYNE

These sites lie about 2 km north-west and 24km west-south-west of Odweina (Oodweyne). They have similar soils.

The alluvial deposits in a wide area around Odweina have their origins in the limestone hills to the north in the region of Go'o. These alluvial deposits have been transported a relatively large distance and are in consequence fine soils, being mainly silt. They are likely to be deep as the area has been one of significant deposition.

5. 8. GOYTA

This site lies about 25 km north-west of Burao. The site is centred on map reference 8544E 1074 E on sheet NC-38-79.

The site occupies a position on the south-western side of a range of low limestone hills and the new Berbera - Burao road. The limestone hills have bare rocky surfaces with a thin covering of cobbles and gravel. Between the hillsides and the new road gravel and cobbles form the surface material, but there is a rapid change around the position of the new road and the soils of the site become deep gravel free calcareous silts and sands with some clay. Over the site area the soils remain uniform except for a slight increase in the cementation of the soil with increasing distance from the limestone hillsides. This cementation is not well developed and therefore not likely to cause any obstruction to rooting or construction.

5.9. BANAANKA BALWEYNE AND TUG DHURCOOD

These sites are located 6 km south-east and 17 km east-north-east of Hadaftimo respectively at map references 9186E 1188N and 9200E 1194N on sheet NC-39-39.

These areas are of similar nature being bounded on one side by anhydrite hills and on the other by a deeply incised tug. The anhydrite hills are steep with a rocky surface. From the foot of the hills there is a gently sloping plain, with thin gypsum soil derived from the anhydrite rocks. This soil has a 'plated' cemented surface and a relatively good cover of grass for the type of soil. Nearer the tugs the soil type changes to become deeper, less cemented and more calcareous. The areas near the tugs have material derived from limestone rocks which outcrop in the catchment of the tugs, as well as from anhydrite rocks. The dividing line between the two soil areas is, at neither site, well defined.

At Banaanka Balweyne a strip of land some 250m in width next to Tug Gebi has soil considered to be suitable for trial development as a water harvesting site. The soil is, in this zone, a pale coloured sandy silt of considerable depth as shown by the deeply incised Tug Gebi.

Similarly, at Tug Dhurcood, a 250m strip of land adjacent to the tug has been selected for development. The soil here is of similar nature as at Banaanka Balweyne but there are some areas of gravelly soil to the east of the area which may prevent development in that direction.

5.10 HAUD AREA SOUTH OF ODWEYNE

Five sites have been considered in this area for development of Stock Water Ponds. The sites are Duur Cad, Cabdi Dheere, Qurac Kudle, Gorayaood and Ceek Ballah. Map references are given for these sites in the Stockwater Pond Report.

The sites lie in the valley of Togga Dulead/Bokh, which runs south-east from Odweyne to the Ethopian border at a very shallow gradient. The side slopes are very gentle having falls of less than ½% into the main flow areas in the valley bottom. There are very few defined or incised channels. Vegetation in the area is largely acacia bush and trees with areas of more open grassland and mixed grass and small shrubs.

A deep red alluvium covers the area and is possibly derived from sandstones and limestones east of Hargeisa The soils of the sites conform to a fairly regular pattern and appear to be essentially a red sand and silt with some clay and gravel of calcareous nodules. The gravel tends to become greater in quantity with depth and the soil also becomes more cemented at depths greater than one or two metres. In some areas there is a patchy development of calcrete in which the gravel becomes cemented into a rock-like layer.

Duur Cad, Cabdi Dheere and Qurac Kudle conform to the pattern of soils outlined above and should have sufficient depth of soil for the development of Stock Water Ponds. At Gorayaood there is a greater development of calcrete in the area and this may limit the depth of soil which can be excavated. At Ceek Ballah shallow sump excavations should not encounter any obstruction in the soft sediments of this shallow depression.

5.11 SAWL HAUD AREA between ERIGAVO and GARDO

Two areas have been considered in this region for the development of Stock Water Ponds. These areas are Xambarre and Rimaaleyse.

The positions of these sites are illustrated on Map 3 of the Stock Pond report and map references given.

The area is generally very flat with little relief especially in anhydrite bedrock areas. The gypsum soil of the anhydrite supports open grassland with virtually no bushes or trees except around sink holes. The limestone soils more commonly develop vegetation areas containing acacia trees and bushes and dense grass.

The soils of the region are generally derived from the underlying bedrock with some additional alluvial material

as in the Xambarre valley, for example, where limestone alluvium has been brought into the area from the north. This material forms cemented gravel ridges lying over anhydrite bedrock.

Xambarre and Rimaaleyse are very similar in nature. They lie in broad flat valleys, some 2 to 3 km across, which are bounded by the cemented limestone gravel ridges. The soil in the valley bottoms is a mixture of gypsic and limestone silts, sands and clays. A tributary tug to the main valley forms an alluvial fan of a mixture of gypsic soil and limestone alluvium in both valleys. Outside the alluvial fans the gypsic silting soils are well cemented at half a metre depth. The alluvial fans, though coarser and containing gravel and cobbles, should provide a greater depth of soil for excavation.

A limestone outcrop running east-west between Xingalool and Ceelbuh forms low ridges of rock and gravel with broad flat valleys with shallow soil, between one and two metres depth.

5.12 GEEL WAN AAJE

This site lies at the foot of the west end of the Buur Dhaab escarpment, to the south-west of Waridad.

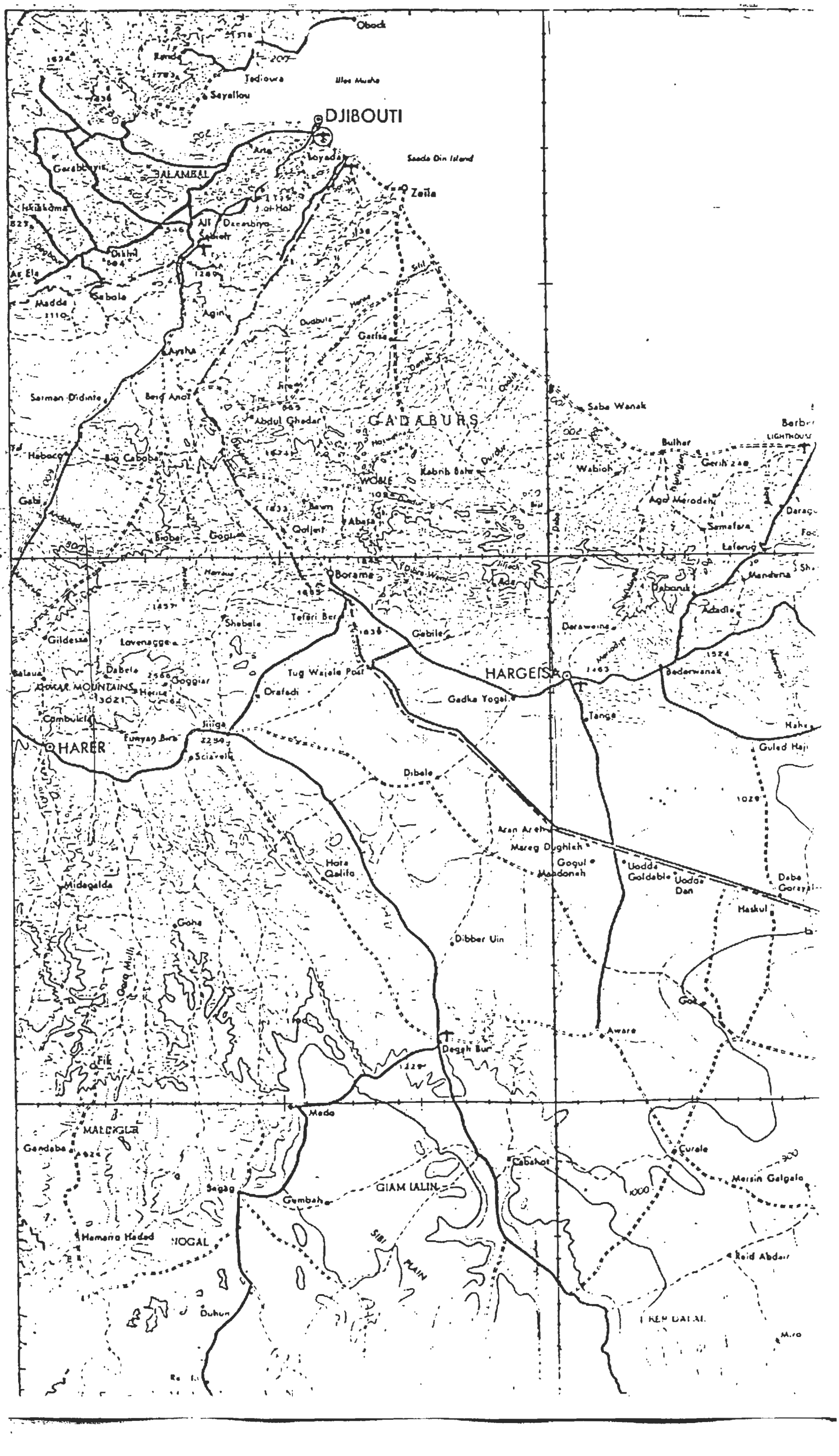
The Buur Dhaab range of hills facing the Nugaal is a retreating limestone escarpment. The face of the range is steep and deeply incised by a series of steep sided rocky valleys. For a distance of between one and two kilometres from the scarp face limestone bedrock is visible, overlain in places by cobbles and other alluvial debris. It is assumed that this is the remnant of the base of the limestone left as the scarp face has been eroded. There is a fairly well defined line between this area and the much flatter alluvial area to the north formed by the eroded limestone debris. It is in this alluvium that the Stock Water Pond could be sited.

Near the dividing line the alluvium is fairly coarse containing gravel and cobbles with the sand and silt of the soil, but the material becomes finer in nature with increasing distance from the limestone scarp. Calcrete layers can be seen at the surface of the alluvium in some parts of the area and should be avoided when excavating.

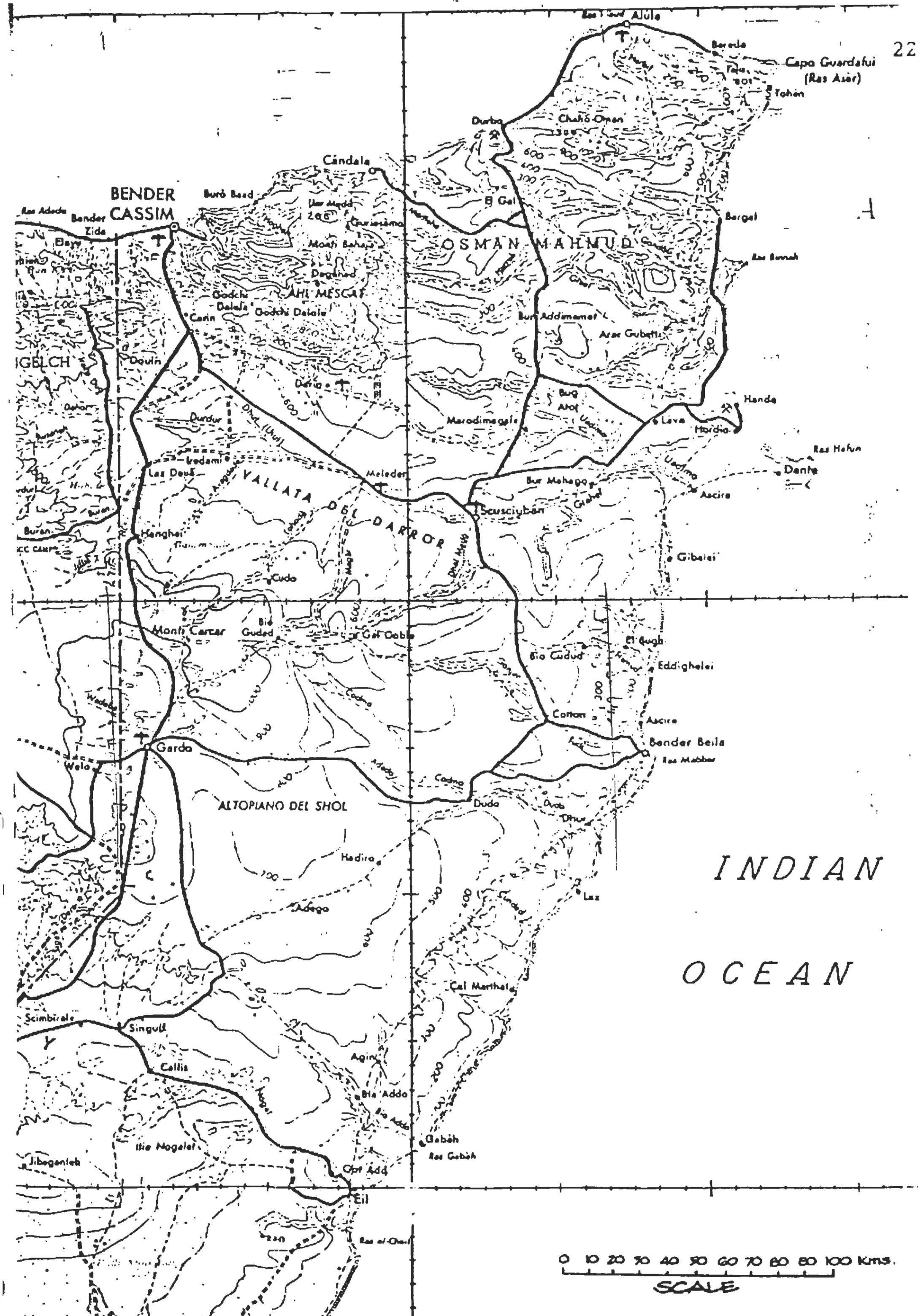
The two alternative sites at Reygat and Hidiido are very much the same as Geel Wanaaje.

5.13 WARTA FAARAX GEEDI

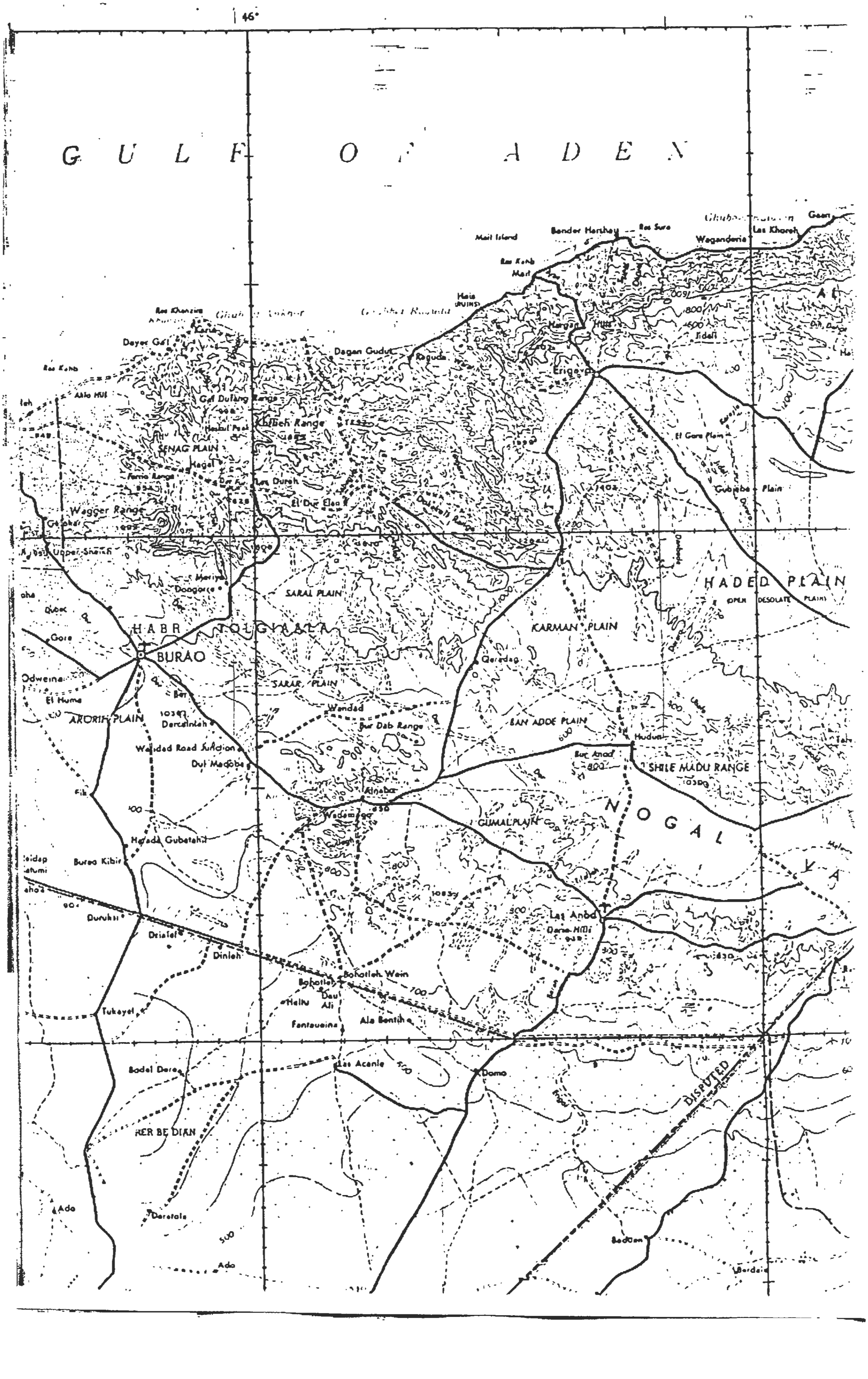
This stockwater pond site lies north of Waridad, on the Banaanka Higlo Xaraf plain.



Obock
Tadjoura
DJIBOUTI
Loyada
Saada Din Island
Zeila
Ali Sabieh
GADABURS
Saba Wanak
Bulhar
Berbera
Borama
Gebile
Tug Wajale Post
HARGEISA
Gadka Yogal
Tanga
Jijiga
HARER
Sciaveli
Dibele
Aran Arehe
Mareg Dughleh
Gogul
Uodda Goldable
Uodda Dan
Haskul
Hora Galifo
Midegalda
Dibber Uin
Goha
Aware
Degeh Bur
Fik
Medo
Gendaba
Sagag
Gembah
GIAM IALIN
SIBI PLAIN
NOGAL
Duhun
Curale
Mersin Galgalo
Reid Abdair
Guled Haji
Ayshe
Sarman Didinte
Gildessa
Lovenagge
Dabele
Goggiar
Combulcia
Fumyan Bura
Orafadi
Teferi Ber
Shebele
Abdul Ghedar
Kabrib Bahe
Wabioh
Agin
Madde
Gerih
Laferug
Mandena
Adadle
Dabaruk
Darawaine
Bedarwanak
Defeh Bur
10°


Alula
Capo Guardafui
(Ras Asèr)
Durba
Cándala
BENDER CASSIM
OSMAN MAHMUD
Bergal
Hande
Dante
Scusciuban
VALLATA DEL DARROR
Gibelei
Monti Carcar
Gardo
Eddighelei
Bender Beila
ALTOPIANO DEL SHOL
INDIAN
OCEAN
Singulf
Eil
El Hamurre
0 10 20 30 40 50 60 70 80 90 100 Kms.
SCALE

MAP OF AREA :


46°
G U L F
A D E N
Mait Island
Bender Harshau
Las Khoreh
Wagandeira
Heis (RUINS)
Dagan Gudut
Erigo
Jidali
El Gore Plain
Gubaba Plain
Gal Dulang Range
SENAG PLAIN
Las Dureh
Wagger Range
Upper Sheikh
HABR
BURAO
SARAL PLAIN
SARAR PLAIN
KARMAN PLAIN
HADED PLAIN
OPEN DESOLATE PLAINS
Odweina
El Hume
Wandad
Bur Dab Range
BAN ADDE PLAIN
Hudun
Bur Anod
SHILE MADU RANGE
Wadidad Road Junction
Dul Madoba
Ainabo
GUMAL PLAIN
N O G A L
Burao Kibir
Las Anod
Duruksi
Dinleh
Bohotleh Wein
Bohotleh
Ala Bentih
Tukayel
Las Acanle
Domo
DISPUTED
RER BE DIAN
Ado
Bodden

The area is a zone of deposition for waters bringing alluvium from the bare and rocky limestone and anhydrite hills to the north and north-east out onto the plain. The water flow from the hills has deposited a fairly uniform sand with silt and a little clay to, apparently, fairly large depths. No cementation of this soil is apparent and the soil i gravel free.

5.14 XUDUN AREA (Xudun Nos. 1, 2, 3, 4, Bur Anod South and Kooratoonshe)

Soils for all these areas are essentially silts and are derived from weathering of limestone from the Bur Anod ridge, mixed with anhydrite from the Nougal valley. The percentage of limestone sands and gravel, and the size of gravel particles increases as the hills are approached whereas the amount of anhydrite increases as they are left behind and the Nougal valley approached. The best soils for both agricultural and engineering purposes are to be found in an intermediate zone between these two cases. There is an abrupt change in vegetation type at the point at which anhydri becomes dominant.

5.15 BUR GALFAY, UURI , BUR MAMAC GABAAN, GARGARO - CEEL DHEERE

The soils of these areas are all the products of weathering of the local limestone hills which overlook the sites. Coarse material is found near the hills but the amount of fine sand and silt increases, as does the depth, as soil moves into the flatter areas below the pediments which are suitable for fodder production units.

5.16 INAAFMADOW, UNUUNLEY

These sites lie astride the Chinese Road, 60 and 35 km from Burao. Soils are limestone derived from higher ground and ridges a few kilometres to the South-east. At Inaafmadow there is a gravelly hard pan which, in places, comes within 1 metre of the surface. At Unuunley soils are rather coarser than at Inaafmadow, especially in the South-east where limestone bedrock comes to the surface.

6. COMMENTARY ON DESIGN ASSUMPTIONS

Early visits by the Geologist and Hydrologists resulted in the publication of "Appraisal of Geology and Soils in the Project Area" and of the Hydrology Report, both dated October 1980 but based upon visits between June and September 1979. Certain design parameters were needed early in the Consultancy and many of them were either set out or implied in one or the other of these two publications. The time has now come to review these.

6.1 Infiltration of ponded water

Experiments at Gaba Gabo, described in Section 3.3.1 and Appendix D of the Hydrology Report, gave ring infiltrometer rates averaging 122mm per hour, with a standard deviation of 59mm, from 16 samples (ignoring the two extremes). The test at Goita referred to at Section 3.2 and Figure 2 of this report shows not dissimilar figures of 128mm per hour for the first 30 minutes falling to about 80mm per hour thereafter. Tests at Gaba Gabo were carried out with 10 and with 50mm at Water in infiltrometer whereas Goita was a larger scale field experiment with water depth steadily falling from 180mm to zero. The effect of head does not seem therefore, particularly significant.

While there was considerable variation in infiltration rates from test to test the round figure first approximation of 100mm given in the hydrology report is as near as one can hope to get for an overall figure. The fear once expressed that the designed impoundment of 200mm behind the bunds might do permanent damage to the crop can be dismissed: even in the extreme case, where an infiltration rate of 20mm per hour was recorded, the bund would absorb the full charge in 10 hours.

6.2 Infiltration of rainwater

No further rainf. ll simulation was possible beyond th. t carried out at Gaba Gabo where I8 spray infiltrometer tests gave an average of 26mm per hour with a standard deviation of I5mm per hour. The difference between these figures and those for ponded infiltration above is of course due to the difference in contact times: rainfall not immediately absorbed is assumed to run off.

From these observations a rainfall runoff relationship was developed in the Hydrology report of:

$$\text{Runoff (in mm)} = 0.2II\ (\text{Rainfall} - 5)^{I.243}$$

where rainfall, in millimetres, is that for the indivdual storm producing the runoff.

Unfortunately historic rainfall records are for daily - or longer - periods with the exception of a record from Burao kept during the latter half of the Consultancy, and some very brief records elsewhere. New rainfall books, to record individual storms have been prepared, wit a column for runoff etc., but it will be several years before the information in them will be sufficient to be a better guide to the rainfall runoff relationship than the equation quoted.

6.3 Soil Moisture Capacity

An early assumption was that the soil moisture capacity of soils to be expected at FPU sites would be between I5 and 25% by volume and that the available water would be about IO% by volume. As grass roots were expected to penetrate to 2m a recharge (after initial filling) of 200mm of water would therefore be needed, and bunds were designed on this basis.

In fact few roots were found to penetrate beyond I metre. The Geology and Soil Report, Section 3.4.I refers to root penetration to 70 cms and regards this as "fairly deep".

This judgement would be endorsed by the resident members of the consultant's team who rarely observed roots much beyond 0.5 metres below the surface. The ground was dense, dry and compacted at this depth and it may well be that regular cultivation under irrigation would give rise to a better structure and deeper roots.

Water penetration during the infiltrometer tests in 1979 was generally shallow, 50 to 400mm, but these were all short duration tests of an hour or less. The test at Goita illustrated at Figure 1 (page 6) shows a fairly uniform moisture content between 0.2 and 0.6 metres depth, slowly decreasing with time over 3 months. Below 0.6 metres the moisture content was falling rapidly with depth. The most significant thing about Figure 1 is the higher moisture content, 3 months after filling the bund, in samples taken from within the bund (15.8% moisture content at 0.45m) than in those from outside the Bund (8.3%).

As recorded in Section 3.2 above moisture contents of 15 to 25% were found to a depth of 2 metres under bunds at Goita at the end of the 1981 GU rains. Outside the bunds the moisture content was only 10% for 0.5m.

While much more work needs to be done, and individual sites may show considerable variation the assumptions quoted at the head of this section were a good intelligent guess based on the information available at the time they were made.

It would now seem that 200mm of water will initially charge about 1m of soil to field capacity. Conversely grass roots do not seem to penetrate below 1 metre under present conditions. These two observations tend to cancel each other out, but a case is beginning to appear for a rather larger charge of water to be retained behind the bunds.

Raising the ponded depth slightly on existing bunds is no great problem and if selected bunds were raised to impound 300mm to full supply level the resulting comparison with adjacent bunds holding 200mm would be instructive. It may well be that this has happened inadvertently at some places due to setting out or construction errors and, if so, the comparison could be sought and made now, even on indigenous vegetation.

6.4 Compaction and Consolidation

The original appraisal of the Northern Rangelands Project laid down that bunds were not to be compacted. This was because of the general shortage of water and the practical impossibility without water of compacting the high silt content soils expected (and found) at practically all F.P.U. sites.

The following of this criterion, albeit reluctantly, has caused much concern to the Consultants. Bund size has been increased over that foreseen in the Appraisal Report, to 0.9 to 1.2m high with 2:1 side slopes and a 0.5m flat top (compared with 1.1m high, triangular, with 1:4:1 side slopes). At this increased cross section bunds were lost in the heavy 1981 GU rains, although severa times overloaded well beyond design assumptions. Smaller hand constructed bunds 0.6m high were however severely damaged.

It is clear from Table 3.1 (page 4) that attempts to compact the dry material met with no success and that the natural consolidation of typical bund material will be a disappointingly slow process. From such experience as may be drawn from one year's floods a seepage path of the order of 1 in 9 during the design flood is sufficient, as this flood usually passes in a matter of 2 hours or less. Temporary overload conditions gave rise to seepage gradients at Goita theoretically unacceptable, but for short periods only. The gradient at full supply for the standard cross section (0.9m high) is 18:1.

6.5 Borrow areas for bunds

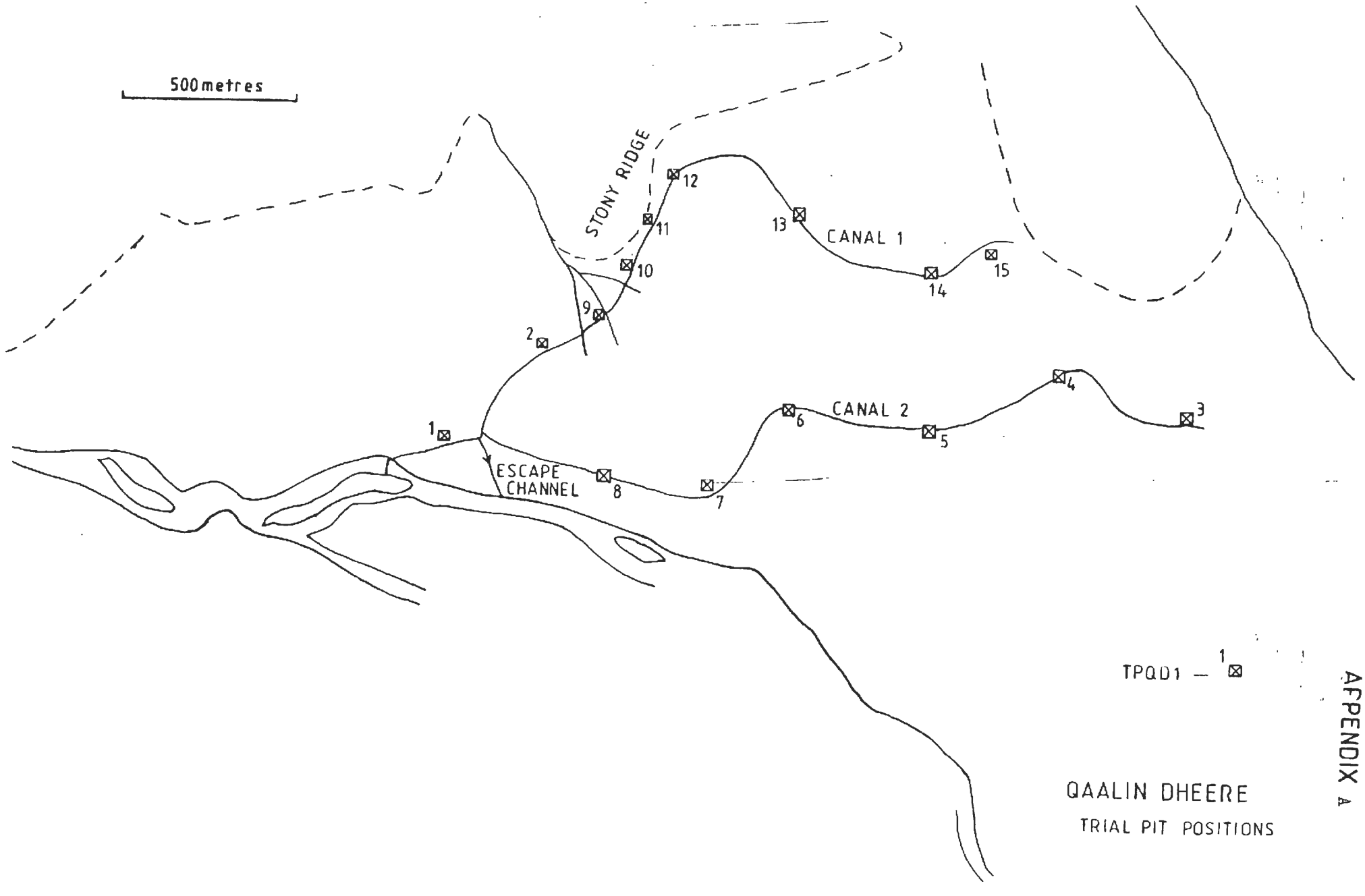
The pros and cons of obtaining fill material from uphill or downhill are set out in Section 9.7 of the Final Report.

From the engineering soils point of view the stability of the bund is improved by pushing the fill from uphill down, as the seepage path is better than in the alternative with its excavation against the downstream toe. The additional and more uniform water storage in the soil is an advantage. On the other hand the loss, or disturbance, of the better topsoil is an adverse aspect as viewed by the agriculturalists.

APPENDIX 'A'

AUGER HOLE AND TRIAL PIT RECORDS

(R.C. Luck September 1980 - June 1981)



QAALIN DHEERE

TRIAL PIT POSITIONS

APPENDIX A

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT No. QDI

SITE QAALIN DHEERE

DATE EXCAVATED 25/2/81	GROUND LEVEL
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION	
0·30			0.00 - 0.30m	Light brown loose to medium dense sandy silt. Some roots.
1·50			0.30 - 1.50m	Light brown, dense, slightly cemented sandy silt.
2·85			1.50 - 2.85m	Light brown, cemented, silt and sand with a very little fine gravel.
				TRIAL PIT COMPLETED AT 2.85m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

APPENDIX A

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT N°. TPQD2

SITE QAAI IN DHEERE

DATE EXCAVATED 2/3/81 EXCAVATION METHOD MACHINE LOGGED BY R.L.	GROUND LEVEL LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00 0·35			0.00 - 0.35m Light brown, loose to medium dense sandy silt. Some roots.
1·50			0.35 - 1.50m Light brown medium dense sandy silt. 1.50 - 2.05m Light brown cemented silt and sand.
2·05			2.05 - 2.35m Light brown, well cemented silt with sand and fine gravel.
2·35			TRIAL PIT COMPLETED AT 2.35m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD3

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81 EXCAVATION METHOD MACHINE LOGGED BY R.L.	GROUND LEVEL - LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
0·35			0.00 - 0.35m Light brown loose silty sand with fine gravel.
			0.35 - 2.25m Light brown cemented silty sand with a little fine gravel.
2·25			TRIAL PIT COMPLETED AT 2.25m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº TPQD4

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81
EXCAVATION METHOD MACHINE
LOGGED BY R.L.

GROUND LEVEL
LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION	
0·00				
0·50	• 0·30-0·40 (b)		0.00 - 0.50m	Light red brown sandy silt with some roots. Blocky structure.
1·20			0.50 - 1.20m	Light red brown slightly cemented silty sand with a little fine gravel.
1·40	• 1·20-1·40 (a)		1.20 - 1.40m	Light red brown, dense, cemented silty sand with some gravel and small cobbles.
2·50			1.40 - 2.50m	Light red brown slightly cemented silty sand with a little fine gravel.
				TRIAL PIT COMPLETED AT 2.50m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD5

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL –
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION	
0·00 0·30			0.00 - 0.30m	Light red brown loose to medium dense sandy silt.
0·80			0.30 - 0.80m	Light red brown dense, cemented, silty sand with a little gravel.
1·95			0.80 - 1.95m	Light red brown, well cemented, silty sand with a little gravel, a few cobbles and some calcareous nodules.
				TRIAL PIT COMPLETED AT 1.95m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº. TPQD6

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81
EXCAVATION METHOD MACHINE
LOGGED BY R.L.

GROUND LEVEL –
LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
			0.00 - 0.50m Light brown medium dense sand and silt with a little fine gravel.
0·50			
			0.50 - 0.80m Rounded cobbles and gravel with sand.
0·80			
			0.80 - 1.95m Light brown cemented silty sand with fine gravel.
1·95			
			TRIAL PIT COMPLETED AT 1.95m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº. TPQD7

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81
EXCAVATION METHOD MACHINE
LOGGED BY R.L.

GROUND LEVEL -
LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 0.90m Light red brown slightly cemented sandy silt. Roots and blocky structure to 0.50m.
0·90			0.90 - 2.00m Light red brown well cemented sandy silt.
2·00			TRIAL PIT COMPLETED AT 2.00m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT N°. TPQD8

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL –
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
0·35			0.00 – 0.35m Light brown, loose, coarse sand and fine gravel with a little silt.
			0.35 – 1.95m Light brown, cemented sand and silt with a few calcareous nodules.
1·95			TRIAL PIT COMPLETED AT 1.95m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD9

SITE QAALIN DHEERE

DATE EXCAVATED	5/3/81	GROUND LEVEL	—
EXCAVATION METHOD	MACHINE	LOCATION	
LOGGED BY	R.L.		

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
			0.00 - 0.60m Light brown dense slightly cemented silty sand with a little fine gravel. Roots abundant to 0.5m.
0·60			
			0.60 - 2.00m Light brown dense well cemented silty sand with a little fine gravel.
2·00			
			TRIAL PIT COMPLETED AT 2.00m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

APPENDIX A

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD10

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL –
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
0·20			0.00 - 0.20 Loose fine gravel and sand with a little silt.
			0.20 - 1.30 Light brown well cemented silt and sand with some gravel.
1·30			
			TRIAL PIT COMPLETED AT 1.30m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT No. TPQD11

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL –
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
			0.00 – 0.60m Angular limestone gravel with silty sand.
0·60			
			TRIAL PIT COMPLETED AT 0.60m.

REMARKS Limestone encountered at 0.60m.

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD12

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL –
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 0.60m Light brown silty sand with fine grave
0·60			0.60 - 1.60m Light brown slightly cemented silty sand with fine gravel.
1·60			
			TRIAL PIT COMPLETED AT 1.60m.

REMARKS Limestone encountered at 1.60m.

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA: NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. TPQD13

SITE QAALIN DHEERE

DATE EXCAVATED	5/3/91	GROUND LEVEL	-
EXCAVATION METHOD	MACHINE	LOCATION	
LOGGED BY	D.L.		

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
			0.00 - 0.70m Light brown silty sand with a little fine gravel.
0·70			
			0.70 - 1.30m Light red brown cemented silty sand with fine gravel. Hard at base.
1·30			
			TRIAL PIT COMPLETED AT 1.30m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº TPQD14

SITE QAALIN DHEERE

DATE EXCAVATED 5/3/81	GROUND LEVEL -
EXCAVATION METHOD MACHINE	LOCATION
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 0.80m Light brown dense silty sand with a little fine gravel.
0·80			0.80 - 1.60m Light brown dense cemented silty sand with a little gravel and small cobbles near base. Well cemented at base.
1·60			TRIAL PIT COMPLETED AT 1.60m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

APPENDIX A

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº TPQD15

SITE QAALIN DHEERE

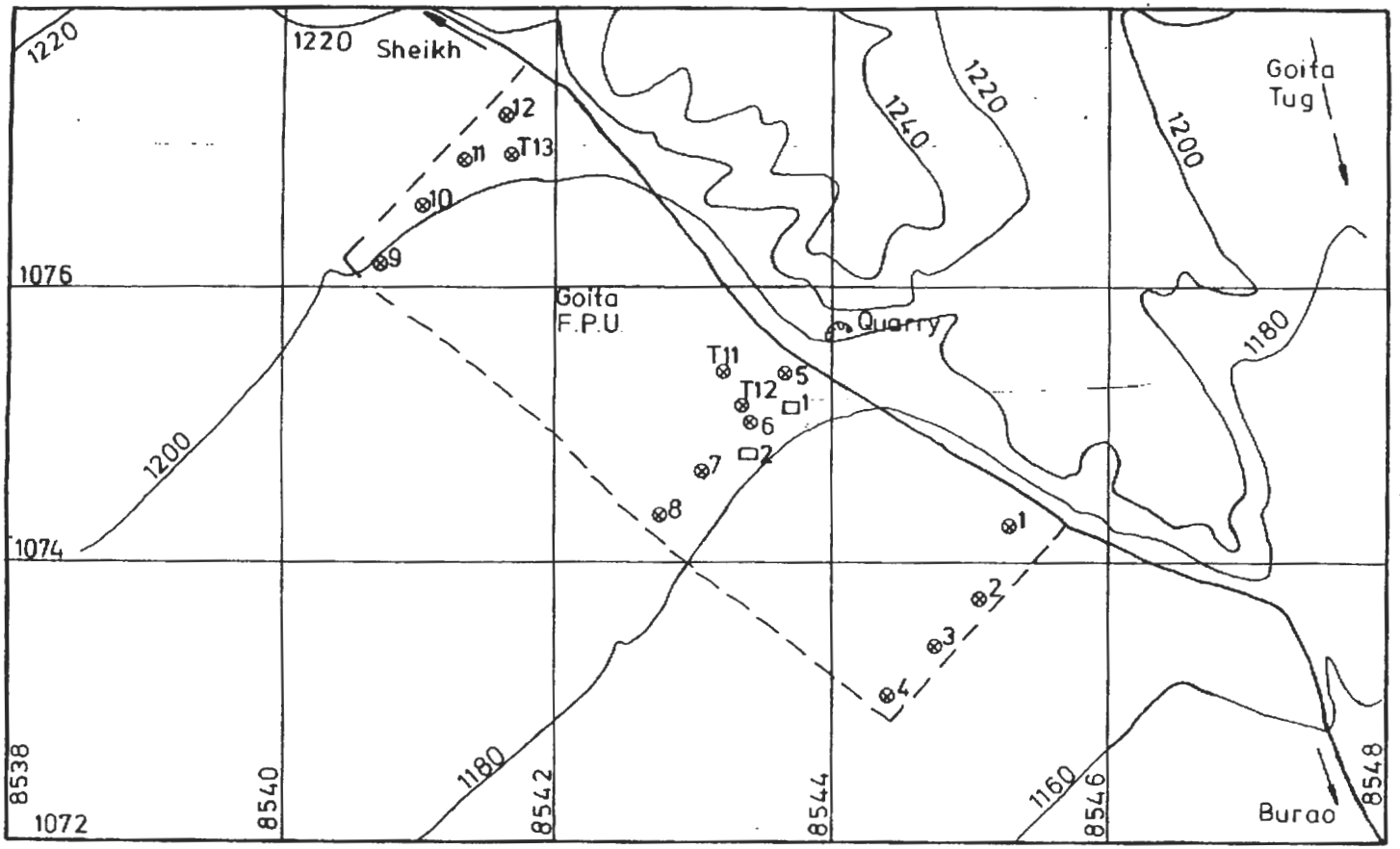
DATE EXCAVATED 5/3/81 EXCAVATION METHOD MACHINE LOGGED BY R.L.	GROUND LEVEL – LOCATION

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 0.80m Light brown dense silty sand with a little fine gravel.
0·80			0.80 - 1.35m Light brown dense cemented silty sand with a little gravel and small cobbles near base. Well cemented at base.
1·35			TRIAL PIT COMPLETED AT 1.35m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners



KEY

- Site boundry furrow
- Old Burao – Sheikh road
- $\otimes^{1}$ – Auger hole AHG01
- $\square^{1}$ – Trial Pit TPG01
- $\otimes^{T11}$ – Site of Infilltration test 1

GOITA F.P.U.

SKETCH PLAN

Scale : 1 : 50 000

Taken from Russian

APPENDIX A

AUGER HOLES AT GOITA (6/10/80 & 7/10/80)

AHG01 to AHGO I2

AHG01

0.00 - 0.50m Brown firm sandy silt with a few calcareous nodules
Weak crumb structure 10YR 5/6

0.50 - 0.80m Brown very dense calcareous sand and silt with a few calcareous nodules.

Auger stopped at 0-80m by hard soil, not gravel.
Samples - 0.4 to 0.5m and 0.7 to 0.8m.

AHG02

0.00-0.60m Slightly damp, yellow brown silt and sand becoming hard at 0.60m 7.5 Y R 6/6

Auger stopped at 0.60m by hard soil, not gravel
Samples - 0.00-01m, 0.1 - 0.2, 0.4 - 0.5.

AHG03

0.00-0.90m Dry, calcareous slightly cemented sand with some silt. 7.5YR 5/6

Auger stopped at 0.90m by hard soil, not gravel
Sample - 0.8 - 0.9m.

AHG04

0.00-0.80m Slightly moist, calcareous dense, slightly cemented sand with some silt. 7.5YR 5/8.
Weak crumb-structure near surface.
Auger failed to recover at 0.80m.
Sample - 0.7 to 0.8m.

AHG05

0.00-0.46m Calcareous sand and fine and medium sub-rounded gravel of limestone. 7.5YR 6/6
Auger stopped by gravel
Sample 0.3 to 0.4m.

AHG06

0.00-0.60m Hard calcareous sandy silt with a very little fine gravel. 5YR 5/6
Auger stopped at 0.60m by hard soil.
Sample - 0.5 to 0.6 m.

* Note: colours from Munsell Soil Colour Charts

AHG07

0.00 - 0.60m Calcareous dense silty sand becoming slightly cemented with depth. 7.5 YR 5/6.
Auger stopped at 0.60m by hard soil

Sample - 0.5 to 0.6m.

AHG08

0.00 - 0.83m Slightly cemented firm calcareous sandy silt.
7.5 YR 5/8
Auger stopped at 0.83m by hard soil.
Sample - 0.7 to 0.80m.

AHG09

0.00 - 0.58m Hard cemented, lightly calcareous sandy silt.
7.6 YR 5/8
Auger stopped at 0.58m by hard soil.
Sample - 0.5 to 0.58m.

AHG010

0.0 - 0.65m Moist, calcareous sandy silt becoming hard and cemented with depth. 7.5 YR 5/8
Auger stopped at 0.65m by hard soil.
Samples - 0.0 - 0.1m, 0.1 - 0.2,. 0.3 - 0.4m, 0.5 - 0.6m.

AHG011

0.0 - 1.00m Damp, firm to hard sandy silt 10YR 4/6
Samples - 0.2 - 0.3m, 0.6 - 0.7m.

AHG012

0.0 - 1.00m Moist calcareous firm silt and sand
7.5 YR 5/6
Sample - 0.9 - 1.0m.

(Trial Pits 15/10/80)

TPG01

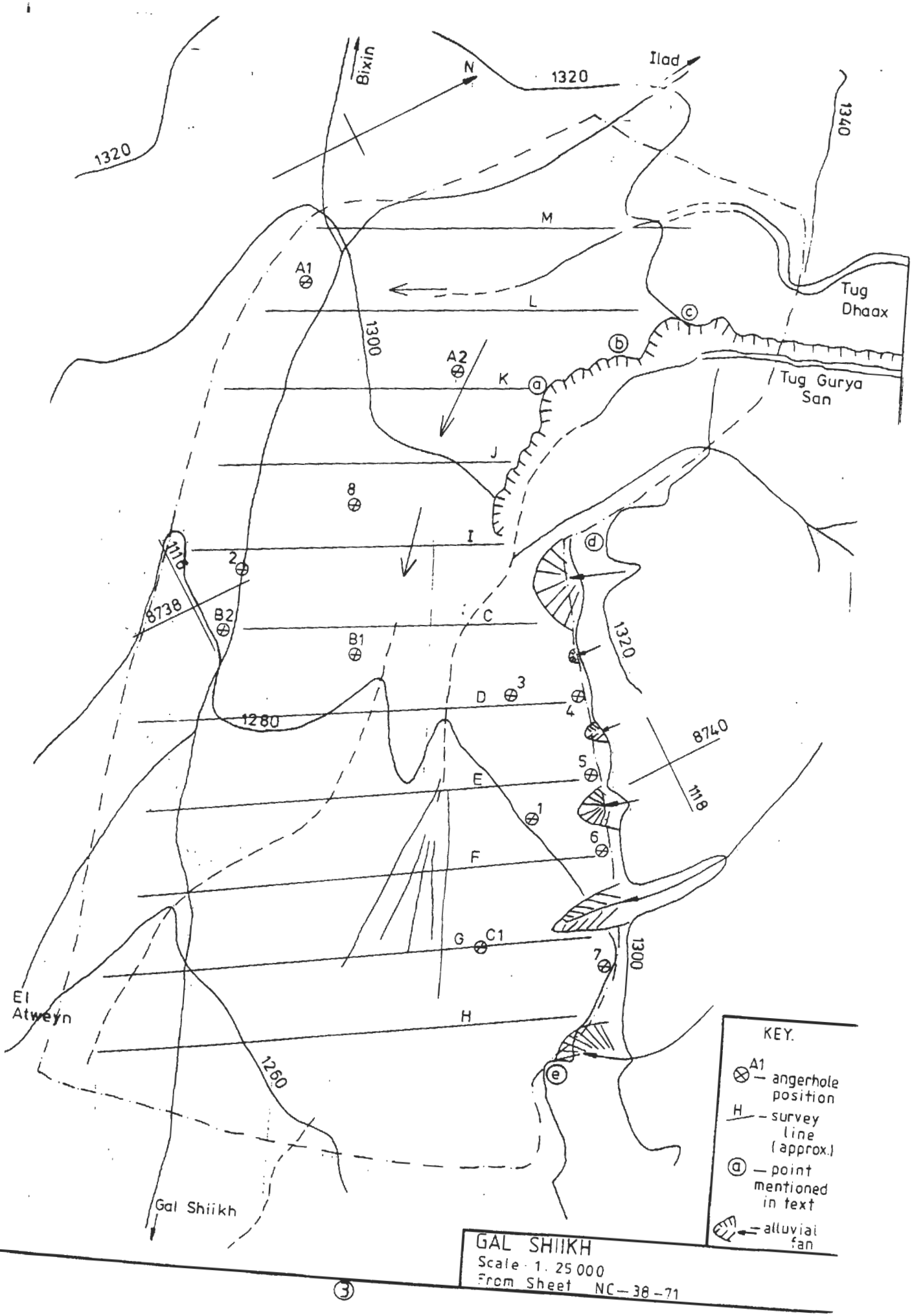
Depth 1.50m (TP to 0.9m, AH to 1.5m)

0.00 - 0.60m	Sand and silt with a little fine gravel Weak crumb structure, slightly cemented below 0.30m. 7.5 YR 5/6
0.60 - 1.50m	Well cemented sand and silt with a little fine gravel and soft white calcareous nodules. 7.5 YR 5/6
Samples -	0.2 - 0.3m, 0.5 - 0.6m, 0.8 - 0.9m.

TPG02

Depth 1.15, (TP to 0.65m, AH to 1.15m)

0.00 - 0.40m	Dense sand and silt 5 YR 5/6
0.40 - 1.15m	Dense well cemented sand and silt with calcareous nodules 5 YR 5/6
Samples -	0.2 - 0.3m, 0.6 - 0.7m, 1.10 - 1.15m.


Bixin
N
1320
Ilad
1340
1320
M
A1
L
1300
Tug Dhaax
A2
K
Tug Gurya San
J
8
I
1110
2
8738
B2
C
B1
1320
D
3
4
1280
8740
5
E
1
1118
6
F
G
C1
7
1300
El Atweyn
H
1260
Gal Shiikh
KEY.
A1 — angerhole position
H — survey line (approx.)
ⓐ — point mentioned in text
— alluvial fan
GAL SHIIKH
Scale 1. 25 000
From Sheet NC—38—71
③

GAL SHIIKH

1. The site at Gal Shiikh was visited on three occasions for the purposes of soils investigations. On 19/11/80 auger holes AHGSA1, A2, B1, B2 and C1 were excavated. On 9/2/81 two auger holes, AHGS1 and AHGS2 were excavated and on 16/3/81 and 17/3/81 auger holes AHGS3 to AHGS8 were excavated.

In addition to auger holes, observations were made of tug banks and the numerous animal burrows around the site.

2. Auger holes AHGSA1, A2, B1 and B2 and C1 were all drilled to approximately one metre depth and proved no obstruction. The material was generally a uniform light brown firm/dense calcareous sandy silt.

3. Auger holes AHGS1 and AHGS2 were drilled principally to obtain samples for testing.

AHGS1 0.0 - 0.7m - light brown sandy silt with a very little fine gravel

Samples (a) 0.1 to 0.2m
(b) 0.35 to 0.5m
(c) 0.65 to 0.7m

AHGS2 0.0 - 0.9m - light brown silt with some sand

Samples (a) 0.1 to 0.25m
(b) 0.4 to 0.55m
(c) 0.7 to 0.9m

4. Auger holes AHGS3 to AHGS7 were drilled to investigate the north-eastern area of the site where the proximity of steep slopes was thought to have a possible effect on the nature of the soil.

5. AHGS3 was drilled on survey line D (see sketch plan attached) approximately half way between the tug and the hillside, at the end of a ridge of surface gravel. The auger hole proved 0.4m of sand and fine gravel with a trace of silt, the auger was unable to recover further material. Observations in the vicinity of the auger hole suggest that this narrow zone, 50m here, of fine gravel and sand is no more than about 1m deep and grades quickly into the more usual sandy silt.

6. AHGS4 was drilled on line D some 20m from the edge of the rocky hillside. To a depth of 0.65m the material was a silt with some fine sand, a little medium and coarse sand and a little fine gravel. At 0.65m gravel was encountered.

Between AHGS3 and AHGS4 there is a large pig burrow in excess of 1m in depth showing a gravel free soil.

7. AHGS5 was sited 100m from the stoney slope on line E. There was no obstruction to 2m in silt and sand with a little fine gravel. On survey lines E and F there are many old pig burrows. One recent burrow, about half way between the tug and the hillside showed 1.5m of the usual silty soil.

8. AHGS6 was sited 40m from the rocky hillside at the end of line F and showed 1.2m of silt with sand and a little fine gravel overlying gravel at 1.2m.

9. AHGS7 was drilled 30m from the hillside between lines G and H. No obstruction was encountered to 2.00m in silt and sand with a little fine gravel.

10. AHGS8 was drilled to 2m to check for obstructions in the central section of the site. This auger hole, together with numerous deep pig burrows suggest no obstruction in this area.

11. Auger holes AHGS4 to AHGS7 were drilled in low areas between the alluvial fans formed by watercourses emerging from the steep hillside. The fans rise some 3 or 4m above the level at which the auger holes were drilled. The influence of the fans in terms of geomorphology extends most of the way to the tug but the limit of the fans, for our purposes, can be taken at a change in slope which often coincides with the edge of the surface gravel area associated with the fan. The sketch plan shows the extent of the alluvial fans.

12. The tug banks between survey station 'D' and the hillside below 'd' were investigated to give an indication of the numbers of gravel beds and lenses occurring in the soil in this part of the site.

13. At station 'D' two metres of soil are exposed showing silt and sand with traces of fine gravel. At distances of 150m and 400m upstream there are gravel lenses up to 0.2m thick and not more than 10m long as exposed in the bank. At station 'C' the tug sides have increased to 4m in height with no gravel present. Fifty metres upstream of 'C' a gravel lens 20m long and 0.5m thick at a depth of 3m can be seen.

14. At various points small lenses can be seen between station 'C' and the confluence of Tug Gurya San and the minor tug from the north. None of these are within 2m of the ground surface. About 100m from the confluence an old stream channel can be seen in the bank of the present tug. The top level of the gravel of the old stream channel is 2.75 below the present level of the surrounding land. The gravel bed is nearly 2m in depth and 3m wide at its base becoming wider at the top.

15. The tug bank material in the minor tug as it flows from the hillside near 'd' is still principally silt and sand to over 2m depth although there is a surface covering of gravel. There are a few gravel lenses near the hillside exposed in the banks but the soil is generally still remarkably gravel free.

16. At position 'a' on the sketch plan the gullies show 5m of virtually gravel free silt and sand. At 'b' gullies show 5m of silt and sand with a little gravel occurring in thin (0.1m) lenses. At 'C' there are only small accounts of gravel in soils over 5m deep.

17. About 4km to the south east of the site the Gal Shiikh Tug can be seen cutting into material at the foot of hills which are a continuation of the range bounding the site. Here it can be seen that the bedrock and scree material associated with the hillside continues to dip under the soils of the surrounding plain at much the same angle as the rock slopes above. It can be seen that the soil has reached a depth of 7 or 8m within 50m of the rocky hillside. It is considered that this situation occurs in much the same way in the site area.

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. AHDCI

SITE DUUR CAD S.W.P.

DATE EXCAVATED 19/4/81	GROUND LEVEL
EXCAVATION METHOD AUGER	LOCATION Beside present stock water pond.
LOGGED BY R.L.	

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 1.30m Red (2.5 YR 4/8) medium dense sand and silt with a little clay and a few soft white calcareous nodules.
1·00	• 1·00 - 1·10 (a)		
1·30	• 1·00 - 1·40 (b)		1.30 - 3.05m Red (2.5 YR 4/8) medium dense sand and silt with some clay and a little fine to medium gravel sized weak calcareous nodules.
2·00	• 2·00 - 2·10 (c)		
2·65	• 2·65 - 2·75 (d)		3.05 - 3.60m Red (2.5 YR 5/8) medium dense sand and silt with some clay, slightly cemented. Some fine to medium gravel of calcareous nodules, nodules and cement increasing with depth.
3·05	• 3·05 - 3·25 (e)		
3·60	• 3·50 - 3·60 (f)		AUGER HOLE COMPLETED AT 3.60m.

REMARKS Auger hole was started approximately 1m below surrounding natural ground level. The hole was sited beside an existing stock water pond and was damp throughout its depth.

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº AHQK1

SITE QURAL KUDLE S.W.P.

DATE EXCAVATED 21/5/81
EXCAVATION METHOD AUGER
LOGGED BY JDF/RL

GROUND LEVEL
LOCATION Approx. 6.5 km SW of Qurac Kudle approx. 500m from AHQK2.

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·90			
1·10	• 0·9-1·1 ⓐ		0.90 - 1.10m Red (2.5 YR 4/8) medium dense sand and silt with a little clay and a few soft white calcareous nodules.
1·90			
2·10	• 1·9-2·1 ⓑ		1.90 - 2.10m Red (2.5 YR 4/8) dense cemented sand and silt with a little clay and gravel of calcareous nodules.
2·90			2.90 - 3.10m Red (2.5 YR 5/8) dense cemented sand and silt with gravel of calcareous nodules and a little clay.
3·10	• 2·9-3·1 ⓒ		
3·26			
3·51	• 3·26-3·51 ⓓ		3.26 - 3.51m Red (2.5 YR 5/8) very dense, well cemented sand and silt and gravel of calcareous nodules with a little clay. Very hard.
			AUGER HOLE COMPLETED AT 3.51m.

REMARKS Auger stopped by hard ground.

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA NORTHERN RANGELANDS DEVELOPMENT PROJECT	AUGER HOLE OR TRIAL PIT Nº. AHQK2

SITE QURAC KUDLE S.W.P.

DATE EXCAVATED	27/5/81	GROUND LEVEL	
EXCAVATION METHOD	AUGER	LOCATION	Approx. 6.5 km SW of Qurac Kudle approx. 500m from AHQKI.
LOGGED BY	R.L.		

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
	• 0·9 - 1·00 (a)		0.00 - 1.50m Red (2.5 YR 4/8) medium dense sand and silt with a little clay and a few soft white calcareous nodules.
1·50			1.50 - 4.00m Red (2.5 YR 5/8) dense cemented sand and silt with gravel of calcareous nodules and a little clay.
	• 3·00 - 4·00 (b)		
4·00			AUGER HOLE COMPLETED AT 4.00m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT N°. AHADI

SITE CABDI DHEERE S.W.P.

DATE EXCAVATED 20/5/81
EXCAVATION METHOD AUGER
LOGGED BY JDF/RL

GROUND LEVEL
LOCATION On old track approx. 9 km south of Cabdi Dheere.

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·90			
1·10	• 0·9-1·1 ⓐ		0.90 - 1.10m Red (2.5 YR 4/8) medium dense sand and silt with a little clay and a few soft white calcareous nodules.
1·90			
2·10	• 1·9-2·1 ⓑ		1.90 - 2.10m Red (2.5 YR 4/8) dense sand and silt with gravel of calcareous modules and a little clay.
2·90			
3·10	• 2·9-3·1 ⓒ		2.90 - 3.10m Red (2.5 YR 5/8) dense cemented sand and silt with gravel of calcareous modules and a little clay.
3·88			3.88 - 4.08m Red (2.5 YR 5/8) dense, well cemented sand and silt and gravel of calcareou nodules and a little clay.
4·08	• 3·88-4·08 ⓓ		
			AUGER HOLE COMPLETED AT 4.08m.

REMARKS Auger hole commenced approx. 1m below surrounding ground level.

SHEET 1 OF 1

Sir William Halcrow & Partners

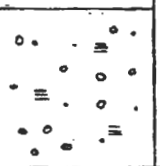
SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº AHAD2

SITE CABDI DHEERE S.W.P.

DATE EXCAVATED 10/6/81
EXCAVATION METHOD AUGER
LOGGED BY RL

GROUND LEVEL
LOCATION Approx. 10 km south-east of Cabdi Dheere and 9 km south-west of Qolgol Ka Madoobe

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 1.30m Light red brown silt and sand with a little clay and a very few calcareous nodules.
1·30			1.30 - 2.30m Red brown cemented silt and sand with calcareous nodules and a little clay.
2·30			2.30m Hit obstruction - possibly calcrete
			AUGER HOLE COMPLETED AT 2.30m.

REMARKS Auger hit obstruction - possibly calcrete.

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT No. AHWDI

SITE near WARTA FAARAX GEEDI

DATE EXCAVATED 17/6/81
EXCAVATION METHOD AUGER
LOGGED BY R.L.

GROUND LEVEL
LOCATION Approx. 1 km south-east of present stock pond at Warta Faarax Geedi.

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			
	• 0·6 - 0·8 (a)		0.00 - 1.50m Light red brown loose to medium dense calcareous sand with silt and a little clay.
1·50			1.50 - 3.00m Light red brown medium dense calcareous sand with silt and a little clay and a few calcareous nodules.
	• 2·00 - 2·20 (b)		
3·00	• 2·80 - 3·00 (c)		
			AUGER HOLE COMPLETED AT 3.00m.

REMARKS

SHEET 1 OF 1

Sir William Halcrow & Partners

SOMALIA
NORTHERN RANGELANDS DEVELOPMENT PROJECT

AUGER HOLE OR TRIAL PIT Nº BDI

SITE BUUR DHAAB

DATE EXCAVATED
EXCAVATION METHOD By hand for water storage.
LOGGED BY R.L.

GROUND LEVEL
LOCATION Approx. 2 km north of Buur Dhaab hills at Mapret.

DEPTH m	SAMPLE	LEGEND	DESCRIPTION
0·00			0.00 - 0. 70m Light brown cemented silt and sand with a little rounded gravel and some calcareous nodules.
0·70			0.70 - 0.90 Lens of very hard calcrete - 2m long.
0·90			0.90 - 1.60m Light brown cemented silt and sand with gravel of calcareous nodules.
1·60			1.60 - 1.80m Lens of rounded cobbles and gravel with sand and silt matrix.
1·80			1.80 - 2.50m Light brown cemented silt and sand with gravel of calcareous nodules.
2·50			

PIT DEPTH MAXIMUM OF 2.50m.

REMARKS This pit had been excavated by hand by locals presumably for water storage. Dimensions 4m x 5m x 2.2 to 2.5m.

SHEET 1 OF 1

Sir William Halcrow & Partners

APPENDIX 'B'

LABORATORY AND TEST RESULTS

(R. C. Luck September 1980 to June 1981)

GOITA

1. Atterberg Limit Tests were performed on samples from three auger holes AGHOT11, AHG03 and AHG08 (depths 0.1m, 0.8m and 0.7m respectively).

Auger hole	Depth	LL	PL	PI
AHGOT11	0.1	33	19	14
AHG03	0.8	30	20	10
AHG08	0.7	35	16	19

All these samples fall into the CL classification (inorganic clayey silts).

2. In-Situ Dry Density (Sand Replacement Method)

A series of dry density measurements were made on site. Densities of natural ground, uncompacted bund and compacted bund, during the dry season, and then constructed uncompacted bund after the rainy season.

On 21st February 1981 in-situ density tests were performed near the position of AHG06.

(i) Natural ground (depth from 50mm)
Density of wet soil 1.56 Mg/m3
Moisture content 2.2%
Dry density 1.53 Mg/m3

(ii) Uncompacted bund.

Density of wet soil 1.46 Mg/m3
Moisture content 2.6%
Dry density 1.42 Mg/m3

(iii) Compacted bund (Compaction by Fiat 8B Dozer)

Density of wet soil 1.46 Mg/m3
Moisture content 2.8%
Dry density 1.42 Mg/m3

On 25th May 1981 a series of tests were performed on bund material from a bund near AHG06. This date was after the rainy season.

The average wet soil density was 1.23 Mg/m3
The average moisture content was 5.4%
The average dry density was 1.17 Mg/m3

There was no significant difference between values at varying depths within the bund. The only change evident as a result of the rain was the formation of a crust of harder soil about 100 to 150mm thick on the surface of the bund. This appears to be the result of recementation of the soil not compaction. The central core of the bund remained loose and uncohesive

3. A sample from AHGOT11, depth from 0.1 to 0.5m, was tested for compaction in a 2.5 Kg Rammer test. The maximum dry density was 1.74 Mg/m3 at an optium moisture content of 20%.

4. Infiltration Testing

Two tests were performed at Goita to investigate the behaviour of water applied to the soil. In addition observations of moisture content of the soil were made at the end of the rainy season.

Test 1 (see Fig. A1)

On 2nd December 1980 water was applied to a depth of 200mm in a small basin approximately four square metres in area. Auger holes were then drilled in the basin at intervals for a period of two months. The decrease in water content with time is shown in Fig. A1 as a series of profiles of water content against depth. The ground surface of the test basin was not vegetated.

Test 2 (see Fig. A2)

On 21st February 1981 a basin approximately 3.7m^2 was filled to a depth of 180mm in 20 minutes. The rate of infiltration from the end of filling for 30 minutes was 128 mm/hr and then 86 mm/hr for the next hour.

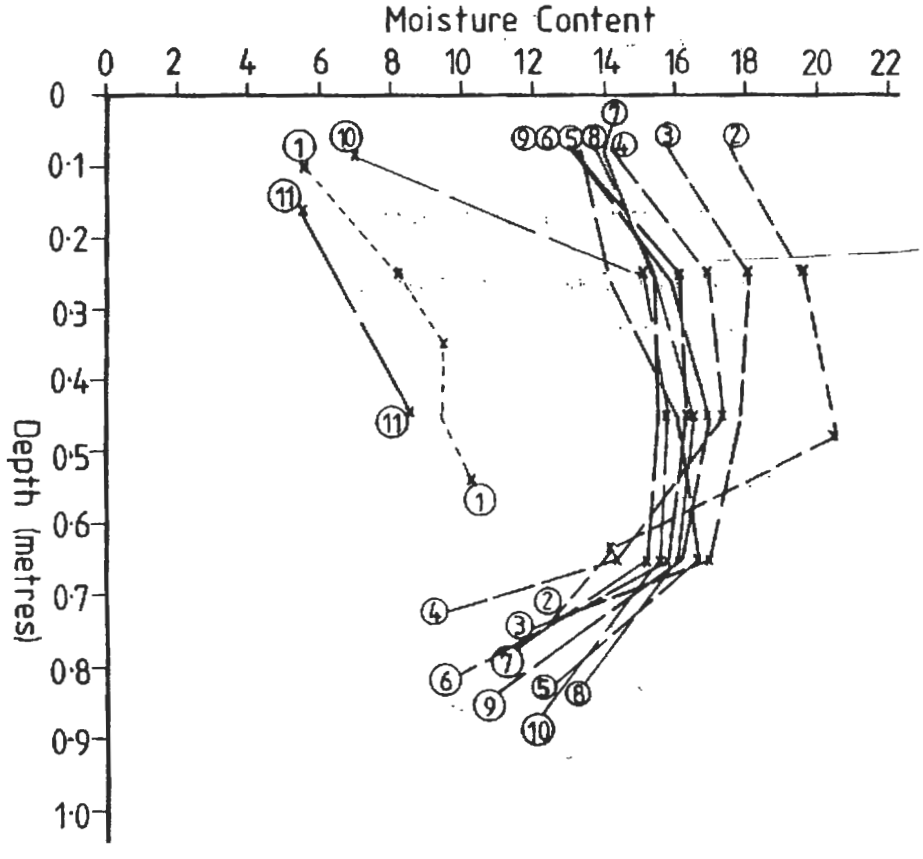
Auger hole AHGOT12 was drilled on 25th May 1981 in a basin behind a bund on line 37, approximately halfway down the present bunded area. On 26th May 1981 auger holes AHGOT13 and AHGOT14 were drilled at bund line 12 near the northend of the site. AHGOT13 was drilled inside a bund basin and AHGOT14 was drilled outside.

Length	Moisture Contents		
	AHGOT12	AHGOT13	AHGOT14
0.1 - 0.2m	15	25	11
0.4 - 0.5m	15	25	10
0.9 - 1.0m	15	25	
1.4 - 1.5m	15	23	
1.9 - 2.0m	16	20	

The auger holes were stopped because the ground became too hard to auger. The rains of the season had penetrated to a depth in excess of two metres. In comparison with the depths reached by the auger in dry periods the moisture enables greater penetration indicating that a continued presence of water breaks down the cementation of the soil.

5. Particle Size Distributions

Two sieve analyses were performed in Burao on samples AHG08 (0.7m to 0.8m) and AHGOT11 (0.1m to 0.25m). Two complete particle size distribution analyses were performed by Soil Mechanics Ltd in England on two samples from AHG07 (0.5m - 0.6m). The results show sand to be the principle component material with between 30% and 50% silt and clay combined.



INFILTRATION---TEST 1

Moisture Content v Depth in area flooded to depth of 200mm on 2/12/80

FIGURE A1

Date of sampling

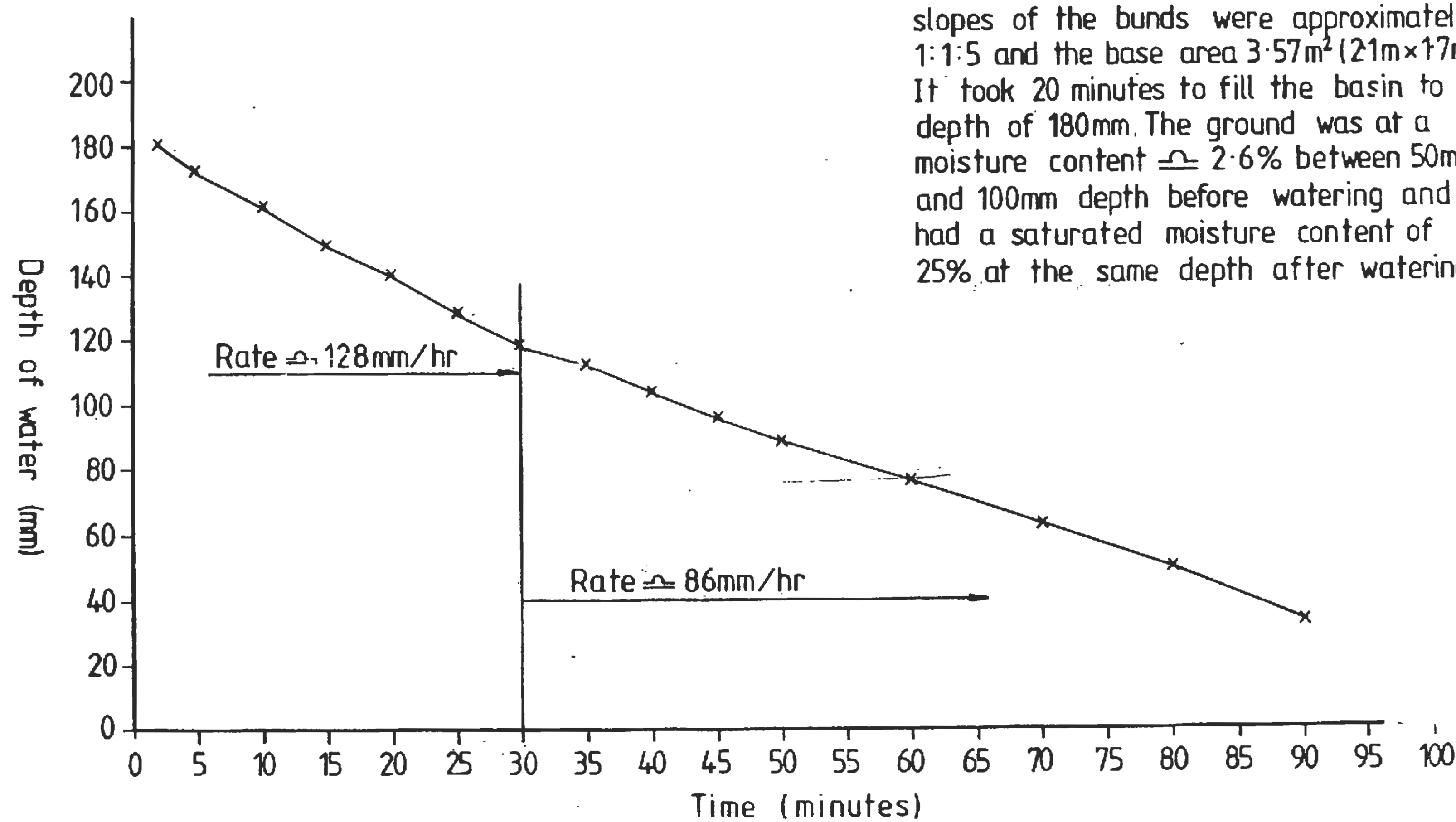
① 2/12/80 ----------
② 4/12/80 — — — — —
③ 6/12/80 — — — —
④ 8/12/80 — — —
⑤ 15/12/80 — — —
⑥ 23/12/80 — — -
⑦ 31/12/80 — — —
⑧ 7/1/81 — — —
⑨ 17/1/81 — — —
⑩ 3/2/81 — — —
⑪ 3/2/81 (Outside wetted area)

①	0·1 5·7	0·25 8·2	0·35 9·5	0·45 9·4	0·55 10·4	m %
②	0·1 17·9	0·25 19·6	0·47 20·6	0·63 19·3	0·73 12·6	m %
③	0·07 15·8	0·25 18·1	0·45 18·6	0·65 17·1	0·75 12·0	m %
④	0·07 14·1	0·25 17·0	0·45 17·4	0·65 14·4	0·72 9·9	m %
⑤	0·07 13·2	0·25 14·1	0·45 16·0	0·65 16·7	0·82 12·7	m %
⑥	0·07 13·1	0·25 15·7	0·45 17·1	0·65 16·1	0·77 10·8	m %
⑦	0·07 14·0	0·25 15·4	0·45 15·8	0·65 15·4	0·77 11·2	m %
⑧	0·07 13·8	0·25 15·7	0·45 16·5	0·65 16·1	0·82 13·4	m %
⑨	0·07 13·0	0·25 15·4	0·45 16·1	0·65 15·4	0·82 11·5	m %
⑩	0·07 6·9	0·25 15·0	0·45 15·8	0·65 15·6	0·85 12·5	m %
⑪	0·18 5·6	0·43 8·3				m %

APPENDIX B

<u>NOTE</u>

Bunds were pushed up to provide a small basin for an infiltration test. The side slopes of the bunds were approximately 1:1:5 and the base area $3 \cdot 57 m^2$ (2·1m × 1·7m). It took 20 minutes to fill the basin to a depth of 180mm. The ground was at a moisture content ≏ 2·6% between 50mm and 100mm depth before watering and had a saturated moisture content of 25% at the same depth after watering.



GOITA F.P.V. - INFILTRATION TEST 2

21/2/81 R.L.

FIGURE. A2

PARTICLE SIZE DISTRIBUTION

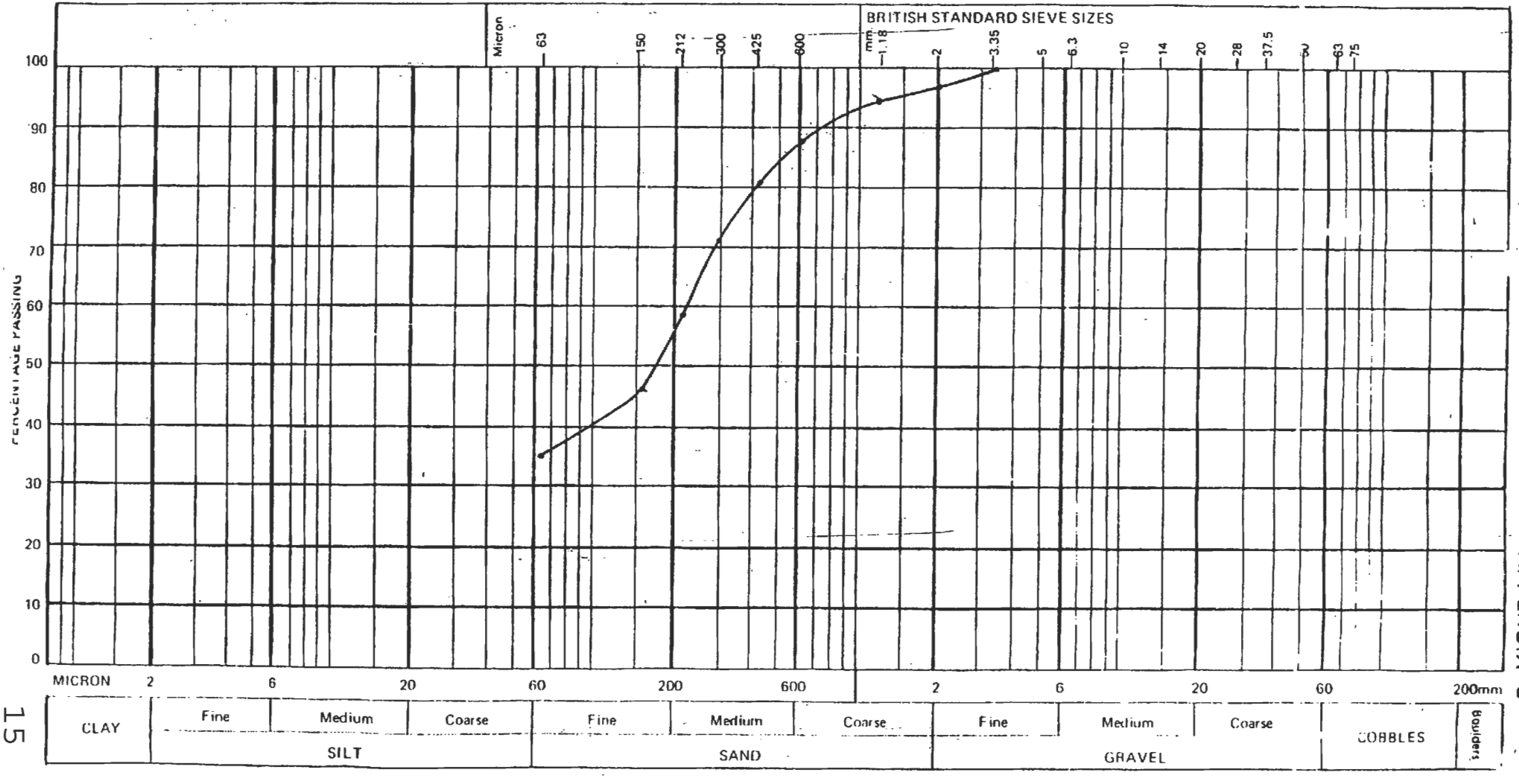
Form No. K4

LOCATION No. GOITA BORE HOLE No. AHG 08 SAMPLE No. 1

PRETREATMENT DETAILS Sodium Hexa metaphosphate

DATE OF TEST 17/2/81 DESCRIPTION Calcareous sandy silt

LOSS ON PRETREATMENT – %



APPENDIX B

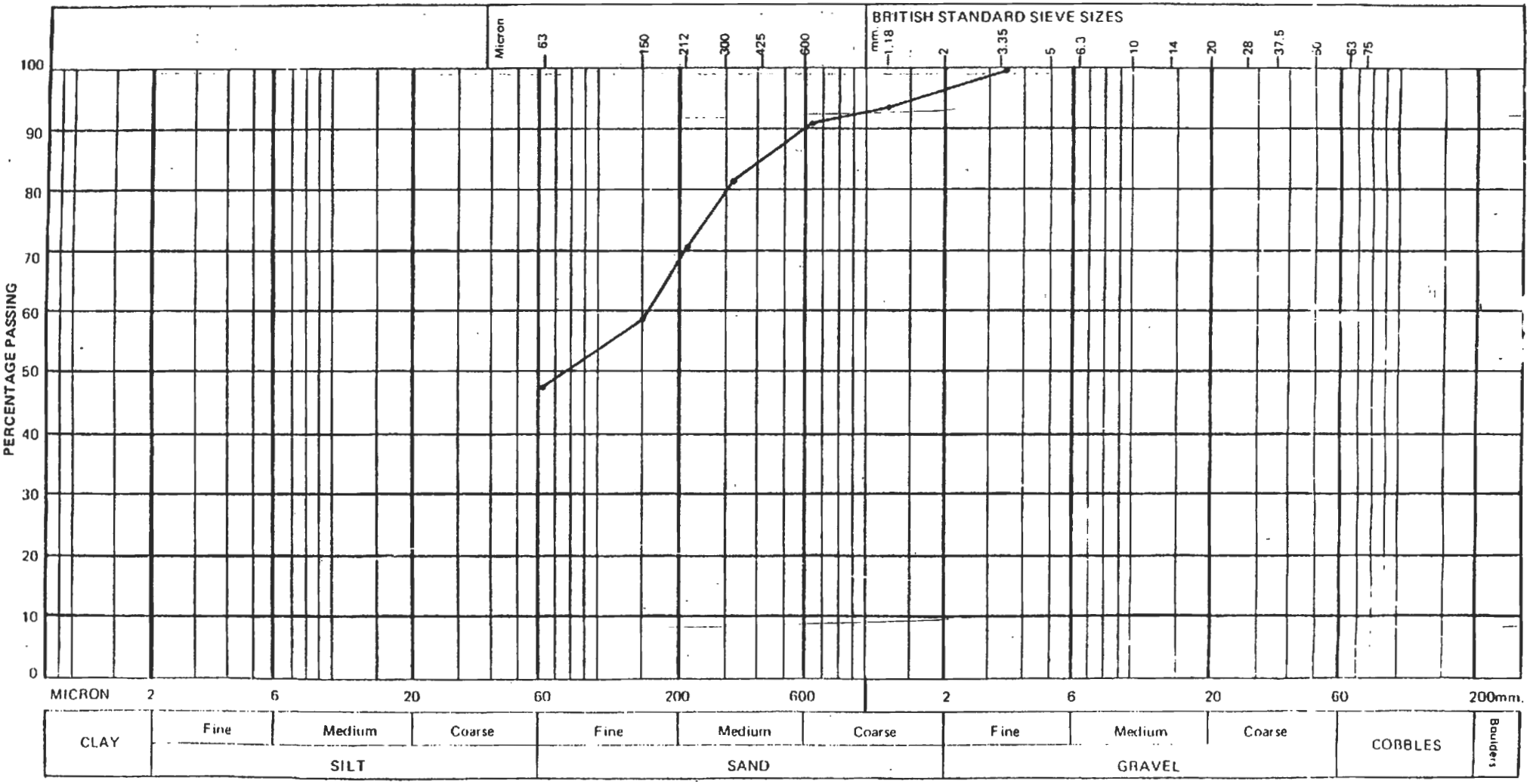
ELE

PARTICLE SIZE DISTRIBUTION

Form No. K4

LOCATION No. GOITA BORE HOLE No. AHGOT 11 SAMPLE No. 1 PRETREATMENT DETAILS Sodium Hexametaphosphate

DATE OF TEST 17/2/81 DESCRIPTION Calcareous sandy silt LOSS ON PRETREATMENT ..... %



APPENDIX B

Signed. .

65

L21 1/77	Tested			Traced		
	Checked			Approved		

Particle Size Distribution

GRADING CURVES

Client

Location Goita

Loc. No. 7946 23

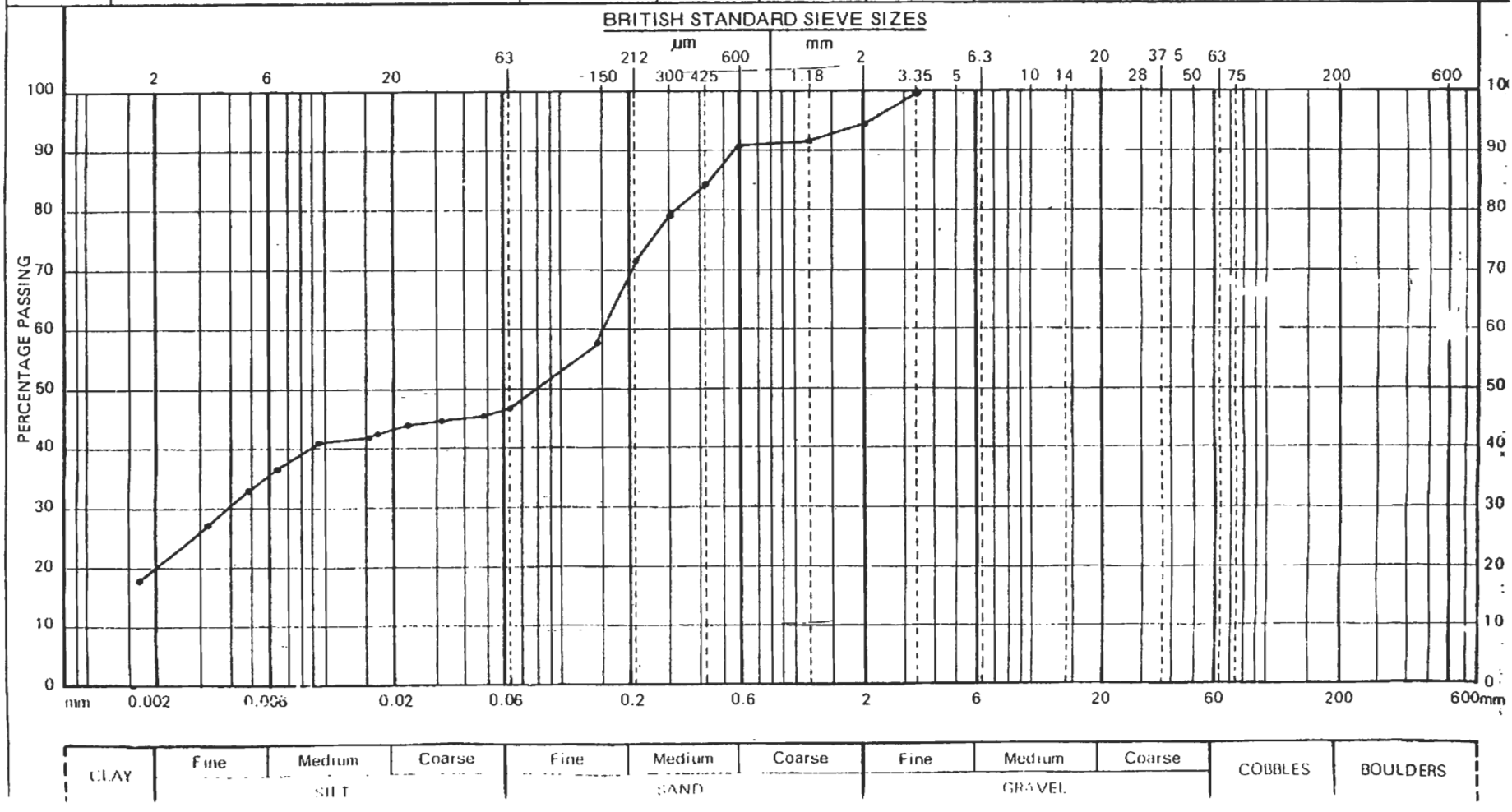
Borehole Nos.

Sample Nos. 2

DESCRIPTION AND PRETREATMENT			SEDIMENTATION		SIEVING	
Sample No.	Description	Pretreatment	Mass g	Specific Gravity	Mass kg	Process
2	Red/brown silty clay	15ml or cm H_2O_2	51	2·65	0·53	Wet

NOTES

1. Tested in accordance with B.S. 1377 : 1975 Tests 7(A) & (D)
2. *indicates S.G. assumed



L21	Tested			Traced		
	Checked			Approved		

Particle Size Distribution

GRADING CURVES

Client

Loc. No. 7946

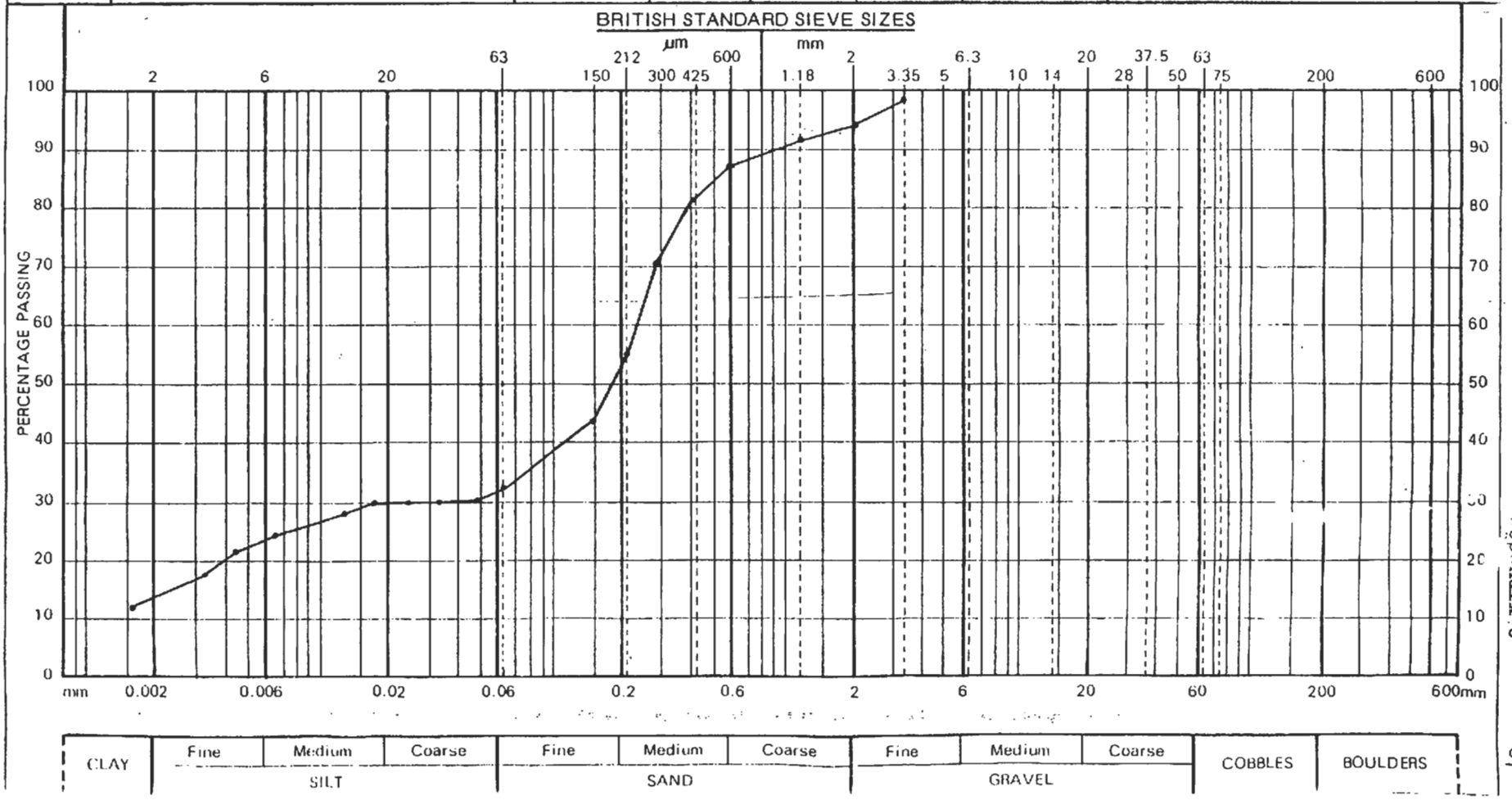
Borehole Nos.

Sample Nos. 1

DESCRIPTION AND PRETREATMENT			SEDIMENTATION		SIEVING	
Sample No.	Description	Pretreatment	Mass g	Specific Gravity	Mass kg	Process
1	Red/brown silty clay	150 ml H_2O_2	51	2·65	0·53	Wet

NOTES

1. Tested in accordance with B.S. 1377 : 1975 Tests 7(A) & (D)
2. *indicates S.G. assumed



Appendix C

67

FORM K17

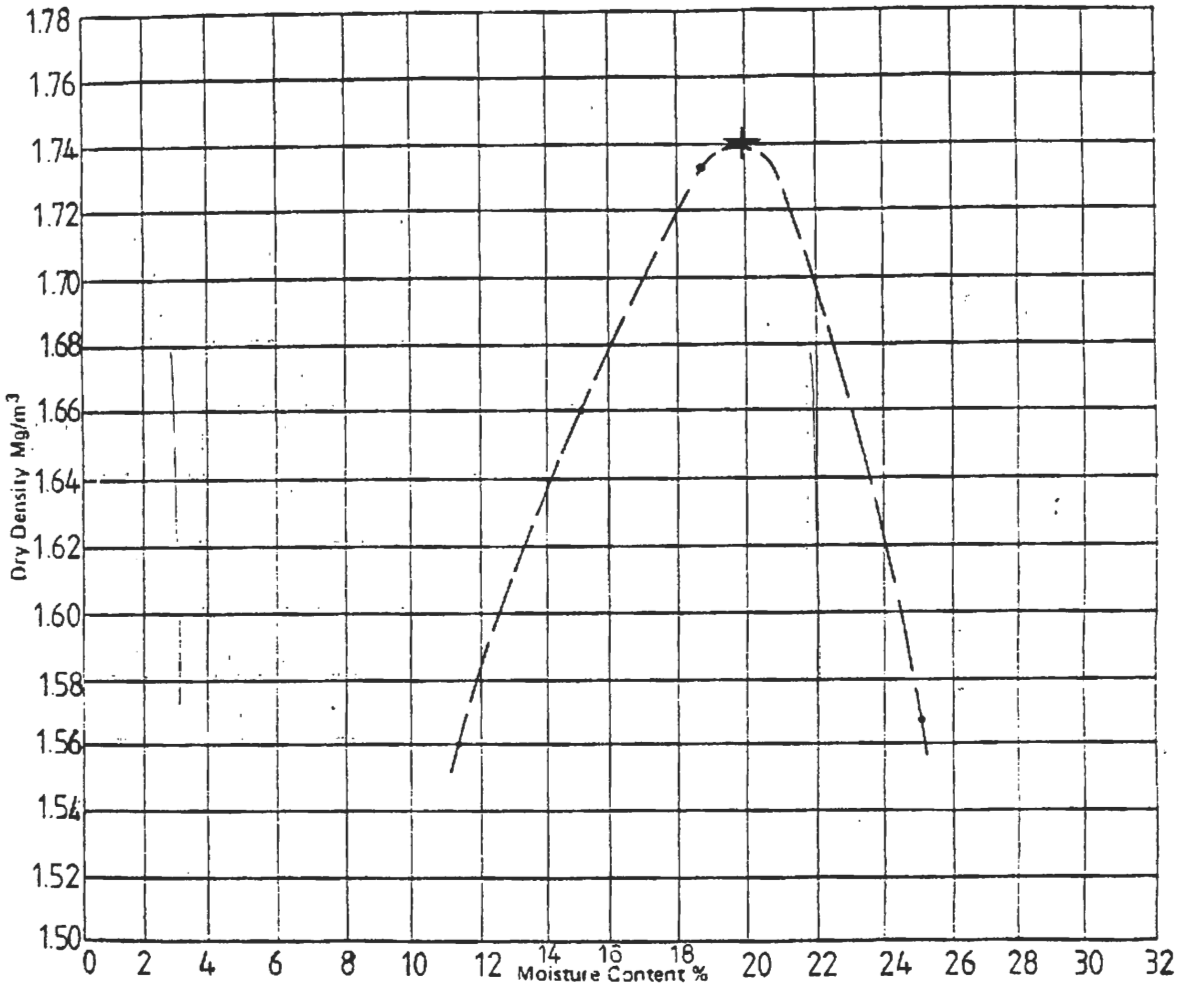
SOMALIA
N.R.D.P.

COMPACTION TEST

Loc. No. ..... Name GOITA

Borehole No. AHGOT 11 Description Light red brown calcereous slightly

Sample No. BAGS 1 & 2 cemented sandy silt.



Type of compaction 2.5 Kg Rammer

No. of layers 3 No. of blows 27 Wt. of rammer 2.5 Kg. Mould 4504 g

Specific gravity ..... Material retained on ..... B.S. Sieve ..... %

MAXIMUM DRY DENSITY 1.74 Mg/m³

OPTIMUM MOISTURE CONTENT 20 % dry weight

NOTES

1. Curves of saturation are shown only when the specific gravity of the soil particles have been measured.
2. Sample of soil ~~oven~~/air dried before compaction.
3. Soil received ~~undisturbed~~/disturbed. Natural Moisture Content 37.0 %

LOC. .....

QAALINDHEERE

TRIAL PITS AND LABORATORY TESTING

1. A series of trial pits (TPQD1 to TPQD12) were excavated by machine between 25/2/81 and 5/3/81. The pits were excavated along the line of the proposed irrigation canals to investigate the ground conditions. The positions of the trial pits and their logs are included in Appendix A.

2. All trial pits reached the required depth except TPQD11 where limestone was encountered at 0.60m. Trial pits TPQD10, TPQD11 and TPQD12 were excavated adjacent to a stony ridge associated with a limestone outcrop. Trial pits TPQDI0 and TPQD12 showed sufficient depth of soil for the excavation of the canal. The line of the canal in the region of TPQD11 only was therefore altered to a position some 25m further away from the stony ridge.

3. The trial pits in general showed a light brown sandy silt with varying degrees of cementation. In one pit (GPQD6) a layer of cobbles and gravel was found where there was 0.3m of coarse material from a depth of 0.5m. More of these minor channel deposits may be met during excavation of the canals.

4. Atterberg Limit tests were carried out on a sample of material from an anthill (samples SSQDAA). The material when dry is hard and very well cemented. When broken down and tested it had a liquid limit of 40, a plastic limit of 16 and a plasticity index of 24. These results would be typical of a medium plasticity clay.

5. Atterberg Limit tests were also performed on two samples from trial pit TPQD4. Sample TPQD4a was from the more cemented layer (1.2 to 1.4m) and TPQD4b was taken from the top half metre of the soil. These tests were performed to indicate the differences in behaviour between the non-cemented and the cemented layers after breakdown of cementation.

	TPQD4a	TPQD4b
LL	31	33
PL	17	22
PI	14	11

These results suggest behaviour as a clayey silt. In the field the grain size seems to be overestimated as a result of the cementation.

6. A total of four particle size distribution analyses were performed on samples of tug bed material.

ELE

PARTICLE SIZE DISTRIBUTION

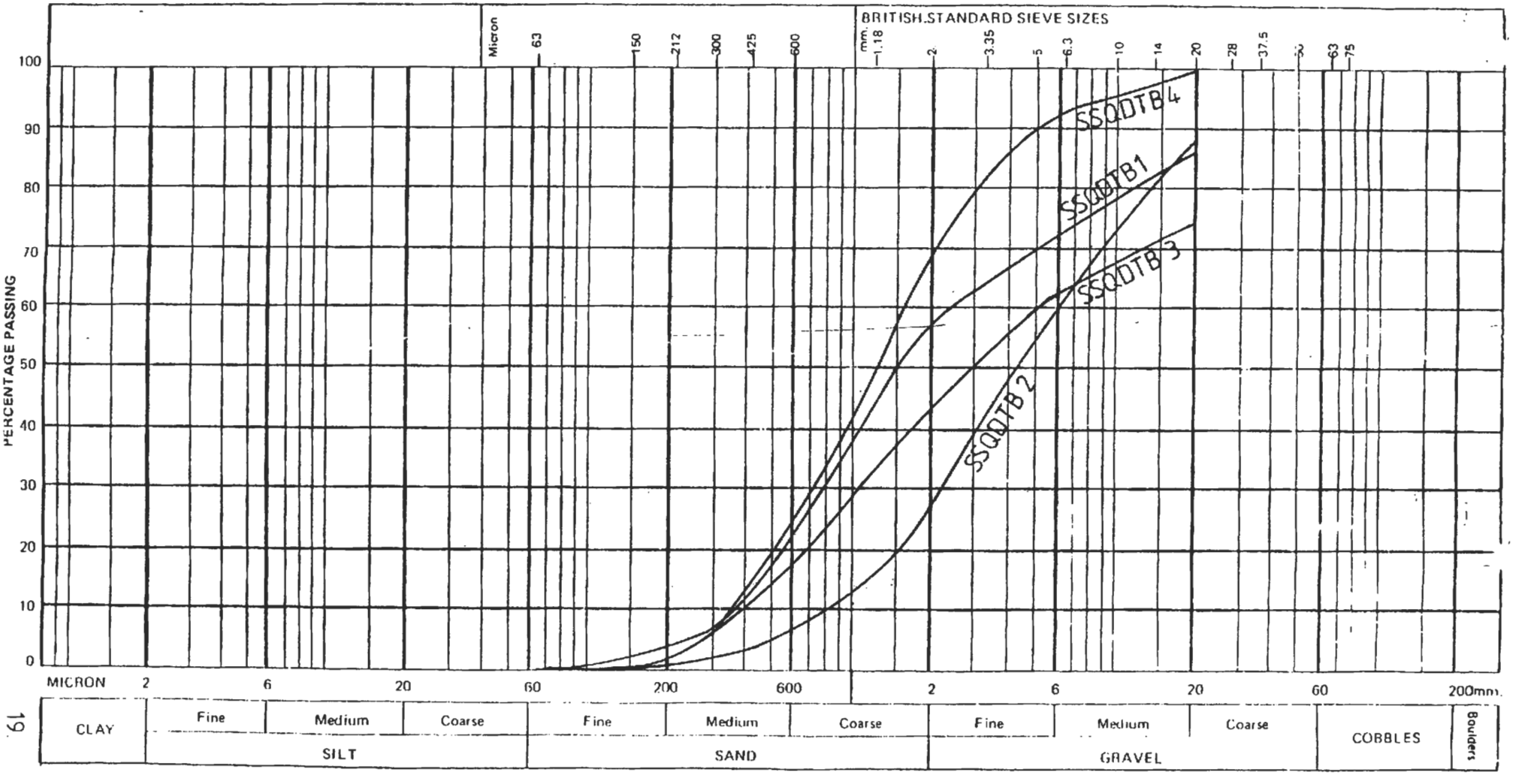
Form No. K4

LOCATION No. QAALIN DHEERE BORE HOLE No. ..... SAMPLE No. .....

DATE OF TEST Sept 80 & Mar 81 DESCRIPTION Samples of Tugbed Material

PRETREATMENT DETAILS .....

LOSS ON PRETREATMENT ..... %



APPENDIX B

GAL SHIIKH

Atterberg Limit tests were performed on samples AHGS1b and AHGS2b.

Sample	LL	PL	PI	Class
AHGS1b	43.2	23.5	19.7	CI
AHGS2b	41.2	23.6	17.6	CI

These samples would be classified as inorganic of clays of medium plasticity.

A particle size analysis was performed on sample AHGS1b. This showed the material to be a sandy silt with a little clay (the relative proportions being approximately 40%, 45% and 15% respectively).

ELE

PARTICLE SIZE DISTRIBUTION

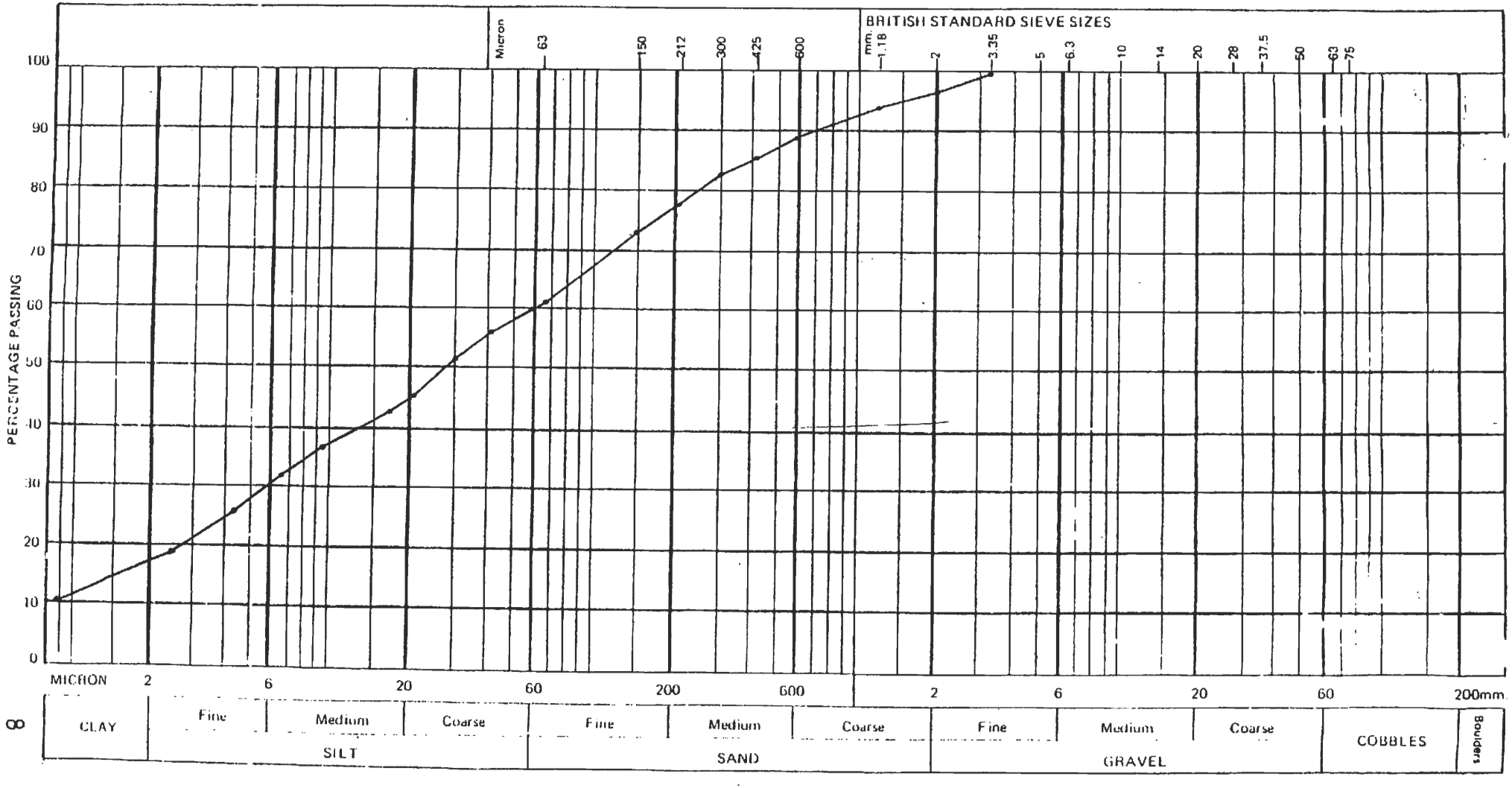
Form No. K4

LOCATION No. GAL SHIIKH BORE HOLE No. AHGS 1 SAMPLE No. AHGS 16

DATE OF TEST 25/4/81 DESCRIPTION Light brown calcareous sandy silt

PRETREATMENT DETAILS —

LOSS ON PRETREATMENT — %



APPENDIX B

HADAFTIMO AND FIQI SHINNI

TEST RESULTS

1. Samples were taken from these sites as representative of the soil which would be used to construct bunds at these sites.

2. The soil from Fiqi Shinni is a light yellow brown very slightly cemented gypsic silt with a little clay and trace of fine sand. This material is of mixed limestone and anhydrite origin. The samples from Hadaftimo were solely of anhydrite origin and were very pale brown gypsic sandy silts with a little fine gravel. Limited tests were carried out on these soils to provide a comparision with results from such limestone sites as Goita and Gal Shiikh.

3. Atterberg Limites tests were performed on one sample from Fiqi Shinni (SSFQ1) and attempted on two samples from Hadaftimo (SSHAD and SSHAZ). A particle size distribution analysis was carried out on sample SSHAZ.

4. The samples from Hadaftimo proved to be non-plastic. The Fiqi Shinni soil had a liquid limit of 36 and a plasticity index of 12 which would classify the soil as a medium plasticity clay (CI) but bordering on clayey silt or silty sandy clay.

5. The particle size distribution analysis of the Hadaftimo sample SSHAZ showed it to be 20% clay, 55% silt and 25% sand despite the fact that this soil was non-plastic.

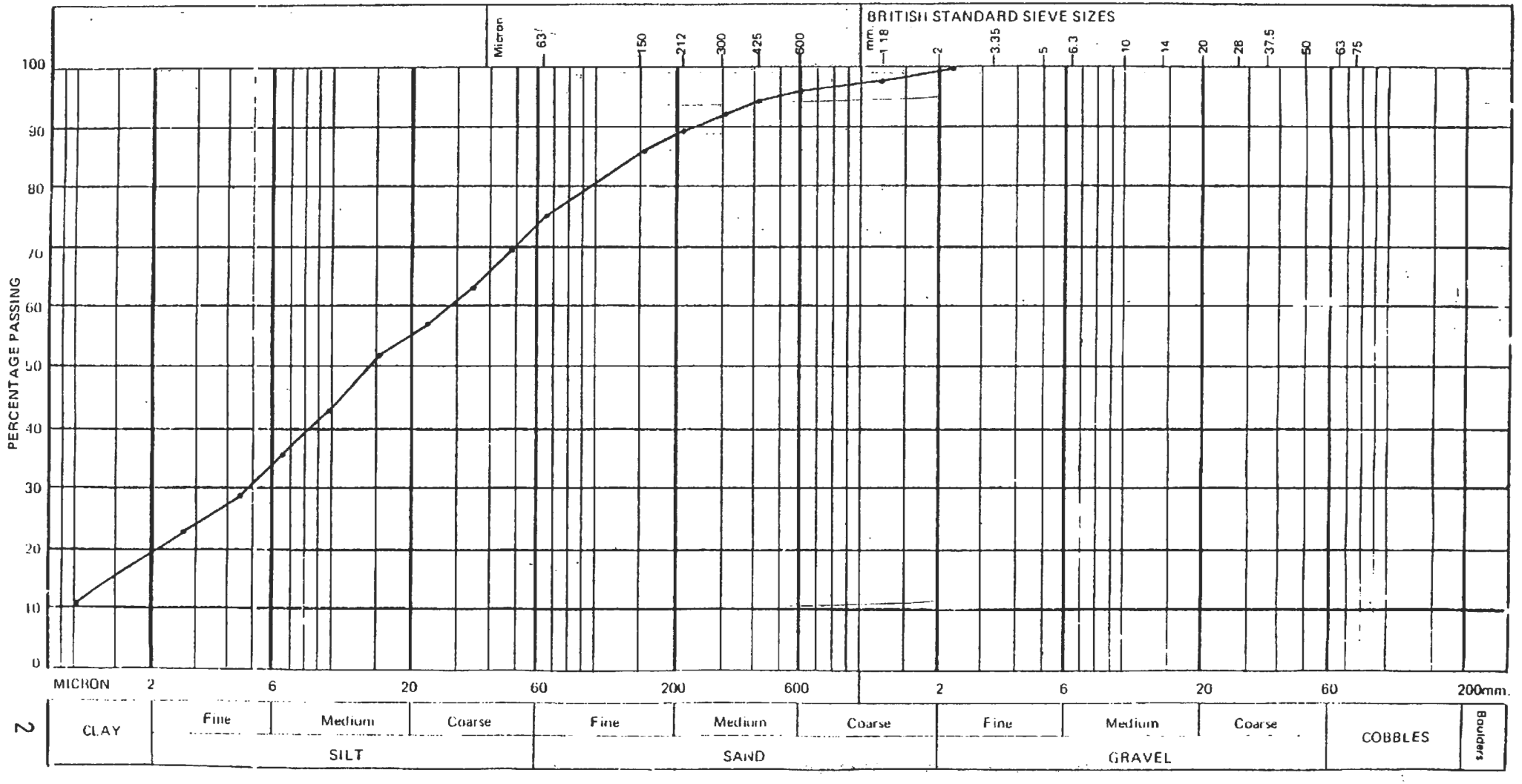
ELE

PARTICLE SIZE DISTRIBUTION

Form No. K4

LOCATION No. HADAFTIMO BORE HOLE No. – SAMPLE No. SSHA2 PRETREATMENT DETAILS

DATE OF TEST 25/4/81 DESCRIPTION Very pale brown gypsic sandy silt LOSS ON PRETREATMENT



APPENDIX B

2

GAMBARA

Eight Atterberg Limit tests were performed on samples from Gambara in addition to one 2.5 Kg Rammer compaction test. The results of these tests are presented below.

The eight soil samples were taken from auger holes drilled at the time of the site survey. The holes were drilled at survey stations. (Ref. plan).

Auger hole	Sample Depth	Plastic Limit	Liquid Limit	Plasticity Index
AH GAG	0.8m	20.7	32.3	11.6
AH GAM	1.0m	18.0	21.0	3
AH GAISE	1.0m	22.5	39.3	16.8
AH GAI1E	1.0m	16.0	33.5	17.5
AH GAK	1.2m	23.7	42.5	18.8
AHGADIW	1.0m	22.2	33.7	11.5
AHGAD	0.8m	24.2	42.2	18.0
AHGAN2W	0.8m	24.2	43.0	18.8

TABLE 1

The samples fall into the C1 or CL classifications (medium plasticity clays or clayey silts).

The 2.5 Kg Rammer test gave a maximum dry density of 1.68 Mg/m^3 and an optimum moisture content of 20%.

The soil of the site is mainly a sandy silt which is cemented by gypsum to varying degrees. The soils are underlain by anhydrite at depths in excess of 4m at the southern end of the site and less than 1m at the northern end (around A HGAO). The area is a zone of deposition for material from the catchment hills to the south. These hills provide a mixture of limestone and anhydrite derived material. Over most of the site this material is of silt or sand size but old and present water courses have deposited coarse material at various times in the past.

GAMBARA

AHGAM

2·5kg Rammer Test

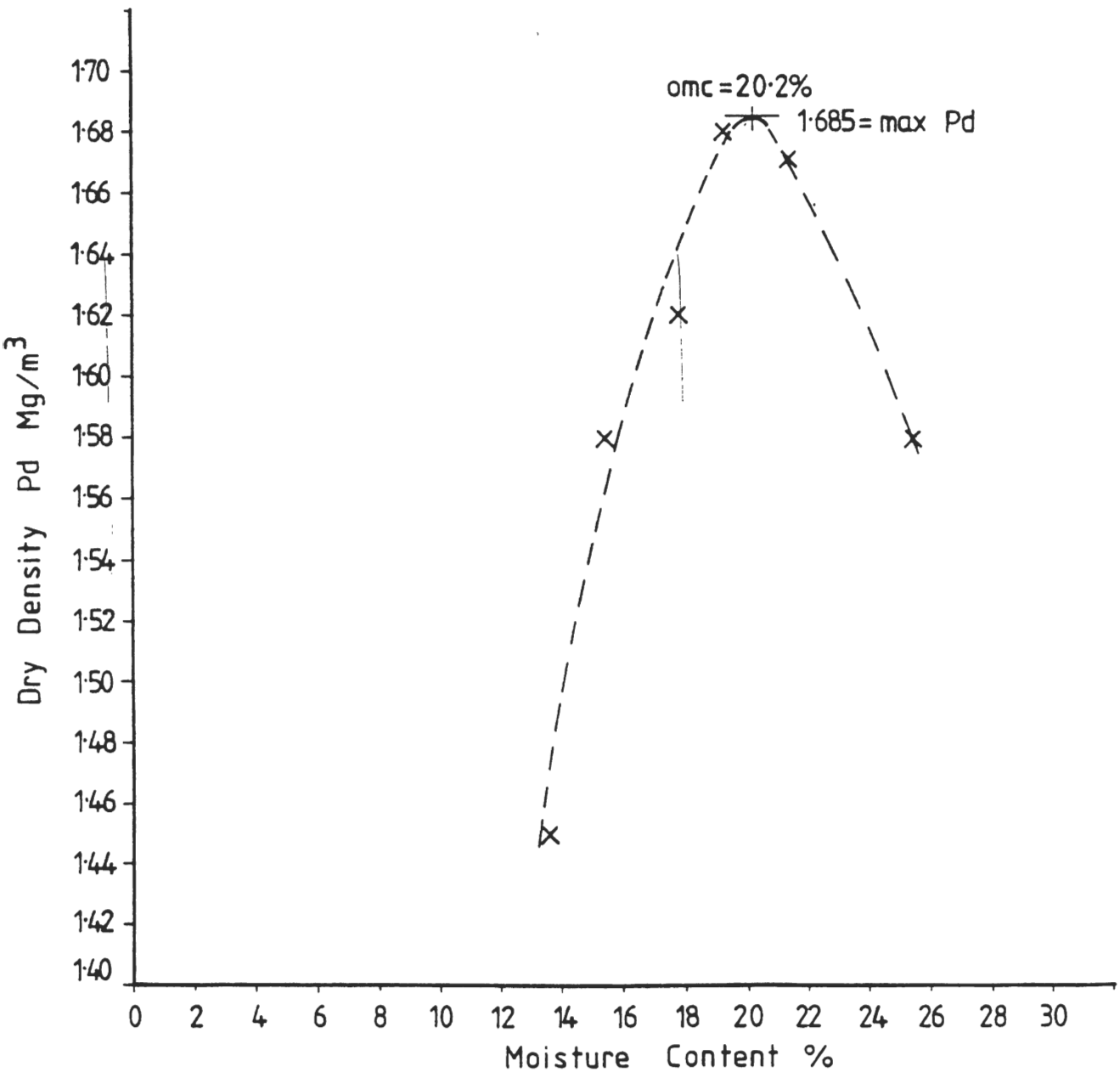


FIGURE A3

DUUR CAD

Two particle size distribution analyses were carried out on samples from Duur Cad. A sample from 1m AHDC1a showed approximately 20% gravel, 20% sand, 30% silt and 30% clay. A sample from 3.6m showed 30% gravel, 20% sand, 30% silt and 20% clay.

Four Atterberg Limit tests were carried out and all gave a high plasticity index in the range 35 to 39 with liquid limits in the range 61 to 77.

Sample No.	Liquid Limit	Plastic Limit	Plasticity Index	Natural Moisture Content
AHDC1a	61	26	35	15
AHDC1b	65	30	35	18
AHDC1c	-	-	-	21
AHDC1d	-	-	-	18
AHDC1e	75	37	38	16
AHDC1f	77	38	39	16

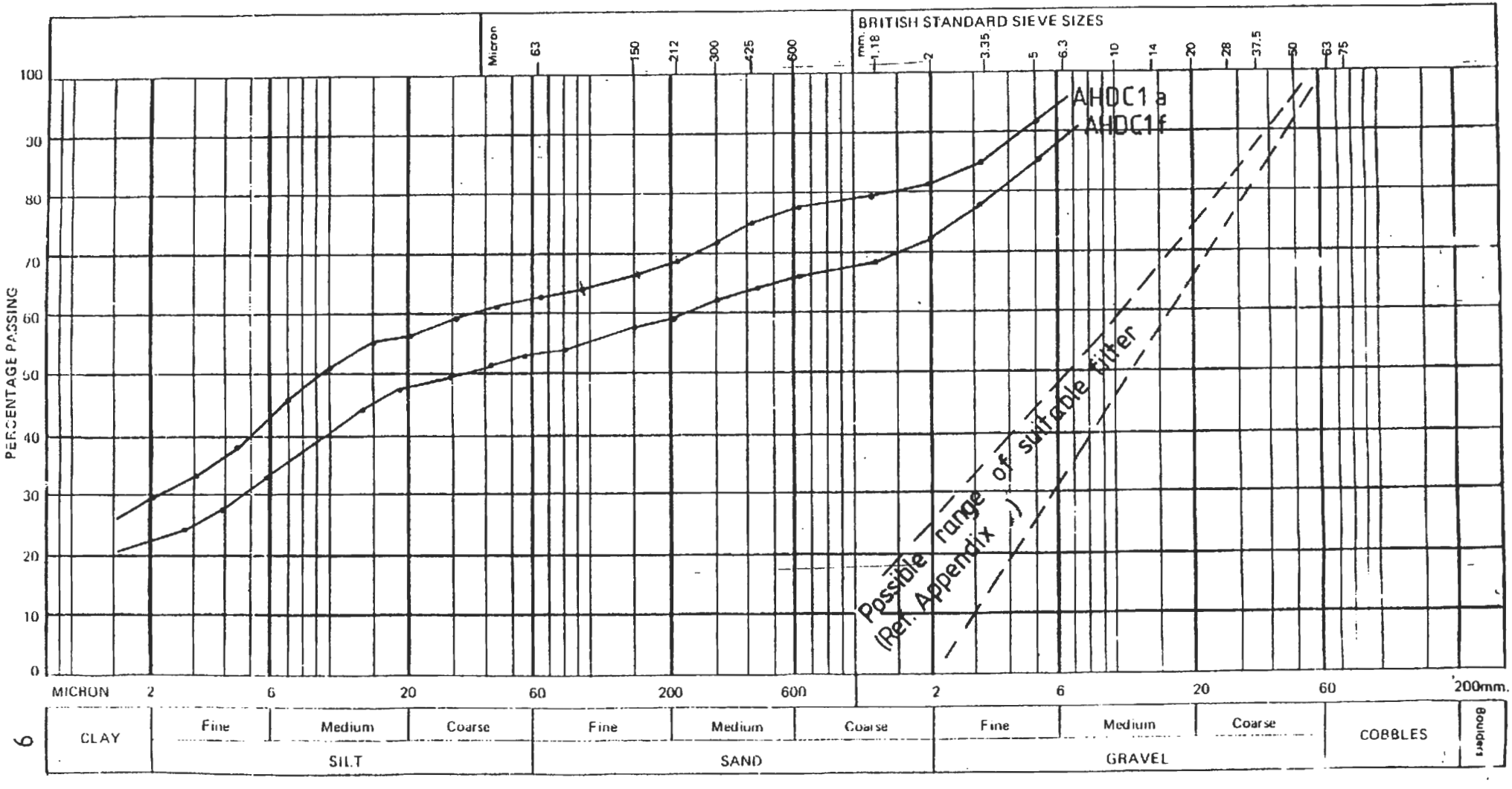
These results are typical of high plasticity clays (CH)

A 2.5 kg Rammer Compaction test was performed on samples AHDC1c and AHDC1d combined. An optimum moisture content of 20% and a maximum dry density of 1.61 Mg/m^3 were obtained.

Form No. K4

PARTICLE SIZE DISTRIBUTION

LOCATION No. DUUR CAD
DATE OF TEST 30/4/81
BORE HOLE No. AHDC 1
DESCRIPTION See attached log
SAMPLE No. a and f
PRETREATMENT DETAILS —
LOSS ON PRETREATMENT — %



APPENDIX D

FORM K17

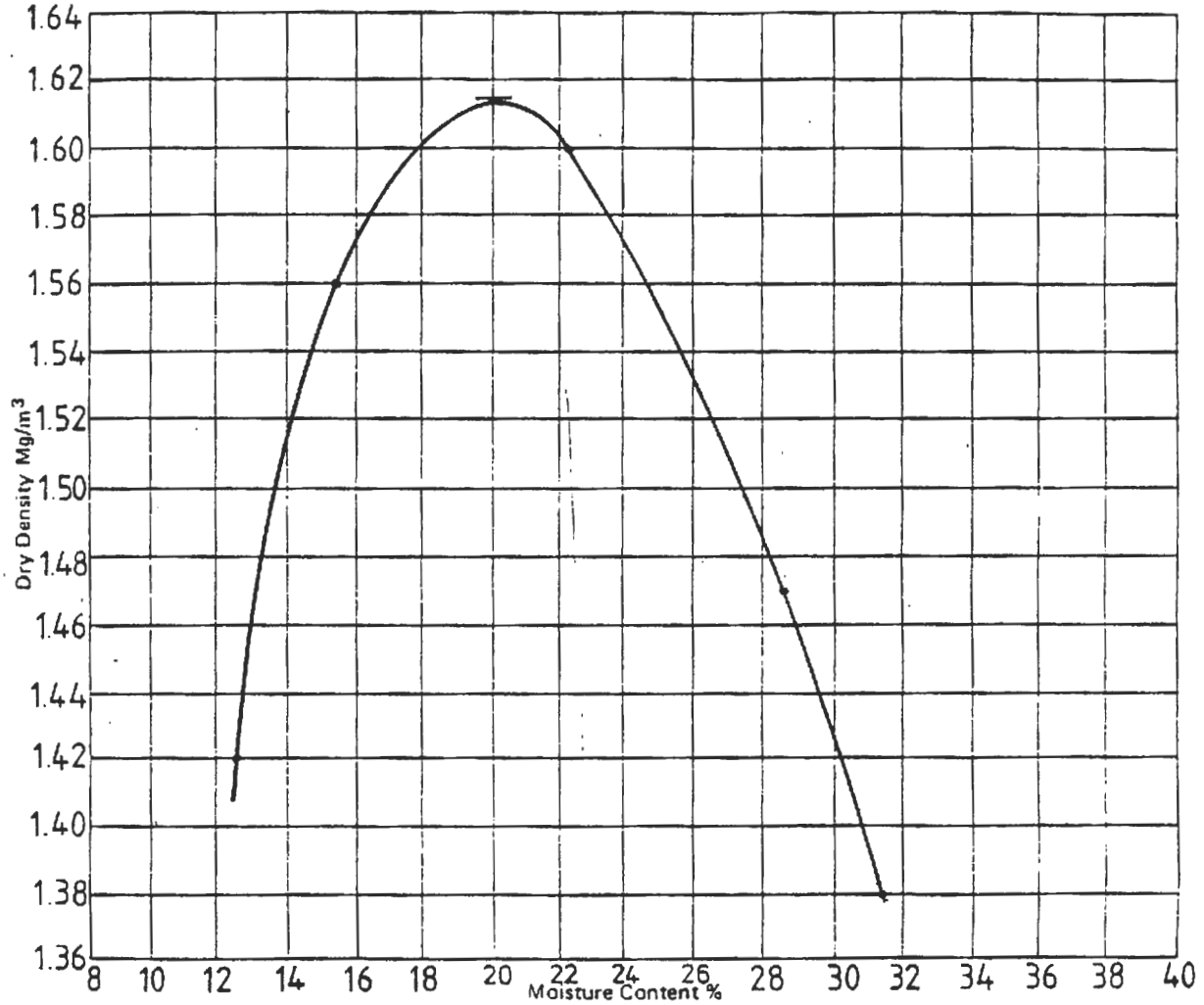
SOMALIA
N.R.D.P.

COMPACTION TEST

Loc. No. ..... Name DUR CAD .....

Borehole No. AH DC1 ..... Description Red sand and silt with clay and

Sample No. AHDC1 'c' and 'd' some gravel



Type of compaction 2.5 Kg Rammer Compaction test .....

No. of layers ..... No. of blows ..... Wt. of rammer .....Kg. Mould.....

Specific gravity..... Material retained on ..... B.S. Sieve .....%

MAXIMUM DRY DENSITY 1.61 Mg/m^3

OPTIMUM MOISTURE CONTENT 20 % dry weight

NOTES

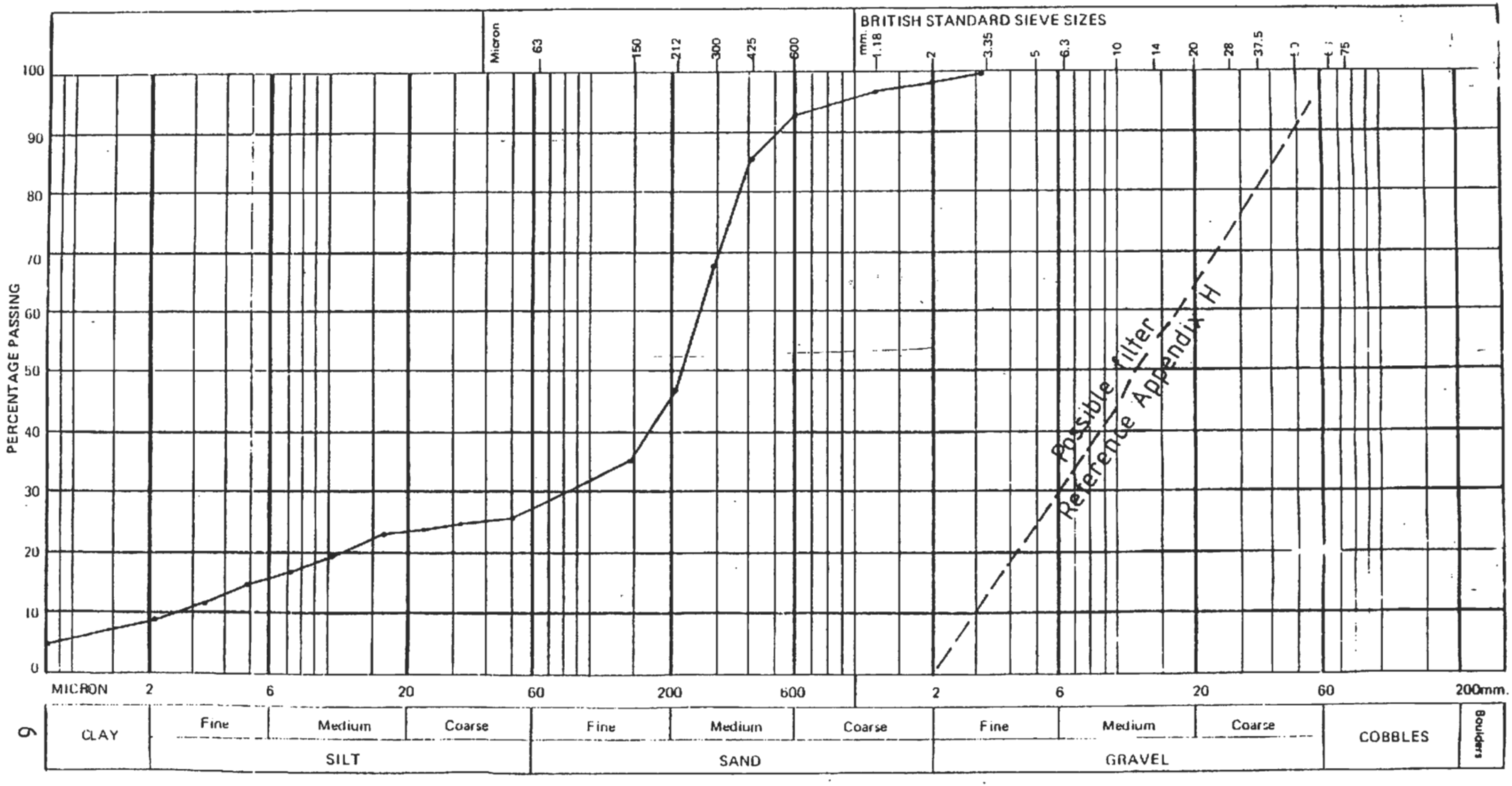
1. Curves of saturation are shown only when the specific gravity of the soil particles have been measured.
2. Sample of soil oven/air dried before compaction.
3. Soil received undisturbed/disturbed. Natural Moisture Content..... %

Form No. K4

PARTICLE SIZE DISTRIBUTION

LOCATION No. WARTA FAARAX GEEDI BORE HOLE No. AHWD1 SAMPLE No. AHWD1@ PRETREATMENT DETAILS Sodium Hexametaphosphate

DATE OF TEST 23/6/81 DESCRIPTION Light red brown sand with silt & a little clay LOSS ON PRETREATMENT — %



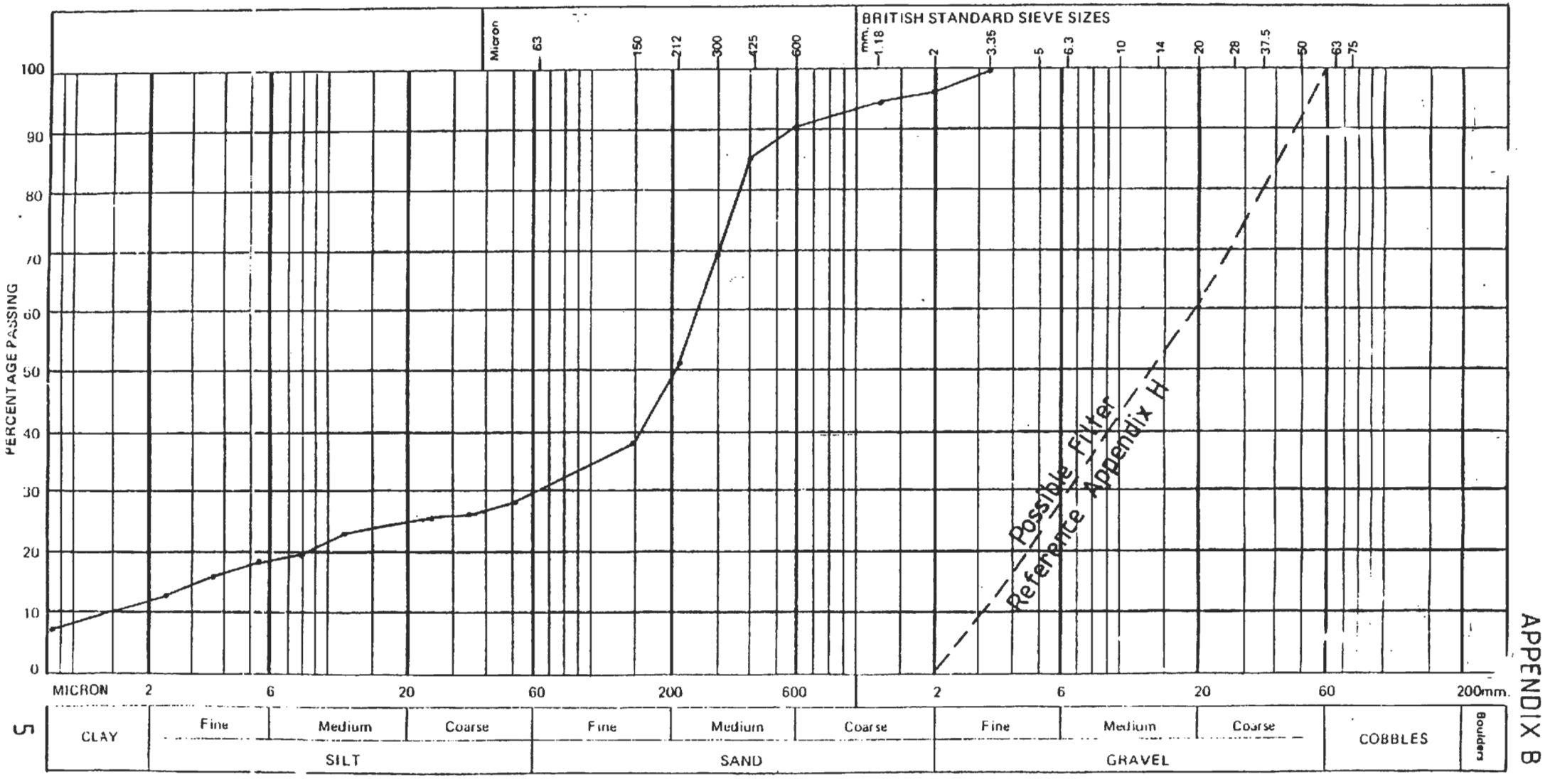
APPENDIX B

Form No. K4

PARTICLE SIZE DISTRIBUTION

LOCATION No. WARTA FAARAX GEEDI BORE HOLE No. AHWD 1 SAMPLE No. AHWD 1Ⓒ PRETREATMENT DETAILS Sodium Hex

DATE OF TEST 23/6/81 DESCRIPTION Light red brown sand with silt & a little clay LOSS ON PRETREATMENT ..... %



APPENDIX B

5

81

APPENDIX C

OTHER SOIL ANALYSES AND TESTS

(selected from A. R. Griffin)

"Appraisal of Geology and Soils in the Project Area"

October 1980

Sample	Depth (m)	LL	PL	PI
Infa Madow Station 'S'	0.2	37	20	17
Infa Madow Station 'A'	0.25	45	23	22
Yufleh Dark Tree (grass)	0.25	41	18	23
Yufleh Dark Tree (bare patch)	0.3	40	17	23
Yufleh Line	0.3	50	22	28
Kalshe'k	0.25	39	19	20
Xudum Area 1 Infiltration test site 3	0-0.25	45	20	25
Xudum Area 2 Infiltration test site 1	0-0.15	26	12	14
Xudum Area 3 Infiltration test site 6	0-0.3	36	17	19
Xudum Area 4 Infiltration test site 4	0-0.3	25	14	11
Qualindheere Station BM'V'	0.45	24	12	12
Abaarcaanale	0.3	18	9	9
Gaba Gaba Sample 1		29	14	15
Burgal Fay Station A	0.2	19	10	9
Ina;Afmadowe by anthill	0.3	39	20	19

ANALYSES OF SOIL SAMPLES

Collected by A. R. Griffin

June - July 1980

(Analyses by Soil Mechanics Ltd.)

See figures C2, C.5 and C.6

for particle size distribution

TABLE C.1

Sample	Depth (m)	pH	$CaCO_3$ %	Organic C %	Total N %	Available P PPM	Fraction of Sample > 2mm	Exchange ions in milliaquivalents					
								Ca	Mg	K	Na	C.E.C	Gypsum
Ina Afmadowe Station 'S'	0.2	8.5	16.3	0.3	0.08	5	16.1	26.0	2.96	1.46	0.24	25.6	< 0.1
Ina Afmadowe Station 'A'	0.25	8.4	20.6	0.7	0.13	3	0	25.0	4.03	1.97	0.07	24.0	< 0.1
Ina Afmadowe by anthill	0.3	8.2	13.0	0.4	0.06	28	22.3	24.5	3.29	2.25	0.15	18.8	-- 0
Yufleh, Dark Tree (grass)	0.25	8.5	51.1	0.9	0.15	2	0	22.0	2.38	1.15	0.04	16.0	< 0.1
Yufleh, Dark Tree (bare patch)	0.3	8.5	51.7	0.6	0.11	2	0	22.0	1.81	0.69	0.13	17.6	< 0.1
Yufleh, Line	0.3	8.4	41.3	0.5	0.10	1	0	18.4	1.48	1.20	0.09	22.0	< 0.1
Kalsheik	0.25	8.3	8.3	0.5	0.11	2	0	22.0	2.63	0.92	0.50	18.4	< 0.1
Xudum													
Area 1, Infiltration Test Site 3	0-0.25	7.4	38.1	0.4	0.04	2	0	37.9	1.15	0.92	0.15	20.8	11.4
Area 2, Infiltration Test Site 1	0-0.15	8.2	58.7	0.2	0.01	7	19.2	15.5	1.23	0.74	0.09	11.2	0
Area 3, Infiltration Test Site 6	0-0.3	8.5	49.3	0.3	0.03	5	7.5	16.5	2.06	0.84	0.91	15.2	0
Area 4, Infiltration Test Site 4	0-0.3	8.3	61.0	0.1	0.02	4	8.0	16.5	1.07	0.46	0.09	12.4	0
Qualindheere Station BM'V'	0.45	8.4	39.6	0.1	0.01	4	4.6	17.5	1.89	0.38	0.13	15.2	0
Arbaareasnale, Sample 1		7.9	9.7	0.1	0.01	5	37.1	18.0	1.40	0.97	0.83	7.2	0
Gaba Gaba, Sample 1		8.3	22.4	0.1	0.01	8	27.1	19.0	1.73	0.54	0.20	16.4	0
Bungalfay, Station A	0.2	8.3	19.1	0.2	0.02	6	17.2	16.5	1.23	1.10	0.09	8.4	0

TABLE C2 RESULTS OF CHEMICAL TESTS ON SAMPLES FROM TABLE C.1

Specific Gravity	In Situ Density	Grade				Voids Ratio	Degree of Porasity	Remarks Solution	
		% Gravel	% Sand	% Silt	% Clay				
2.65		2	45						
		2	38						
		3	45						
		10	47						
	1.46		52			0.83	0.45	32	
		2	56						
		2	20						
2.60			18						
	1.43	6	50			0.87	0.46	21	
2.64	1.29	3	37			1.06	0.51	19	
68		9	42						
77		2	63						
.51	1.68		11			0.58	0.36	72	

in Project Area" A. R. Griffin. October 1980.

lected by A. R. Griffin. June - July 1979

Table C3

Sample No.	Sample Description	Figure	Moisture Content %	Atterberg Limit		Soil Group
				Liquid Limit %	Plastic Limit %	
S-B 16.4/0.7	SILTY FINE TO MEDIUM SAND	C.1	7.2			
S-B 32/0.15	FINE SANDY SILT, TRACE OF CLAY	C.1	8.8			
S-B 32/0.6	FINE SANDY SILT	C.1	17.6			
S-B 36/0.6	FINE SANDY SILT	C.1	4.6			
S-B 27/0.2	SILTY SAND	C.1	9.8			
S-B 27/0.8	SAND-SILT	C.1	5.2			
S-B 32/0.8	CLAYEY SANDY SILT	C.1	17.9			
S-B 32/1.2	SANDY SILT	C.1	8.9			
JAL/DAM/0.6	SILTY FINE SAND	C.2	4.4			
JAL/SADDLE/0.4	FINE SANDY SILT	C.2	7.7			
JAL/HILL 802/0.3	FINE SANDY SILT, TRACE OF CLAY	C.2	6.2			
JAL/HILL 802/1.0	SILTY SAND AND GRAVEL	C.2	3.6			
LA/EXP/0.15	SILTY FINE TO MEDIUM SAND AND GRAVEL		7.1			
LA/EXP/0.40	SILTY FINE TO MEDIUM SAND		5.9			
LA/EXP/0.90	MEDIUM TO COARSE SAND	C.3	10.2			
LA/SITE 2/0-0.4	SANDY SILT - GYPSIFEROUS		15.4			
AINABO/ 0.4	SILTY CLAY - GYPSIFEROUS		24.3			
YEROWAH/0.2	SANDY SILTY CLAY	C.3	15.6	51	29	MH-CH

Note: for borehole log sheets refer to "Appraisal of Geology and

Sample No.	Sample Description	Figure	Moisture Content %	Atterberg Limit		Soil Group
				Liquid Limit %	Plastic Limit %	
OG/76/0.2	SILTY FINE TO MEDIUM SAND	C.4	4.2			
OG/79/0.2	CLAYEY SILTY SAND	C.4	6.1			
)G/154/0.3	SILTY MEDIUM TO COARSE SAND	C.4	2.7			
OG/221/0.3	CLAYEY MEDIUM TO COARSE SAND	-	3.6			
)G/248/0.3	CLAYEY SANDY SILT	C.4	7.7			
)G/274/0.3	CLAYEY SANDY SILT	C.4	16.5			
GEBA GEBO:						
17014/0.1	SANDY SILT WITH GRAVEL	C.2				
17014/0.2	SILTY SAND	C.2				
17021/0.3	SILTY SAND, TRACE OF CLAY	C.2				
ERIGAVO:						
17305/0.2	SILT, GYPSIFEROUS	C.3	12.4	32	20	CL
17411/0.2	SILT, GYPSIFEROUS	C.3	6.8			
17469/0.10	SILTY CLAY, GYPSIFEROUS	C.3	15.4			
17506/0.3	SANDY SILT	C.3	10.1			
17570/0.15	SILTY CLAY, GYPSIFEROUS	C.3	22.3			
17749/0.10	SANDY SILT	C.3	4.8			
17749/0.4	SAND-SILT	C.3	4.2			
17799/0.3	SANDY SILT TRACE OF CLAY	C.3	9.4			
17874/0.1	SILTY CLAY, GYPSIFEROUS	C.3	9.4			
17874/0.4	SILTY CLAY, GYPSIFEROUS	C.3	17.5			

Specific Gravity	In Situ Density	Grade				Voids Ratio	Degree Remarks		
		% Gravel	% Sand	% Silt	% Clay		Porosity	Solution	
2.67			73						
2.[illegible]3	1.64		71			0.62	0.38	26	
2.75			79						
2.[illegible]5		5	25						
	1.78	3	33			0.5	0.33	88	
		8	69			pH 8.2			pH 8.2
		11	54			pH 8.0			pH 8.0
2.[illegible]8		7	53			pH 8.8			pH 8.8
2.66		5	48						
2.64		2	23						
2.[illegible]69		4	47						
2.[illegible]65		3	27						

Table C3 Continued

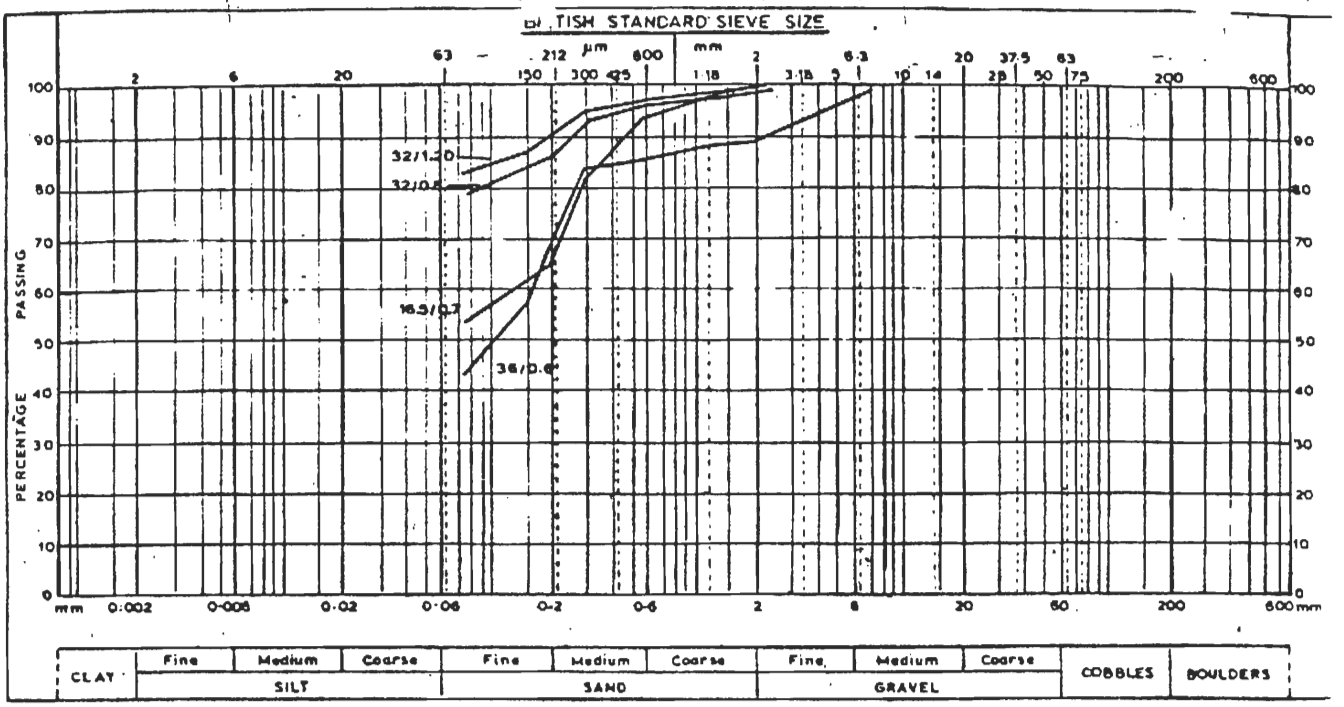
Sample	% H20 by wet weight at				Bppm	Saturation Paste Extract Analyses Mill equivalents per 100gm oven dried soil								
	0.2 bars	1 bar	5 bars	15 bars		Conductivity Micro-mhos/cm 25°C	Na	K	Mg	Ca	HCO_3	CL	SO_4	
Ina Afmadowe Station 'S'	21.2	17.0	14.1	12.7	1.3	0.43	0.03	<0.01	0.02	0.07	0.08	0.04	0.03	0
Ina Afmadowe Station 'A'	29.0	23.2	18.9	16.6	0.9	0.30	<0.01	0.01	0.04	0.09	0.14	0.09	0.20	0
Ina Afmodowe by anthill	23.4	19.3	16.1	14.0	1.6	Insuff Sample	0.03	0.03	0.07	0.31	Insufficient Sample			0
Yufleh, Dark Tree (grass)	24.2	18.5	15.0	13.9	0.9	0.42	0	0.01	0.04	0.12	0.15	0.08	0.05	0
Yufleh, Dark Tree (bare Patch)	23.1	17.1	13.9	11.6	0.9	0.71	0.04	<0.01	0.04	0.20	0.11	0.06	0.15	0
Yufleh, line	27.5	21.6	18.0	16.3	1.2	0.99	0.02	0.02	0.06	0.50	0.13	0.05	0.51	0
Kalsheik	26.9	18.6	14.1	11.6	1.4	3.75	0.25	0.02	0.28	1.14	0.08	0.56	1.32	0
Xudum														
Area 1, Infiltration Test Site 3	28.9	22.8	19.1	17.3	0.2	2.40	0.04	0.01	0.12	1.93	0.11	0.02	2.37	<0
Area 2, Infiltration Test Site 1	14.9	11.8	9.3	7.6	0.05	0.45	0.01	0.01	0.03	0.08	0.08	0.01	0.03	<0
Area 3, Infiltration Test Site 6	22.0	16.0	12.4	10.4	0.1	0.92	0.21	<0.01	0.02	0.06	0.11	0.15	0.04	<0
Area 4, Infiltration Test Site 4	14.5	10.6	8.0	6.4	0	0.43	0.01	<0.01	0.02	0.07	0.05	0.01	0.04	<0
Qualindheere Station BM'V'	14.6	10.8	8.4	6.8	0	0.39	0.02	<0.01	0.02	0.07	0.05	<0.01	0.04	<0
Arbaareaanale, Sample 1	11.7	8.1	6.1	5.1	0.7	Insuff Sample	0.73	0.12	0.04	2.02	Insufficient Sample			0
Gaba Gaba, Sample 1	16.5	12.4	9.6	8.1	0.7	0.76	0.06	<0.01	0.04	0.18	0.08	0.09	0.05	0
Bungalfay, Station A	12.6	9.1	6.8	5.3	0.2	0.77	0.02	0.04	0.03	0.12	0.07	0.03	0.07	<0

WELL NO	COLOUR TURBIDITY	pH	E.C mnhos/cm	HARDNESS (As $CaCO_3$) TOTAL	CALCIUM (mg/1)	MAGNESIUM	ALKALINITY $CaCO_3$ 'mg/1)	CHLORIDE Cl (mg/1)	SULPHATE SO_4 (mg/1)	NITRATE N (mg/1)	ANMONIA N (mg/1)	PHOSPHAT PO_4 (mg/1)
Los Anod Depres.	NONE CLEAR	7.9	3.4	1795	1625	170	68	15	600	1	-	1
Los Anod Tug Depres.	NONE CLEAR	7.8	4.4	2479	2394	85	51	91	1000	2	-	1
Ainabo Well	NONE CLEAR	6.9	4.0	1496	1453	43	157	181	1000	1	-	1.0
Burao Well	NONE CLEAR	7.7	0.75	248	188	60	154	44	93	6.0	0.5	1
Goitah Tank	White Moderate	8.3	0.21	86	69	17	103	8	50	2.0	0.5	1
Wada-Maso Well	NONE CLEAR	6.9	4.1	1573	1573	0	222	136	250	4	-	1
Fagiyaab Spring	NONE CLEAR	7.5	7.5	1339	684	655	273	1358	550	4	1.5	1
Fagiyaab Well	NONE CLEAR	8.2	11.4	3762	1710	2052	290	3228	1080	13	-	1.0
Geba Gebo Spring	NONE CLEAR	7.0	0.73	291	188	103	273	60	50	3	0.5	1

WATER SAMPLE ANALYSIS TABLE C4 (from A. R. Griffin)

Sheik well river bed	Sl. green SLIGHT	8.0	1.8	513	170	343	393	211	92	2	1.0	1.0
Ogaden Tank 41 km	NONE CLEAR	8.1	0.31	103	86	17	145	6	50	2	1.0	1
Ogaden Tank 91 km	RED HIGH	7.7	0.15	51	34	17	86	6	50	-	-	-
Ogaden Bund 119 km	SI. Red SLIGHT	8.1	0.48	134	103	31	171	6	50	2	0.5	1.0
Widwid Well	NONE CLEAR	7.6	1.2	427	170	257	428	53	78	5	1.5	1.0
Wadi Well nr Ainabo 354 km	NONE CLEAR	7.4	0.48	137	137	0	188	6	50	2	2	1.0
Erigavo 17462 Water Hole	NONE CLEAR	7.5	0.28	103	86	17	137	6	50	3.5	2	1
Hengolo Well	NONE CLEAR	7.5	9.3	2907	1667	1240	137	1297	2600	18	-	-
	NONE CLEAR	7.5	1.2	479	291	188	188	37	-	9	0.5	1
	YELLOW HIGH BROWN	7.7	0.70	171	102	69	239	23	-	3	25	1
	BLUE MODERATE	7.0	0.65	205	154	51	239	6	50	1	2.5	1

PARTICLE SIZE DISTRIBUTION



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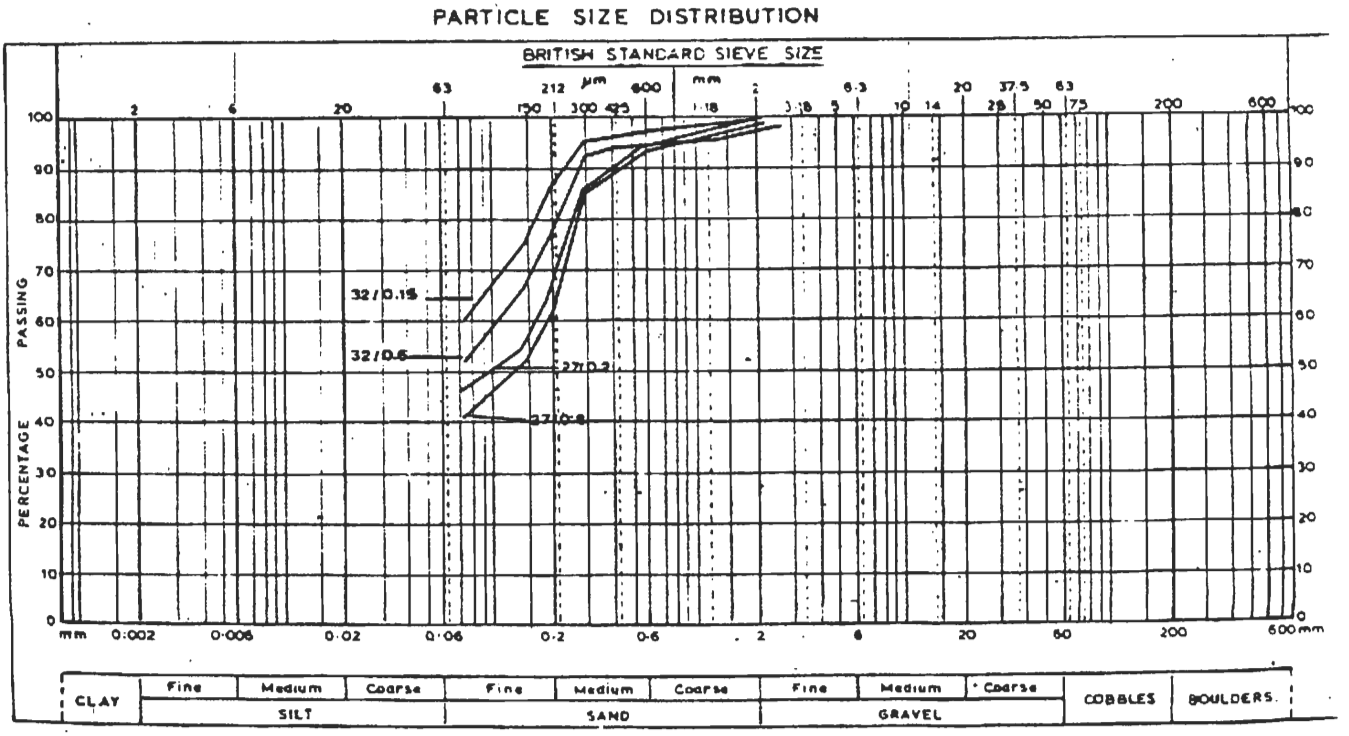

Sheik – Burao

FIG

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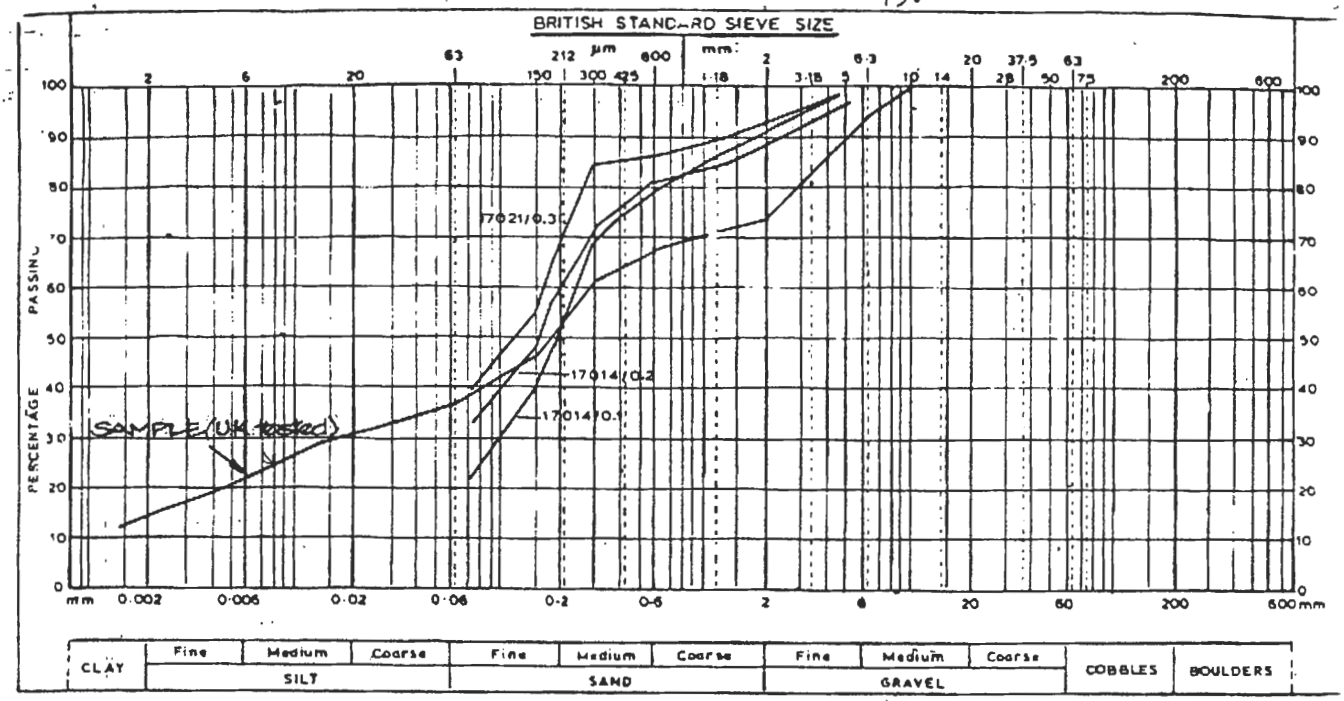
FIG.

PARTICLE SIZE DISTRIBUTION



Geba Gebo

PARTICLE SIZE DISTRIBUTION

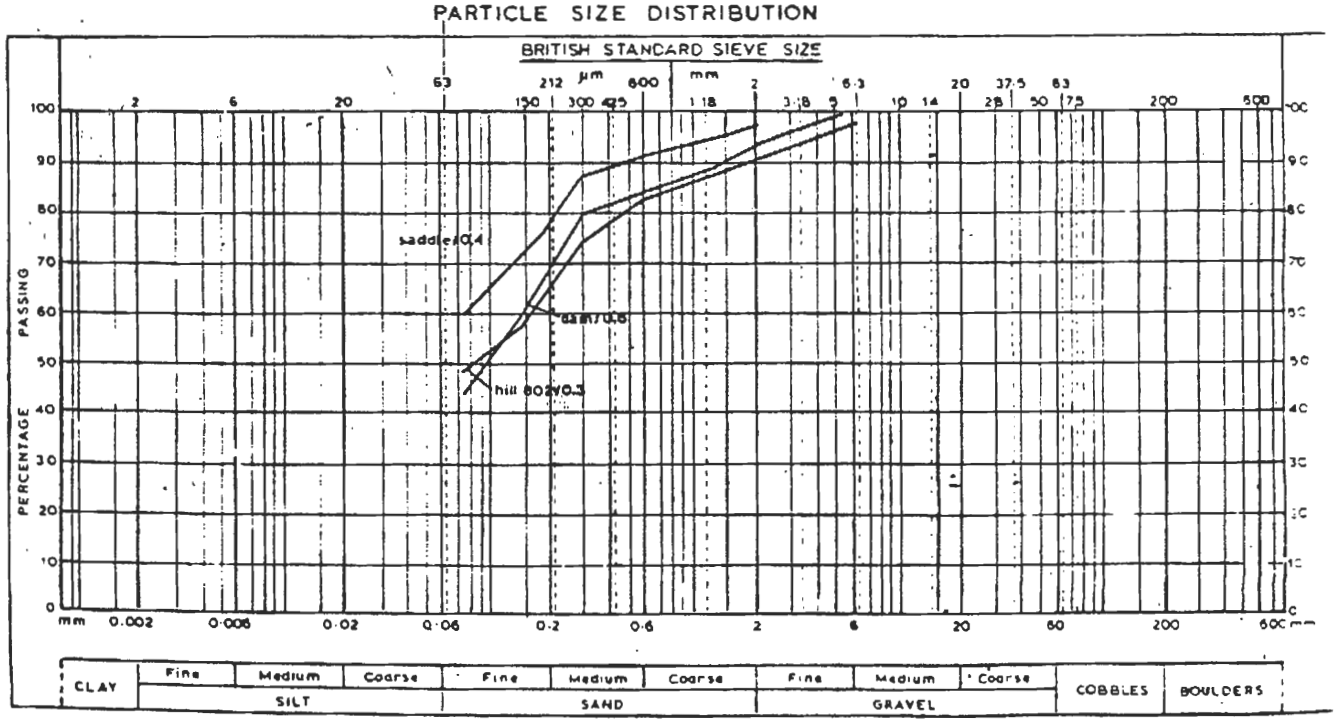


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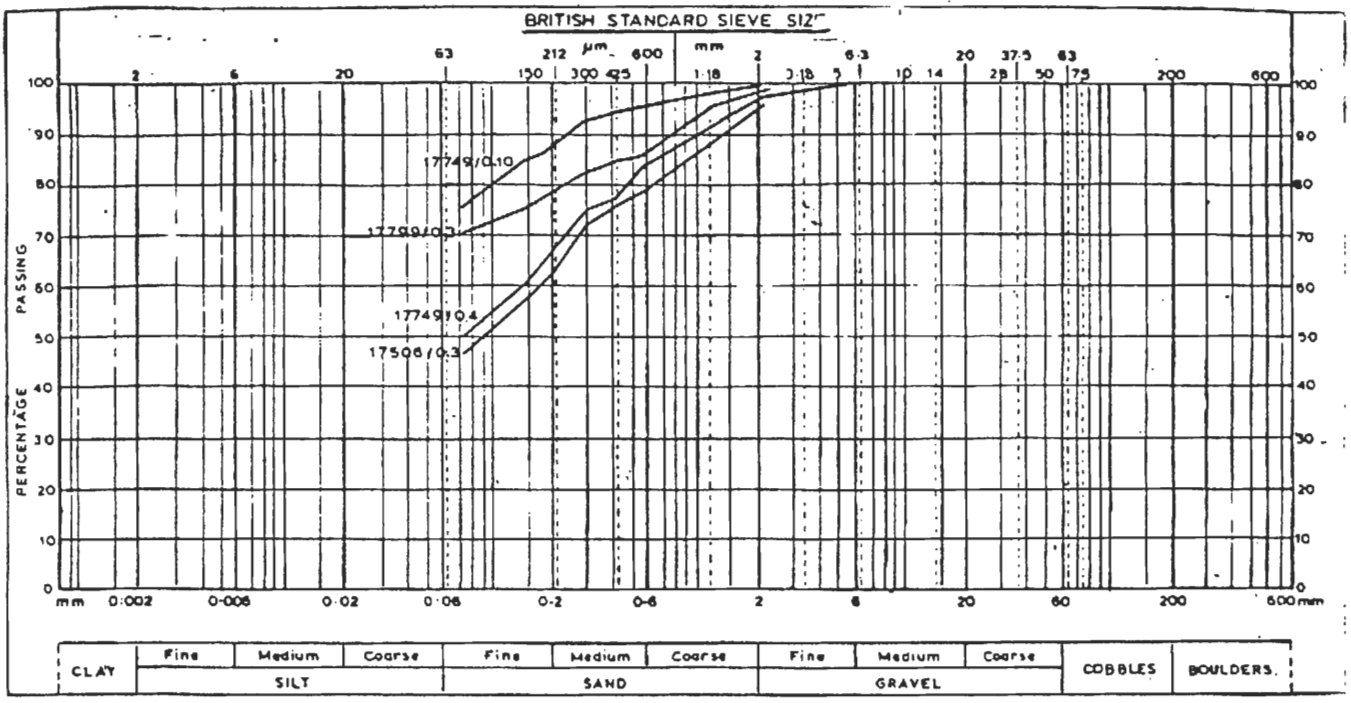
FIG.

PARTICLE SIZE



Erigavo

PARTICLE SIZE DISTRIBUTION

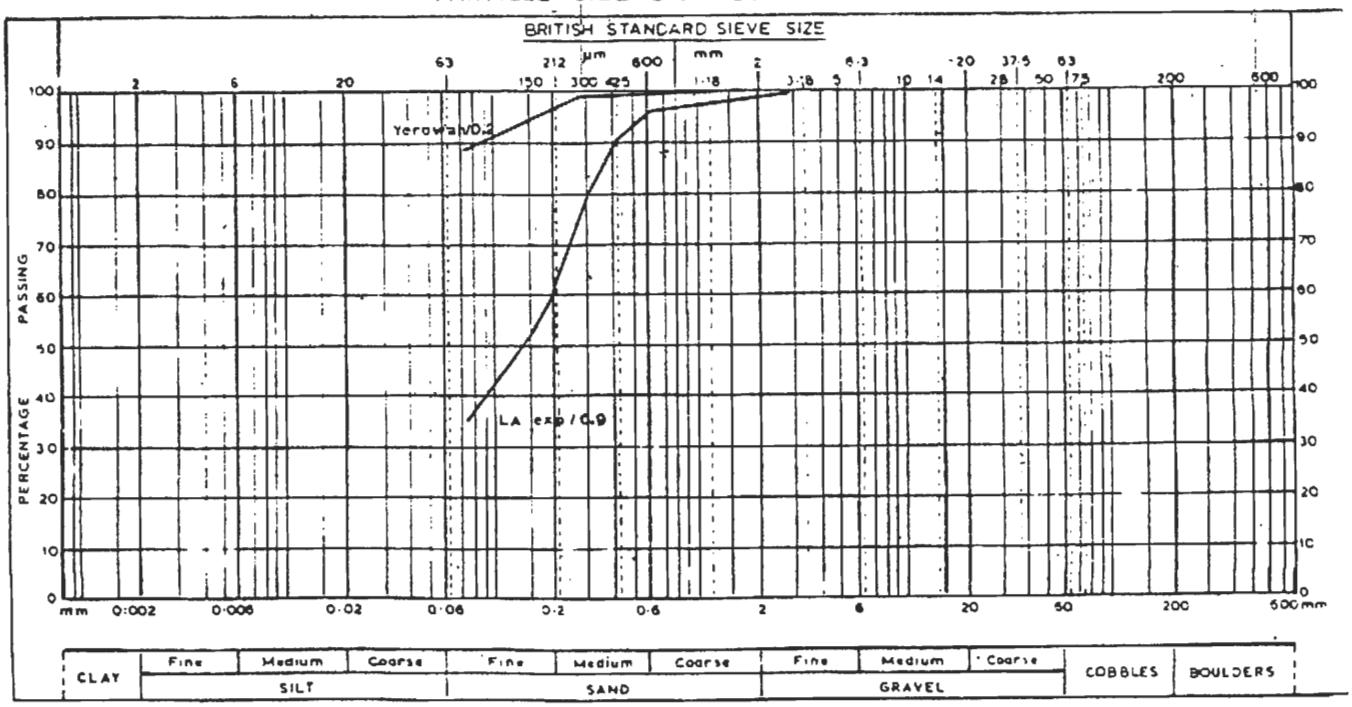


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FIG.

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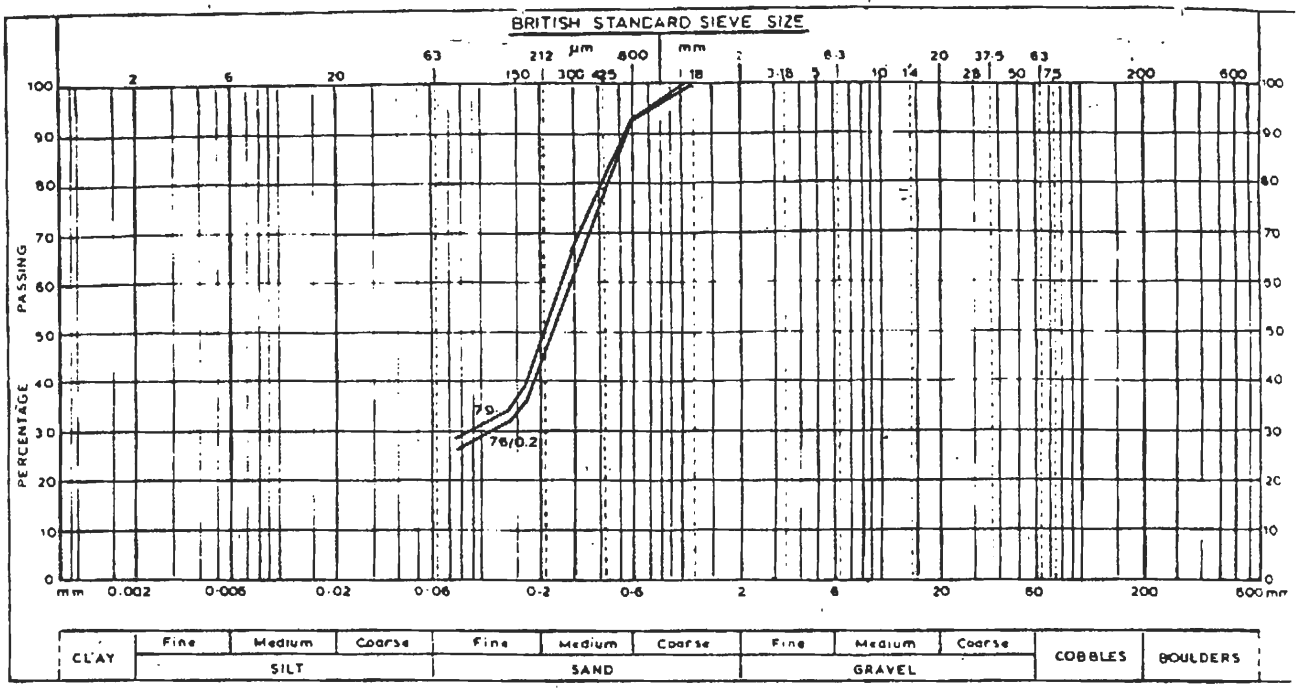

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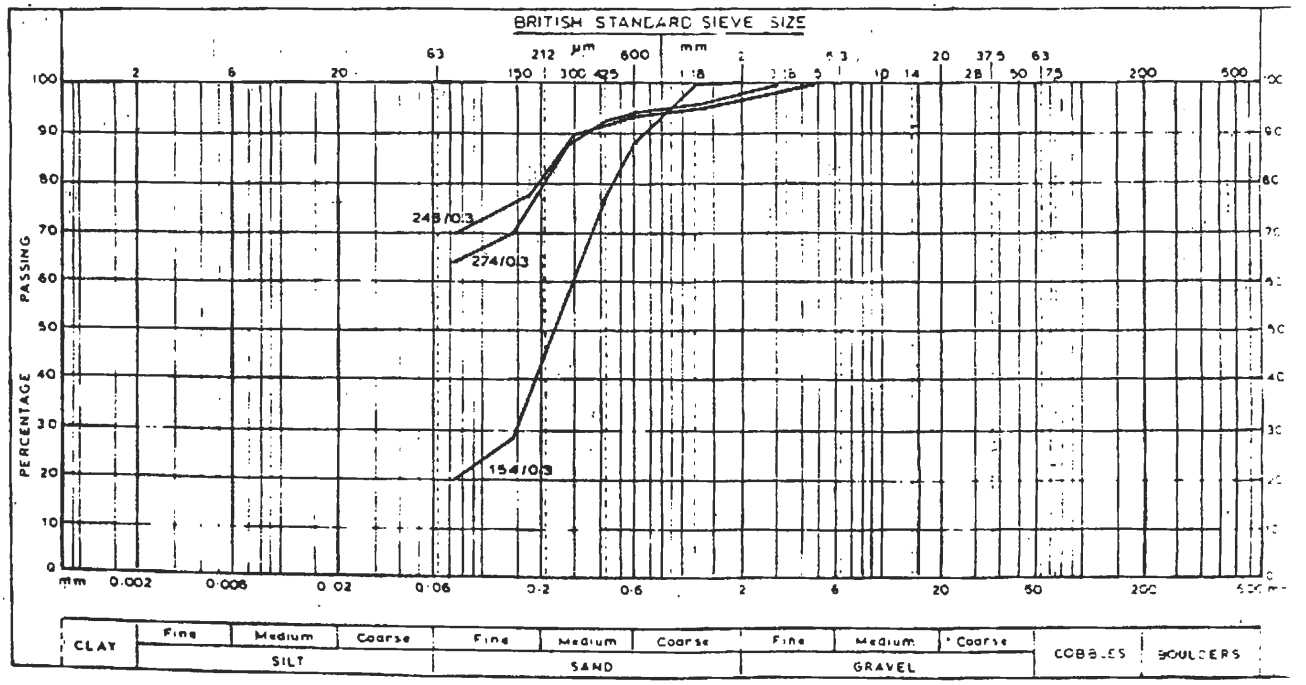

Ogaden

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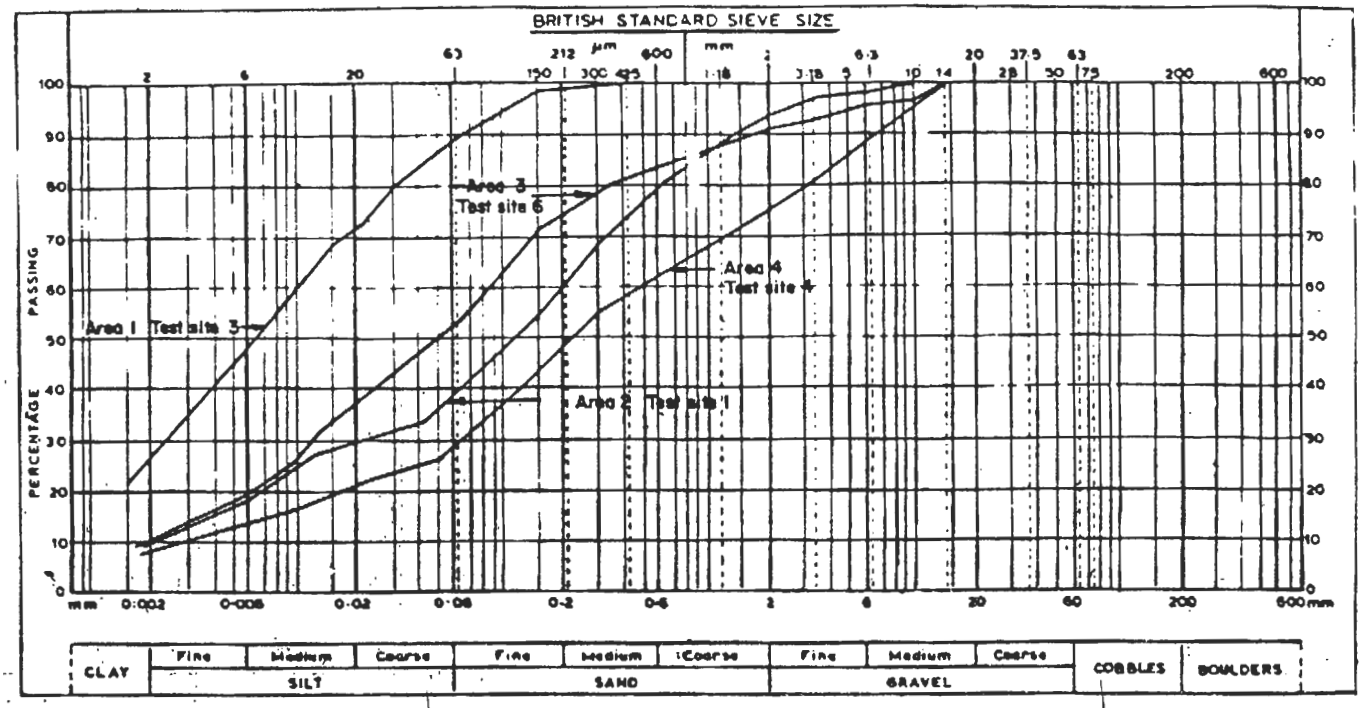
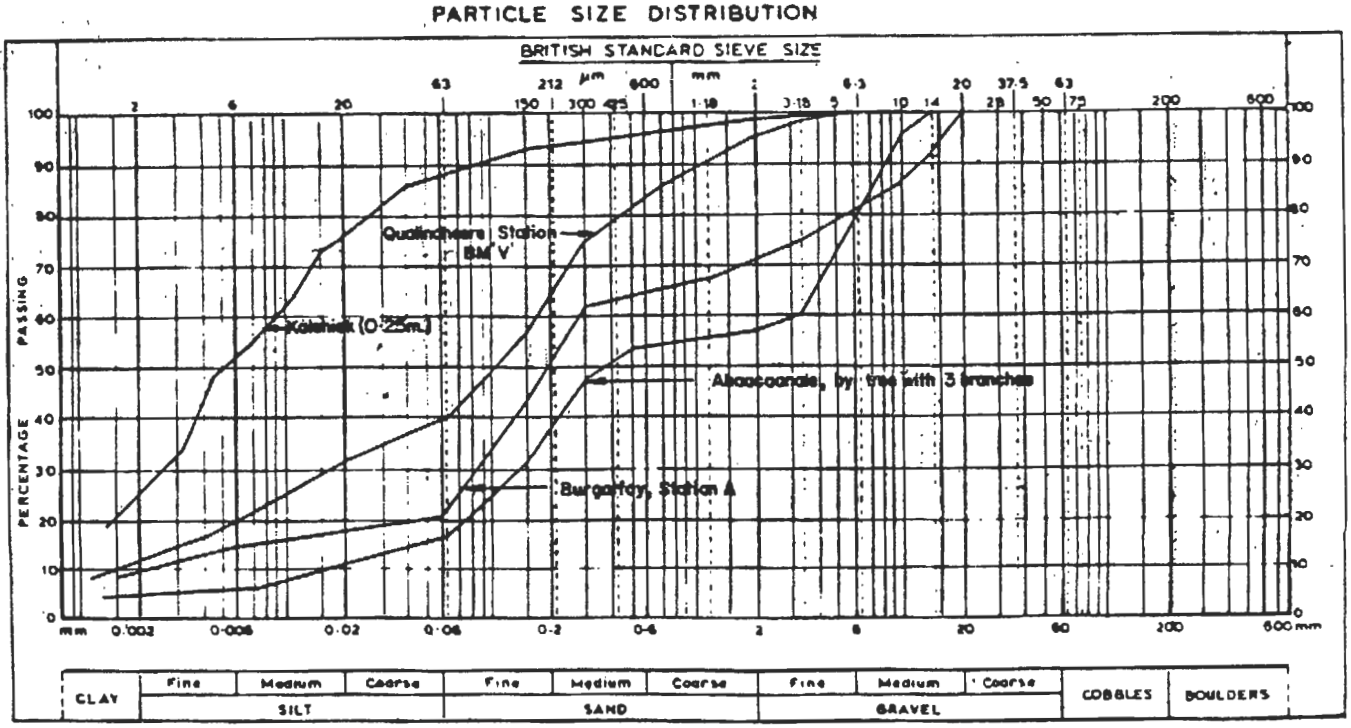
PARTICLE SIZE DISTRIBUTION 82



Xudun (U.K. tested)

PARTICLE SIZE DISTRIBUTION



GENERAL (U.K. tested)

FIG

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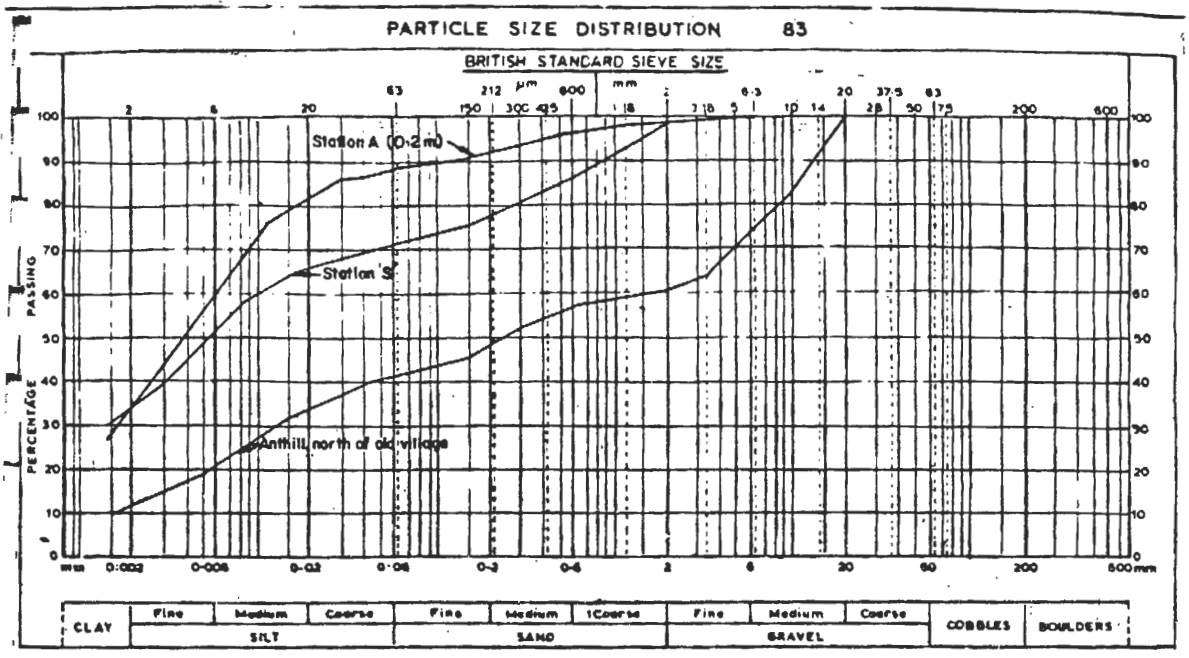
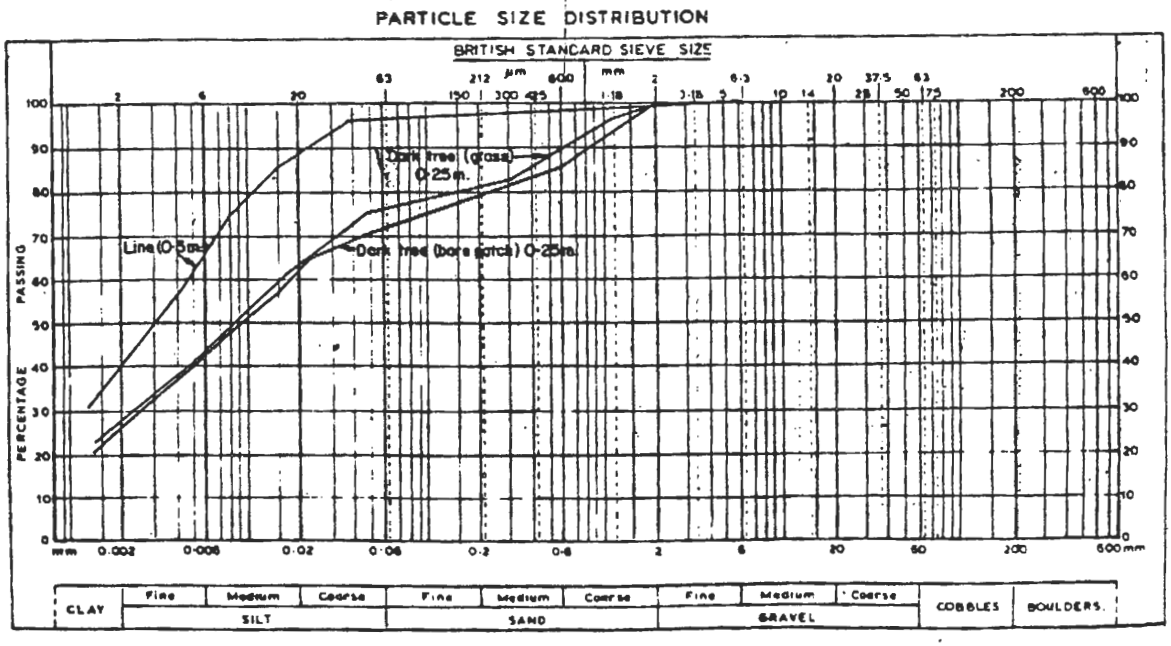
FIG C



Ina Afmedowe (U.K. tested)



Yufleh (U.K. tested)

FIG

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FIG C