SF/YEM 1-3/LA
Technical Report 8

SURVEY OF THE AGRICULTURAL POTENTIAL OF THE WADI ZABID

YEMEN ARAB REPUBLIC

SOILS AND LAND CAPABILITY

TESCO
VIZITERV-VITUKI
Budapest, 1971

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Report prepared for
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by
TESCO
VIZITERV-VITUKI

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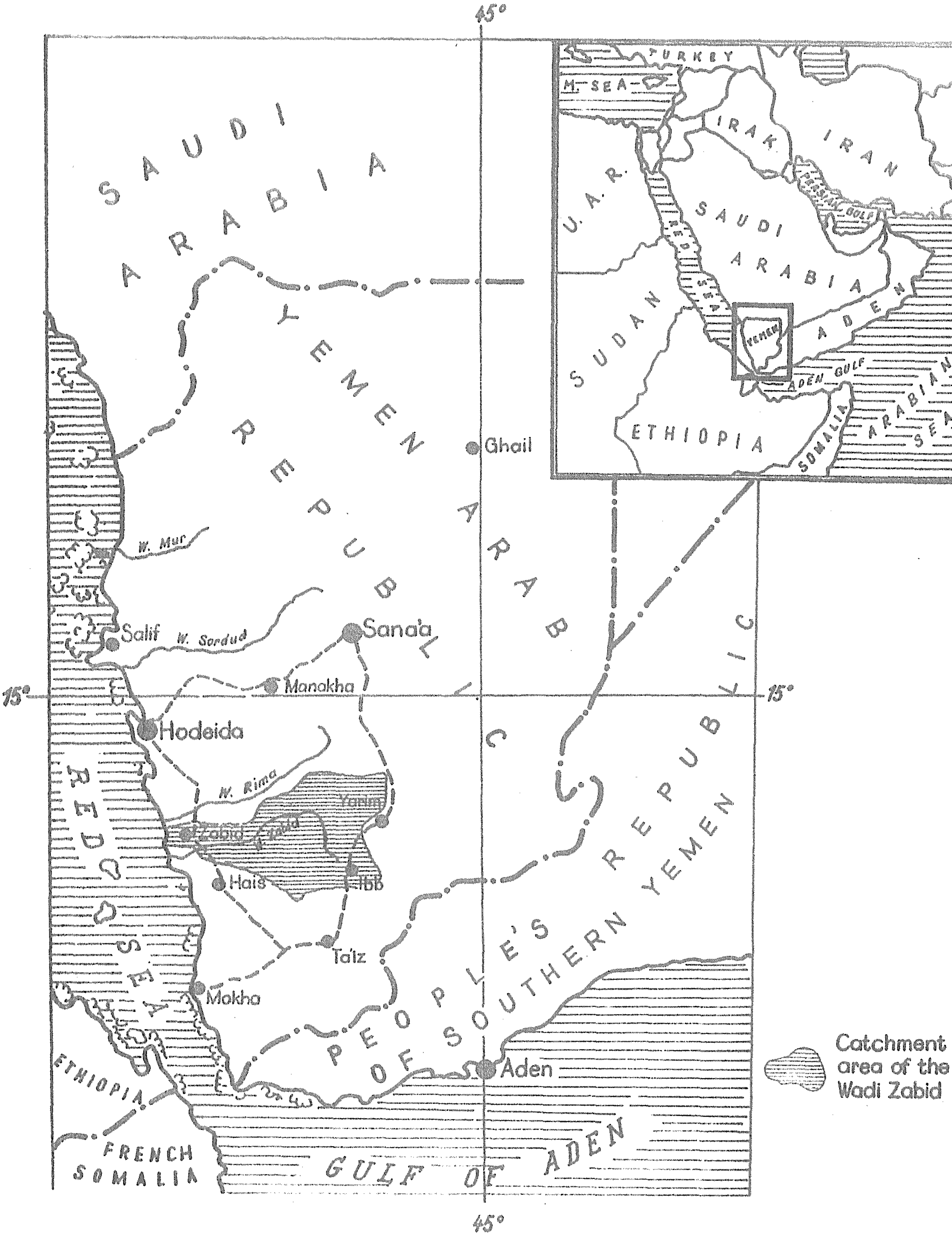
This technical report is one of a series of reports prepared during the course of the UNDP/SF project identified on the title page. The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.



MAP 1. SKETCH OF YEMEN ARAB REPUBLIC

ABSTRACT

Soil survey and land classification activities formed an important part of the UNDP/FAO SF/YEM 1-3/LA Project entitled: "Survey of the agricultural potential of the Wadi Zabid" subcontracted to TESCO/Organization for International Technical and Scientific Cooperation in Hungary/, with the aim of investigating the soil and water resources of the Wadi Zabid area of the Tihama Plain, Yemen Arab Republic.

A semi-detailed soil survey was carried out between June 1969 and June 1970/ the first 12 months of the Project/ on the area controlled by the proposed diversion structure at Ma'ath covering 20 000 hectares of the irrigation scheme. Based on the interpretation of aerial photographs, morphological descriptions of 301 soil profiles, field examinations, as well as laboratory analysis of the samples taken from the representative profiles, soils and land capability maps /scale 1:20000/ were prepared. The soil forming factors /meteorological, geological, geomorphological conditions, surface water and ground-water hydrology, relief, vegetation, human activity/ were analysed and the main soil forming processes were described. The soils were classified into four main groups as follows:

1	Alluvial Soils	30 %
2	Soils affected by wind erosion	22 %
3	Arid brown soils	47 %
4	Salt affected soils	1 %

The soils, formed on fluviatile and aeolian sediments, are calcareous /1,5–7,5 % $CaCO_3$/, have alkaline reaction /ph 8,0–8,4/, low humus and total N^{-}, $P_2O_5^{-}$ and K_2O content. There is a large range in their grain-size distribution /texture/, field capacity, infiltration rate and permeability. The limiting factors of the soil fertility are the wind erosion, low plant nutrient content, shortage of irrigation water and in some parts of the area the stoniness or salinity and/ or alkalinity.

Five major categories of potential land-use have been established. Two-third of the project area is suitable for irrigated cultivation /from the viewpoint of soils/ and one-third has restricted irrigation potential.

Based on a detailed soil survey soil and land capability maps were prepared at a scale of 1:1000 covering an area of about 35 hectares for the Experimental Farm.

On the basis of soil studies recommendations were given for the soil utilization, fertilization and irrigation to establish investment feasibility and permit the development of irrigated agriculture.

ACKNOWLEDGEMENTS

István J. Boros, the soil scientist of the Hungarian TESCO-Team is greatly indebted, beyond the Hungarian Management to N.G. Titov, FAO Resident Engineer, Dr.A.K. El-Eryani, Representative of the Yemeni Government for providing the necessary information and facilities, for their help, advice and suggestions as well as for the constructive criticism, which were of invaluable assistance at this work.

Many thanks are due to Prof.Dr.I.Szabocs, director of Research Institute of Soil Science and Agricultural Chemistry of Hungarian Academy of Sciences and R.Gy. Várallyay, head of Department of Salt-Affected Soils in the same Institute under supervision of whom the laboratory analyses were carried out, who promoted the completion of this work in every way. Their direct help, criticism and suggestions were of great value for this work.

A special word of thanks is also due to Mr.Hassan Hussein, senior soil technician of Wadi Zabid Project for his self-sacrificing work and versatile help.

István J.Boros wishes to express his appreciation to all Yemeni people, who collaborated with him during his assignment in Wadi Zabid Project.

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EXPLANATORY NOTE

Cation Exchange Capacity - The total quantity of cations which a soil can adsorb by cation exchange, usually expressed as milliequivalents per 100 grammes.

C_2S_1 - Medium salinity low sodium water. Example of classification of irrigation water; C denotes electrical conductivity, S denotes sodium adsorption ratio /SAR/ classes; numbers denote respective numerical quality classes.

C_3S_1 - High salinity low sodium water. Details see above.

Deflation - wind erosion - destructive effect of wind activity deteriorating soil fertility.

Electrical conductivity - The reciprocal of the electrical resistivity. The resistivity is the resistance in ohms of a conductor, metallic or electrolytic, which is 1 cm long and has a cross-sectional area of 1 cm^2. Hence, electrical conductivity is expressed in reciprocal ohms per centimeter.

Exchangeable Sodium Percentage - The degree of saturation of the soil exchange complex with sodium. It may be calculated by the formula:

$$ESP = \frac{\text{Exchangeable sodium /mEq/ 100 g soil/}}{\text{Cation exchange capacity /mEq/ 100 g soil}}$$

Field Capacity - The moisture content of soil in the field 2 or 3 days after a thorough wetting of the soil profile by rain or irrigation water. Field capacity is expressed as a moisture percentage, dry-weight basis.

German Degree of Water Hardness /N^{o}/ - 1 N^{o}= 10 mg CaO per litre or 7.19 mg MgO per litre.

Infiltration Rate - The rate at which a soil will adsorb water ponded on the surface at a shallow depth /10 cm/, when adequate precautions are taken to minimize the effect of divergent flow at the borders. It is the volume of water passing into the soil per unit of area per unit of time, and has the dimension of velocity. The average infiltration rate during the first hour of observation is taken as a characteristic figure for these soils.

Mapping unit - A single soil name stands for a specially defined unit in the taxonomic system of classification and identified on the map by symbol. In this case the mapping or classification units are grouped in decimal system in brackets with the aim of distinction from the chapter divisions. For istance: /1/ Alluvial soils: /2/ Soils affected by wind erosion; /3/ Arid brown soils: /4/ Salt-affected soils etc.

Müncz - Lainé Apparatus - Small portable field laboratory equipment named after constructors for filed permeability studies.

Normality of solution /n/ - 1 n= equivalent weight of a material /compound/ dissolved in one litre of solution.

Saturation extract - The solution extracted from a soil at its saturation percentage.

Saturation Percentage - The moisture percentage of a saturated soil paste, expressed on a dry-weight basis.

Silt - Soil fraction having the particle size between 0,05 and 0,002 mm.

Sodium Adsorption Ratio - A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil

$$SAR = \frac{Na^{+}}{/Ca^{++} + Mg^{++}/:2}$$

, where the ionic concentrations are expressed in milliequivalents per litre.

Soluble Sodium Percentage - A term used in connection with irrigation waters and soil extracts to indicate the proportion of sodium ions in solution in relation to the total cation concentration. It may be calculated by the formula:

$$SSP = \frac{\text{Soluble sodium concentration } /mEq/lit/}{\text{Total cation concentration } /mEq/lit/}$$

Terrace I - The first terrace of river deposition counted from the bottom towards its embankments.

Terrace II - The second terrace of river deposition counted from the bottom towards its embankments.

Water permeability - The specific property of a soil which is a measure of the readiness with which the soil transmits water. The permeability is a velocity and for agricultural purposes it can be conveniently expressed in mm per hour. The average water permeability during the sixth hour of observation is taken as a characteristic figure for these soils.

Wetting profile - The pattern of moisture placement in a soil profile dug out 2 or 3 days after the field water permeability study conducted by iron frames.

GLOSSARY

Alluvium - alluvial deposits formed in river valleys and are characterized by stratification and good sorting of material. They are transported by the river waters.

Calcic horizon - horizon of secondary carbonate enrichment that is more than 15 cm thick, and has a $CaCO_3$ - equivalent countent of more than 15 per cent and at least 5 per cent more $CaCO_3$ - equivalent than the C horizon.

Collovium or prolovium - crude weakly sorted deposits moved to the foot of slopes by gravity or water-flows of mountains.

Gypsic horizon - horizon of secondary $CaSO_4$ - enrichment that is more than 15 cm thick and has at least 5 per cent more gypsum than the C horizon.

Illuvial B horizon - horizon immediately underlying the surface A-horizon, which accumulates considerable part of weathering products of mineral material leached out form the overlying A-horizon.

Melanic A-horizon - it is a surface layer which after the surface 18 cm is mixed as by ploughing /detailed properties see in /6/.

Ochric epipedons- are those that are too light in colour, too low in organic matter and too thin to other epipedons. They may have rubbed colour values lower than 5.5 when dry or lower than 3.5 when moist, provided they are essentially no darker than the C horizon.

Pallid A horizon - it is the layer which is too light in colour, too low in organic carbon or too thin to be melanic, sombric or etc.

Pseudomycelium - neoformation of $CaCO_3$ in a soil profile which has the appearance of veins or mycelium of fungi.

Pseudo-sand dunes - material with the character of sand dunes but consisting of loam or clay, cemented to sand-size grains.

Salic horizon - layer of 15 cm or more in thickness with secondary enrichment of salts more soluble in cold water than gypsum. It contains at least 2 per cent salts.

Sombric A horizon - it includes those thick dark surface horizons that have a base saturation less than 50 per cent /by the NH_4OAc method/ or that are both hard and massive when dry.

Xerophyte - drought - resistant plants.

ABBREVIATIONS

AL - Ammonium-lactate
Al - Aluminium
C:N - Carbon-Nitrogen Ratio
CEC - Cation Exchange Capacity
$EC_{25}{}^{o}C$ - Electrical Conductivity measured at the temperature of 25 centigrades
EDTA - Ethylenediaminetetraacetate /Versenate/
ESP. - Exchangeable Sodium Percentage
g - gramme
g/lit - grammes of solute per litre of solution
h - hour
ISSS - International Society of Soil Science
lit - litre
mEq - milliequivalent or one thousandth of an equivalent
mg - milligramme
mm - millimetre
mmhos/cm - mS or millisiemens
N - Nitrogen
N^{o} - German degree of water hardness
n - normality of a solution
Na % - SSP or soluble sodium percentage
SAR - Sodium Adsorption Ratio
SP - Saturation Percentage
u - micron /10^{-6} metre/
% - per cent or percentage
1 - less than 1
1. - more than 1

Chapter 1

INTRODUCTION

1.1 ORIGIN OF THE PROJECT

In accordance with the request of the Government of the Yemen Arab Republic in December 1967 the Plan of Operation for the Survey of the Agricultural Potential of Wadi Zabid was signed by the Government of Yemen, the United Nations Development Programme /Special Fund/ and the Food and Agricultural Organization of the United Nations, as the Executing Agency. The cooperating Government agency is the Ministry of Agriculture and the Project was implemented by a sub-contract to TESCO - VIZITERV - VITUKI of Budapest, Hungary. The project became operational on 1st November 1969 and the field work started on 1st June 1969, with a planned duration of two years.

The Wadi Zabid is one of the seven major wadis which drain to the Tihama, an arid coastal plain some 25-45 kms wide which extends along the length of Yemen between the mountains and the Red Sea. The mean annual rainfall on the plain ranges from about 100 mm at the coast to perharps 300 mm at the foothills of the mountains. The rainfall is subject to marked annual variation and falls in summer as widely scattered.

relatively intensive storms.

The wadis drain mountain catchments which receive mean annual rainfall in the range of 500 to 800. A proportion of this rainfall discharges a run-off to the Tihama plain. Each of the wadis has formed a sub-aerial delta on the plain. Only in exceptional cases does run-off reach the sea.

Rainfed agriculture is practised in the higher rainfall area of the Tihama. However the level of production is extremely low and crop failure is common in low rainfall years.

The population of the Tihama has, over the centuries, developed system of spate irrigation to make use of the floods which run-off to the deltas. The perennial base flows of the wadis are also used for irrigation, and in more recent years, irrigation by groundwater pumped from wells has become increasingly important.

According to the Plan of Operation, the purpose of the project is to investigate the irrigation potential of the Wadi Zabid and to prepare designs for a flood irrigation scheme.

In particular the project will:

a./ Assist the Government of Yemen, over a period of two years, in investigating the irrigation potential of the Wadi Zabid by surveying the land and water characteristics of the area.

b./ Design the structures most appropriate for a flood irrigation system covering a projected 20 000 hectares.

c./ Prepare a feasibility appraisal in terms of the organisation, operation and economics of alternative investment projects in the area.

At the end of the project a Feasiblity Report, a Final Report and a series of Technical Reports an investigations are to be submitted.

This paper is one of the Technical Reports titled Soils and Land Capability written by István,Boros, Agric.Eng.,Research Institute of soil Science and Agricultural Chemistry, of the Hungarian Academy of Sciences, Soil Scientist of TESCO.

1.2 OBJECTIVES AND SCOPE OF ACTIVITIES IN RELATION TO THE PROJECT

With special reference to the activities listed in 1.B./1.5. of the Plan of Operation the objectives and scope of activities in relation to this Technical Report described as:

1./ Soil studies based on aerial photographs and filed investigations with some laboratory work, probably performed outside Yemen. The soil survey will involve soil classification and determination of the extent of land under command of irrigation canals from the Wadi Zabid suitable for flood irrigation.

The territory of the Yemen Arab Republic is is mostly covered by barren, steep rocky mountains and hills. Agricultural production has been carried out for centuries in these places which can hardly provide the population with the minimum food supply. The development of agriculture in Yemen has a potential possibility primarily in the Tihama Plain, since on the aeolian and fluviatile deposits of the Tihama Plain having hot and dry climate, crop-growing can be successfully carried out with the help of irrigation. But the century old practice of flood irrigation wastes water and make irrigation possible only in a relatively small area and during the short and rapsodic flood periods of the wadis. One of the most extensive and oldest irrigated areas of the Tihama Plain is the Wadi Zabid area.

The task of the Wadi Zabid Project is to estimate the agricultural pontential of the Project Area, to find out the possibilities and conditions of its agricultural utilization and finally, to work out the agricultural development programme of the territory. Since under the given climatic conditions the successfull agricultural production basically depends on the adequate artifical water supply, the fundamental questions of the development of agriculture are as follows:

a./ Whether the soil conditions of the territories, which can be supplied with water, are suitable for a more-up-to-date irrigational farming if they guarantee the soil conditions of an effective irrigation.

b./ How and from where can the quantity of water bigger and expecially more even than at present - be procured.

c./ How can the available water be distributed on a larger territory and how can the present low effectiveness of irrigation be increased.

In accordance with the United States Department of the Interior Bureau of Reclamation Manual /26/ a semi-detailed soil survey had been carried out, on the area commanded by the proposed diversion structure at Ma'ath covering 20000 hectares of the irrigation scheme.

The soil survey was based on the aerial photographs /stereoparis/ in scale 1:125000 and 1:25000 and on the aerial photomontage /photomosaic/ at a scale of approximately 1:25000. Aerial photograph was interpreted simultaneously through checked them in the field. On the characteristic spots soil pits were explored and examined with and average density of 3 profiles per 2 sq km and it was completed by the necessary amount of intermediary auger borings.

Representative profiles were sampled and subsequently subjected to the detailed laboratory analysis whilst the other soil profiles and boreholes were identified by macroscopic field examinations.

With regards to the climate, geology, geomorphology, hydrology, soil formation process, field and laboratory analyses the soils were classified.

1.3 PREVIOUS INVESTIGATIONS

The Wadi Zabid Project aims at providing a design for an improved spate-irrigation supported by a technical-economic feasibility study. The Lowlands Farm Development Project aims at experimental studies demonstration and extension for commercial crop production using groundwater. It also intends to make a study in depth of the agro-economic problems associated with groundwater development for irrigation. The Wadi Sordud and South Gumeisha Projects are run under Soviet and German Democratic Republic bilateral assistance respectively. The Sordud Scheme is aimed at settlement through land clearance, and exploitation of groundwater. The South Gumeisha development is highly mechanised commercial irrigated farm which has little relationship to the farm systems existing in the Tihama. Up to now no surveying and no detailed soil investigations have been done - apart from one or two minor projects - in the Project Area or on the territory of the Yemen Arab Republic.

Chapter 2

AREA SURVEYED

The area surveyed is a part of the Tihama Plain in the Yemen Arab Republic, which is situated on 45 long. and 15 S. lat. in the S. W. of Arabia. The Wadi Zabid Project Area covers about 25000 hectares and soil surveys was carried out on about 20000 hectares. /Map 1/

2.1 SURVEY METHODS

For locating the place of the characteristic soil profiles and for plotting the boundaries of the mapping units aerial photographs /stereo-pairs/ at scale 1:12500 and 1:25000 and aerial photo-mosaic /montage at scale 1:25000 were used. They successfully substituted the base topographycal maps.

301 soil profiles were dug, examined and described /1,5 profiles per km²/ and 28 intermediary borings were made to characterize the soil conditions of the area. The morphological description of the characteristic profiles can be found in the Appendix 4 attached to Report.

On 16 soil profiles field permeability measurements were carried out in order to determine the water management properties of the soil. Frame method /23/ and modidifed Münz-Lainé apparatus /24/ were used for the determination of the infiltration rate, water permeability, field capacity, and the wetting fronts of the soil. The results of the examinations are given in Appendix 5, Table 7.

Soil samples were collected from 44 profiles for laboratory analysis, further on 63 water samples were taken /well water, ground-water, wadi water/. The analyses of soil and water samples were done at the Department of Salt Affected Soils of the Research Institute of Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, Hungary under the direct supervision of Professor Dr. István Szabolcs, Director of the Institute. The laboratory analyses were as follows:

Laboratory analysis		
pH	348	tests
particle-size distribution	166	"
saturation percentages	332	"
exchangeable Na^+ ions	244	"
cation exchange capacity	244	"
total N-content	113	"
$CaCO_3$-content	348	"
particle density	166	"
total salt content of saturated soil paste	335	"
humus content	113	"

aqua regia soluble P_2O_5-content	113 tests
aqua regia soluble K_2O-content	113 "
lactate soluble P_2O_5-content	155 "
lactate soluble K_2O-content	155 "
pH determination of saturation extract	112 "
Na-content of the saturation extract	41 "
electrical conductivity of the saturation extract	112 "
total chemical analyses /hydroscopic moisture content, ignition loss, SiO_2, R_2O_3, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, P_2O_5, SO_3, MnO/	48 "
analyses of 1:5 water extract /dry residue, ignition residue, pH, EC, carbonate, hydrocarbonate, chloride, sulphate, calcium, magnesium, sodium, pottasium/	65 "
water analyses /dry residue pH, Ec, total-, carbonate- and residual hardness, soda equivalent, carbonate, hydrocarbonate, chloride, sulphate, calcium, magnesium, sodium, pottasium, nitrogen/	63 "

The methods for laboratory analyses are summarized in Appendix 1. The results of the laboratory analyses are given in Table 1-10. Appendix 5.

Tables:

1./ Horizons and sampling depths

2./ Analytical data

3./ Particle-size distribution of soils

4./ Salinity and alkalinity status of soils

5./ Results of the analysis of 1:5 water extract of soils

6./ Results of the total chemical analysis of soils

7./ Water management properties of soils
8./ Results of water analysis
9./ Origin of water samples
10./ Results of analysis of the water samples taken from the newly drilled deep tube wells

A soil map and map of land capability classes were prepared at scale 1:20000 for more then 20000 hectares of the Project Area on the basis of the interpretation of aerial photos, field survey, the results of field examinations and laboratory analyses.

For choosing the site of the Project Experimental Farm detailed soil survey was carried out on a territory of 35 hectares, the soil map and map of the land capability classes of which were prepared at scale 1:1000. The above listed maps are enclosed to the Report /Appendix 6/. In order to raise the effectiveness of soil surveying and to do some simple field examinations and laboratory analyses a soil science laboratory was established which gives the possibility for basis and further training of technicians of the counterpart-staff in Yemen in soil science. Most of the laboratory equipments and chemicals were supplied by TESCO-VIZITERV-Enterprise. The analytical and technical balances and the water destillator were sent by FAO.

Electrometric and colorimetric determination of pH, determination of CaO_3, humus and nutrient content, measuring the moisture content, determination of some soil physical parameters and total salt content, examinations of qualitative chloride, sulphate and soda can be carried out in this laboratory. Out of these primarily the measuring of pH, of total salt content, and informative chloride sulphate and soda examinations have been done.

2.2 NATURAL CONDITIONS

Between the hilly areas at 2500-3500 m above sea level of the Arab Peninsula and the deep tectonic graben of the Red Sea stretches a long, narrow /30-40 km/, relatively flat, lowly situated subsided territory, that is the so-called Tihama Plain. The Wadi Zabid Project Area is located on this territory in the southern part of the Yemen Arab Republic, at the south-eastern tip of the Arab Peninsula /north latitude 14°10', and east longitude 43°15'/, 25 km east of the Red Sea. The Tihama Plain is cut by seasonal currents, wadis flowing from east to west, from the hills towards the sea. Out of these the most important one is the Wadi Zabid. The territory of the Project Area is about 25000 ha. On more than 20000 ha of the territory soil survey was carried out. The territory under consideration lies on both sides of the "Russian Road" /Hodeidah-Mocca junction/ south of Zabid, on a territory approximately 28 km long /east-west/ and 15 km wide /north-south/ surrounded by the Zabid-El Tuheita-Husseina-El Subaita-Mahwa El Turba-Ma'ath-Auqbi-El Maukher-El Habil-El Turaibah- Zabid lines.

3.2.1 Meteorology

Observations and data regarding the meteorological conditions of the area are scarce. Systematic observations were started in 1969 in the frame of the present Project /4/. According to the data of the literature /13,25/ of those territories of the Tihama Plain which are under similar natural conditions, the mean annual temperature is 30°C. The hottest month is June /34,5° C average monthly temperature/, the relatively coolest one is January /monthly average temperature 25°C/. The daily fluctuation of temperature is extremely big, especially on territories covered with scattered flora. The dominating direction of wind is north and north-west. Dust storms are frequent throughout the year but especially in August. The average relative humidity is 50-60 per cent. Its fluctuation contrary to that of temperature, is very significant: in the morning 80-95 per cent, in the afternoon 25-30 per cent. The annual rainfall is about 70-100 mm, its monthly quantity and territorial distribution have a marked fluctuation. The major part of precipitation /60-80 per cent/ falls in July and August, the number of rainy days is about ten. The mean daily evaporation of the free water surface is 9 mm /7-10,5 mm/ it totals up to more than 3 000 mm in a year.

The most important meteorological features observed at the meteorological station of the Wadi Zabid Project are as follows:

Monthly average temperature °C	33,9	33,5	31,9	29,3	27,8	25,5	26,5	26,8	29,2	31,0	33,1
Monthly rainfall mm x	45,4	15,2	30,5	0	0	0	14,9	0	0	1,7	0
			80,9	0	0	0	2,9	0	0	3,2	0
Monthly evaporation mm xx					219,0	220,1	179,8	204,4	275,9	354,0	396.-
Relative humudity %	55	54	63	59	64	65	66	69	66	54	50
	1969 July	Aug	Sept	Oct	Nov	Dec	1970 Jan	Febr	March	April	May

x= Zabid

xx= FAO Camp

[illegible].2 Geomorphology

Geomorphologically the territory of the Project Area is actually the enormous detrital cone on the Wadi Zabid. The surrounding hills and mountains forming the catchment area are of Tertiary material of volcanic origin /basalt, andesite, Mesozoic lodes lamprophyre, aplite, quarth, etc., Paleozoic granite, etc./. The Pleistocene detrital cone of the upper stream of the Wadi Zabid, widening out in the form of a fan after Kollah, joins the extensive and thick Tihama sediments in the area of Ma'ath. The volcanic base rock of the Tihama Plain along the faults parallel with the deep tectonic graben of the Red Sea subsided in the depth west of Ma'ath with dike-like breaking at the end of the Tertiary and at the beginning of the Quaternary and became the erosion base of the surrounding hilly and mountainous area covering some 5000 km². This depression was filled in by erosion and the wadis with an approximately 200-1000 m thick layer which is composed mainly of gravel, boulder-stones, and sand, in some places fine grained desert sand and transported loess-like interbedded matter, the formation of which had been simultaneous with that of the detrital cone. The coarsely textured material of the detrital cone is well fixed by a mixture of the fine desert sand and the silicic-gel debris of rocks of the hills. On the surface of the detrital cone at present a 1-10 m thick layer can be found containing yellow brownish transport loess-like matter, silicic gel proluvial and deluvial sediments, desert sand /in some places mixed with the gravel material of the detrital cone/, alluvial deposits /sandy silt, silt/ of the wadis and/ or of century-old flood irrigation. This forms the base material of the soil forming processes. At the same time in the wide beds of the wadis the coarse gravel is on the surface in certain places. The coarse gravel bed of the detrital cone is generally situated 0-9 m under the finer deposits on the territory of the Project Area and it serves as a natural drainage of the territory.

According to the macrorelief the Project Area is flat, the detrital cone slightly slopes towards the sea in east-west direction. Its altitute above sea level is 270-280 m at Ma'ath, 95-100 in the vicinity of the Zabid, 70-80 m at Tuhetia.

As against the relatively uniform macrorelief pattern of the territory under consideration its microrelief is rather varied, with an undulating mosaic-like lay-out. This is partly due to natural causes /formation of dunes, ravines of the wadis etc./ but mainly the result of human activities. The farmers inhabiting the territory have been striving for centuries to save as much water as possible during the uneven, unsystematic, sudden and rapide floods of the wadis by ingenious but simple means, without structures, pumps, machines, and technical equipments. A specific system of water management, water distribution and water rights has developed an and intricate system of high dams was built. These dams are frequently as high as 6-7 m and as a consequence of this the difference of level of the neighbouring fields is great their irrigability, water-cover, moisture-dynamism, their flora, and consequently their soils differ.

2.3 Surface Water hydrology

No lakes or seasonal surplus water occur on the territory. The only permanent water-course of the area is the Wadi Zabid. The water yield and the load of the Wadi Zabid is changing, the precipitation among the hills brings about intencive and short flood waves, whereas it contains hardly any water in the dry season /4/. Parallel with its water yield its suspended matter content changes significantly. Its quantity is 40-85 g/lit during flood waves and not more than 0,01-2 g/lit during low water. The suspended matter was silt, composed of relatively homogeneous particles /0,002-0,05 mm/. The bed load is only about 10 per cent of the load and its quantity is decreasing downstream, its material is mainly andesite, granite and basalt.

The eroding activity of the Wadi in the Project Area is rather insignificant /widening the river bed, washing away loess walls, etc./, but its sedimentation-forming influence prevails. The soil forming role of the bed load is negligible since it is confined to the not-cultivated wadi beds. The role of the suspended matter is much more important since its greatest part settles down on the surface of the soil of the irrigated territories of the Project Area and becomes an important factor of soil forming processes and crop cultivation. The thickness and material of the sediment layer on the area under consideration depends on the suspended matter content of the Wadi water and also on the way, the distance and the time the water is taken from the Wadi to the field, on the quantity of water and speed of its flow. Since irrigation water is in most cases not taken in canals but led directly on the field the eroding /wash-away and sediment forming/ effect of the water, which is big in quantity and quick in flow, must be taken into consideration. The horizontally layered profiles of the alluvial soils in the Project Area have been formed accordingly. In the course of irrigation the speed of the water used for flooding decreases to the minimum, and thus its suspended matter deposes in the form of a characteristic silt layer. These silt layers, can easily be perceived in the profiles of the alluvial soils in certain cases even on the surface. It is especially in microdepressions that 20-50 cm silt layer accumulates. Its particle-size distribution is generally as follows:

Loss in HCl processing	Size of particles in mm 1-0,25	0,25-0,05	0,05-0,002	0,002
% 13	-	1	58	28

Their permeability is low, they shrink and crack considerably. For this reason the thick silt-cover on the surface is undesirable but this silt layers in the profiles of soils of course texture, raise the water capacity and water holding capacity of the soils and favourably influence their water management properties and fertility. The recurrent silt cover may have a certain fertilizing effect. Concerning this the data of tests regarding nutrient content of a silt crust and of the neighbouring soil are given:

	Total N %	Aqua Regia soluble P_2O_5 %	Aqua Regia soluble K_2O %	Lactate soluble P_2O_5 mg/100 g soil	Lactate soluble K_2O mg/100 g soil	Total humus %
Silt	0,15	0,150	0,640	34	30	1,7
Profile 147.	0,06	0,060	0,400	40	35	0,9

There is no difference in the available P_2O_5 but K_2O content and especially the humus and N-content are significantly increased by the silt cover. Altough it is highly probable that the favourable effect of silt accumulation layers shows itself in the deflation control and in the improvement of water management properties.

The water of the Wadi Zabid is suitable for irrigation. According to the data of Table 8/ Appendix 5./ water samples No 42-44 the total water soluble salt content of the Na-HCO_3, Cl, SO_4 - type water is 500 mg/lit, its chemical reaction is slightly alkaline, its soda content is insignificant, its SAR value is low and the Na per cent is not high either. According to the USA classification of irrigation waters /7/ this water belongs to the C_2S_1 category /medium salinity, low sodium water/ and as such, it can be used for irrigation without any specific salinity control, especially if the drainage conditions of the soil are satisfactory and if the crops grown here are not too sensitive to salt /or Na/. The quantity of the residual sodium carbonate is in every case under the 1,25 mEq/lit threshold value: 0-0,6 mEq/lit.

Wadi water	Dry residue	EC_{25^oC}	pH	CO_3^{2-}	HCO_3 g/lit	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
Wadi water	0,47	0,74	8,0	0,01	0,21	0,08	0,09	0,04	0,02	0,09	0,01
Water of irrigated field	0,47	0,75	8,1	0,01	0,22	0,09	0,09	0,04	0,02	0,10	0,01

	Na %	SAR	Nmg/lit	Type of water
Wadi water	47	2,7	4,0	Na- HCO_3, Cl, SO_4
Water of irrigated field	48	2,8	2,0-4,0	Na- HCO_3, Cl, SO_4

These results of laboratory analysis pertain to samples taken during low water periods and so during flood periods the chemical composition of water is even more favourable: its salt content and Na % are lower. The soluble salt content of the water does not actually change while being led from the wadi to the field /Appendix 5, Table 8, water samples No 36-41/. The conditions of the present irrigation practice, the favourable natural drainage /slope towards the sea, water table in the gravel layer, etc./ prevented salt accumulation, and alkalinization, the big quantity of flood irrigation water provides a good leaching effect. But in the future, under the conditions of an up-to-date irrigation practice applying far lower quantities of water this leaching effect - especially in the case of soils of lower water permeability - will decrease, and transform into moisture migration. Under such conditions unfavourable salt accumulation and alkalinization processes may take place as a result of intensive evaporation under hot and dry climate /perhaps only after a few years of irrigation/. For this reason the control of the water regime and salt dynamism is of primary importance. To realize this profiles 8, 9, 12 and 13 on the territory of the Experimental farm give very good possibilities since these soils are to a certain extentsalt-affected at present, too and in the area of the farm different up-to-date irrigation methods are being tested. The examination of this should be the most important task os the small soil science laboratory established here since facilities are available and the data obtained can be used not only for the Project Area but they can be successfully utilized for the development of irrigation systems of the other wadis on the Arab Peninsula as well. The total N-content of the wadi water is about 4 mg/lit consequently its nutrient content should not be neglected either /calculating with 500 mm water dose it totals up to 20 kg N/ha/.

2.2.4 Ground-water hydrology

Earlier data on the ground-water conditions of the territory under consideration are hardly available. Accordin ; t. the data of measurings the average depth of water tal e in the Project Area is 7-33 m, the water table is in most cases in a gravel layer, and it slightly slopes towards the sea. Undoubtedly the main sources of the water supply are the precipitation running down the uncovered barren hillsides and infiltrating into the soil through the debris-cone the water of the Wadi, percolating through the gravel bed and the irrigation water. Quantitatively the first two sources are of importance. As the percolating water touches mainly coarse skeletal parts and deposits and only for a short time, the chemical composition of the ground-water /Appendix 5. Table 8, water samples No-1-35 and 45-57/ differs from the Wadi water to a negligible extent. And since the ground-water is in most cases in a gravel deposition layer there are not local differences either in its chemical composition, although its salt content and Na % is slightly increasing from east to west. The average chemical composition of the ground waters is as follows:

Kind of analysis	Result	
dry residue	0,50-0,70	g/lit
electrical conductivity	/E /: 0,80-1,00 mmhos/cm	
carbonate	0,01-0,02	g/lit
hydrocarbonate	0,25-0,35	g/lit
chloride	0,07-0,09	g/lit
sulphate	0,07-0,09	g/lit
calcium	0,03-0,05	g/lit
magnesium	0,03-0,04	g/lit
sodium	0,09-0,10	g/lit
potassium	0,01	g/lit
Na %	40-50	
SAR	2,5-3,0	
pH	8,0-8,2	
nitrogen	5-10	mg/lit

The intrusion of the salty sea-water under the surface is limited because of the specific structural set-up of the detrital cone /solid basement of the basin, both gravel layer and water table slope towards the sea/, and even in the case of a more intensive exploitation of the ground water by pumping irrigation from the tube wells there is no danger of its increase.

At present the ground-water has no effect on the soil forming processes, since, it is positioned at a considerable depth and stands in a gravel deposition layer: although the water table must rise significantly during the flood periods /which follows the periods, when the hilly catchment area is aboundant in precipitation/, but in most cases probably it doesn't reach the finer sediment layers. Thus no water can reach the top layers of the soil with capillary movement and thus no salt can be delivered there. The rise of the ground water is easily levelled off with the undisturbed flow of the ground water in the gravels due to the slope of the water table. Under the given conditions the ground-water will not have any pedological effect in the future either.

The utilization of the ground-water for irrigation /irrigation from wells/ is gaining ground on the whole Tihama Plain including the Wadi Zabid area. The experiences of the farmers up to now are very favourable, the vegetation of the irrigated land is rich, fresh-green, the data given in Table 8. Appendix 5, are warning, as the chemical composition of the ground water according to the classification of irrigation waters is not expressly favourable. The total soluble salt content of the waters belonging to the $NaHCO_3$ type may be as high as 700-750 mg/lit., and their Na % 50-55 %. For this reason, although the chemical reaction of waters is only slightly alkaline, the residual sodium carbonate content is also lower than the 1,25 mEq/lit. threshold value, the SAR value is also low, in spite of this, their utilization may result in alkalinization /salinization after a few years of irrigation. This took place in the surroundings of profiles 17 and 18, where salt accumulation and alkalinization have started - probably as a result of two and six years of irrigation from the wells respectively /Appendix 5, Table 8, water samples 6. and 2/. According to the USA classification of irrigation waters /7/, the waters belong to the C_2S_1 medium salinity - low sodium water /and C_3S_1/ high salinity - low sodium water/ categories, thus they can be used only for the irrigation of crops not sensitive to salt, grown in soils of high permeability, on territories being under good drainage conditions, and observing the necessary regulations. The danger is increased by the fact that in the case of irrigation with well-water, due to the expenses of the exploitation of water, smaller water doses are applied, which have practically no leaching effect. The problems with the quality of water arise primarily in the western part of the Project Area /in the vicinity of Tuheita/. This may have two causes: the ancient fossile sea sediments increase the salt content, or /and this is more likely/ the waters filtering through the thick, fine textured sediment layers of the Project Area become enriched in salts on their way. In all probability the increased exploitation of the ground water resources, the increased supply of the ground water with Wadi water /impounding, under-surface storage etc./ would probably result in the favourable change of the quality of the water. For this reason tube well-irrigation can be recommended to be used primarily on soils of high permeability of loose coarse texture, on territories under favourable drainage conditions, controlling the irrigation water and the irrigated soils continuously and systematically. The Soil Science Laboratory of the Project could in this respect as well give data for the suitability of the ground water resources of the whole Tihama Plain for irrigation, and through this it could help to outline the possibilities of the agricultural development of the area.

It should be noted here that these data justified the hypothesis which explained the beneficial effect of the well waters /promoting the growth of rich and fresh-green vegetation/ with the N-content of waters. The ground-water in the Project Area has an avarage 5-10 mg/lit. N-content. This value is as high as 20 mg/lit. in certain places. Calculating with an irrigation water rate of 500 mm, the quantity of N totals up to 25-50 kg/ha, which is rather significant in case of soils deficient in humus and nutrient content, even if the evaporation and leaching loss is considerable. This is the only artificial N-supply in Yemen at present.

2.2.5 Vegetation

The natural vegetation of the Project Area can be found only in the non-cultivated desert areas. It is scattered and has a limited effect on the soil forming processes. Regarding the type of the vegetation the greatest part of the territory belongs to the Somali-Arab vegetation formation of the tropical deserts. Its minor part belongs to the Somali-Yemen formation of xerophyte arborescent-bushy-shrubby vegetation of dry tropics. The characteristic representative of the grass vegetation are: Chrysopogon aucherii, Paspaladium desertorum, Coelachyrum praeflorum, Maerua grassifolis, Euphorbia sp., etc., shrubs are represented by Helitropium bicolor, Croton cliffordii, Olea chrysophylla, Tarchonantus camphoratus, Juniperus procera, Calystegia sepium and soldanella; cactaceous plants, Lactarius volemus, Euphorbia sp., etc., among arborescent plants Acacia asak, mellifera, spirocarpoides, and trotilis; Cammifora opobalsamum, Pistacia sp., Tamariscus sp., Rhododendrum sp., palms, etc.

The most important crops grown on the irrigated and cultivated lands are: among cereals the Sorghum species /durra/, Pennisetum species /duha=/, on territories evenly supplied with water; maize, among leguminous plants cowpea /digira/, among industrial plants the local perennial and American one-year varieties of cotton, the oil-seed sesame, among vegetables radish, carrot,cabbages, tomato, capsicum, lady's finger, garden egg-plant, pumpkin, cucumber, melon, onion, lettuce, molochia, among fruits banana, date, mango, papaya and cactus-fruit. The characteristic weed-vegetation of the above listed plants has also developed on the vultivated lands.

Although the root system of the cultivated crops, especially that of the rich durra stands produce a significant quantity of organic matter in the soil, but this quantity of organic matter rapidly decomposes under the given climatic condition, and it has a limited effect on the formation of the humus layer of the soil. But irrigation and vegetation play and undoubtedly important part in the chemical weathering of the parent materials, anf for instance in the migration of the calcium carbonate content of the soil profile.

Chapter 3

THE SOILS

3.1 SOIL FORMATION, MORPHOLOGY, CHEMICAL AND PHYSICAL PROPERTIES

Under the given natural conditions the conditions of the soil formation are very limited. The soil-climate is extreme: the soils are dry and hot /the surface layers often warm up to 60-70°C/. The precipitation falling unsystematically during the summer months in the form of rapid showers make only the thin surface layer of the soil wet for a short time, but the major part of the soil profile remains constantly dry /dead horizon/. Physical weathering is strong, primarily caused by the significant daily fluctuation of temperature, and specific geochemical system of the territory developed.

Due to the aridity, the vegetation is scarce in certain places totally missing. The root volume of thorny xerophyte herbaceous plants, of the bushes and short trees having deep roots, is small, their organic matter production is insignificant, it is distributed evenly in the soil profile. No significant clay or $CaCO_3$ migration takes place in the profile either. Thus the profile of the developed soils is homogeneous, no genetic horizons can be percieved in them, and only layers of different texture diversify them. Wind erosion played an important part in the settling of the latter layers above each other. It is wind that forms the characteristic dune formations of the deserts, e.g. on the territories to the west, north and east of the Project Area. The so-called pseudo-sand-dune formation is also characteristic of the territory. They can be met at the marginality of nearly all deserts, on territories more or less blown up with sand. The pseudo-sand-dune behaves exactly like coarse blown sand /even strong wind does not lift it high, dams of even 50-60 cm height give protection against the damage of sand storms etc./, but its granules are not coarse, elementary particles, but silt aggregates of similar size cemented with $CaCO_3$. This is the explanation for the relatively high quantity of the silt fraction of the deflational sand-covers among the data of the particle-size distribution determined after HCl processing. /Table 3, Appendix 5/.

Apart from dune-formation, the wind played and does play an important role in the transport, shifting and stratification of fine textured weathering products as well. Thus the loess-like sediment layer is primarily of aeolian origin which is as thick as 5-8 m in certain places of the Project Area and serves as the parent material of the formation of tropical arid brown soils on the major part of the cultivated area. This sediment matter exhibits macro- and microstructure quite similar to that of loess: it forms steep walls /where the beds of the wadis cut deep into the loose material/, it is porous, soft, and spherical lime concretions can be found in it, etc. The greatest part of its material originates from the rock material - weathered to different degrees - of the surrounding hills, which was transported to the territory under consideration by the wind. Probably, human activities also played a part indirectly in its accumulation since, the fine aeolian sediment of irrigated vegetation covered, wet soils could not easily be blown away by successive wind storms.

Sediment formation, <u>fluviatile sedimentation</u> is a very important geogenetic process in the formation of soils, since a considerable part of the Project Area /about 30 %/ is covered by different alluvial soils. Actually the whole area under consideration is the detrital cone of the Wadi Zabid. The early phase of sedimentation is the settling of the coarse gravel material of the drifted matter. In the past this activity on the given territory had been much more intense than it is at present, and probably it effected much more extensive territories /the floods of the Wadi are now lower than in the past, as part of the hilly catchment area was terraced where significant quantity of water is retained for the water supply of the cultivated crops. The lines of the ancient wadi beds even their geological history can be traced back on the basis of the analysis of the deposition conditions of the gravelbeds located under the present surface or right on the surface. Today this activity is restricted to the main bed of the Wadi Zabid and it has no direct agricultural importance.

The sedimentation of the suspended matter is much more important. In this respect the following processes and their effect can be observed on the territory:

1. On territories regularly effected by the Wadi water in the past/ or by irrigation water originating from the wadi and led there by human activity/but have not got water cover and consequently sediment cover for a long time, soil formation started on the accumulated alluvial sediment /eg. on territories irrigated from tube wells and protected against deflation/, but in most cases the territory was blown with sand.

2. On territories where Wadi water / or irrigation water originating from it/ still reaches the territory, but neither its eroding nor its sedimenting effect is significant, soil forming processes slowly start on the fluviatile or aeolian sediment.

3. On territories which are reached by not only the Wadi water /or irrigation water originating from it/, but by its considerable sediment matter, soil forming processes are limited by the recurrent silt covering. Similarly,no soil forming process can start in parts where the eroding, wash-away, drifting-away effect of the water prevails.

It has to be noted here that the major part of the sediment formation in the Project Area was not brought about by the Wadi but by the practice of the flood irrigation and thus the deposits occuring here are not the typical alluvial, but so-called "irrigation deposits". /3/

If there is no deflation, erosion, or sedimentation on the territory and the growth of the plants is guaranteed by the artifical water supply, a slow soil forming process starts: slight humus accumulation and formation of structure in the root-zone, certain carbonate leaching out and accumulation under the root-zone. All these factors are not sufficient to form characteristic soil horizons and soil profiles.

Although the extent of salt-affected soils is not great, attention has to be given to the process of salt accumulation and alkalinization. As it was demonstrated by the description of the climatic conditions of the Wadi Zabid area the constant high temperature and the low humidity result in a potential evaporation and the quantity of precipitation is insignificant. The strongly negative water balance promotes the rise of the concentration and accumulation processes. The water table is located at a considerable depth under the Project Area, the ground water stands in the gravelly sediment layer and it does not generally reach the finer sediment layer even in the case of maximum water table. Thus the water and salts cannot reach the soil layers above the water table with capillary movement. The slope of the water table towards the sea is quite significant and since the ground water gets fresh water supply from the debris-slopes of the food of the mountains and from the Wadi and from the irrigated lands, its flow is significant and no danger of the intrusion of the salty sea water. These facts guarantee that no salinization from the ground water will take place, not even in case of increasing the irrigated territories:

a. irrigation from tube wells lowers but in no case raises the water table
b. the same applies to the modernization of irrigation with Wadi water, retaining the water of the Wadi decreases the supply of the ground water with Wadi water, and replacing flood irrigation with up-to-date methods of irrigation /decreasing the infiltration loss/ lowers the supply of ground waters on the irrigated territories.

The possibility of the salinizing effect of irrigation water cannot be ignored in spite of the good natural drainage conditions of the territory /coarse-textured soils, gravel subsoil, deep ground water table/. This is justified by the salinization of the surroundings of profiles 17 and 18, the salt and exchangeable Na^+ accumulation in the deeper layers of the profiles 8, 9, 12, 13 on the territory of the Experimental farm, etc. The salinizing effect of irrigation can be realized in two ways:

a. through promoting local weathering and the accumulation of the products of weathering in site
b. through accumulating the salt content of the irrigation water

If it is consiered that the material of the soil of the main part of the area is composed of partly weathered Na-containing minerals /olivine, orthoclase feld spar/ of basic volcanic rocks/ andesite, basalt/, it is easily comprehensible that irrigation water promoting weathering directly or indirectly/faciliting the growth of vegetation/ and accumulating the products of weathering in site may bring about the increase of the salt and/ or exchangeable Na^{+} content of the soil and alkalinization and salinization there. Even if the quality of the irrigation water is excellent. And this is not the case here as it was shown in detailed description of the hydrological condition - and sometimes not only the water of the tube wells but that of the Wadi too, are not of excellent quality. And still extensive territories after a few centuries of irrigation did not become salt-affected, this can be explained by the fact that the quality of water during the flood periods of the Wadi /when most of the irrigations take place/ is good, and on the second hand the large quantities of flood irrigation water were sufficient for leaching the accumulated salts. This is not guaranteed by the up-to-date practice of irrigation /low irrigation rate for flood irrigation, other ways of surface irrigation/ which means the rational water balance and economic use of water/ distributing smaller doses on larger territories/. For this reason the constant quality testing of irrigation waters and irrigated soils is vital when modernizing the irrigation system /at least in the early period of gaining experiences/. If it is not done so irreversible damage may be caused by extending the irrigated territories. But establishing a proper control system, irrigation /mainly from tube wells with ground water/ can be carried out on more and more extensive Yemen territories of the Tihama Plain.

Besides natural conditions, human activities had an important and sometimes decisive influence on soil forming processes in the Project Area; irrigation, building of canals and dams, growing crops, protection against deflation, etc. The result of irrigation was that instead of the desert soil, which is a characteristic zonal soil type of territories, under similar climatic conditions, tropical arid brown soils, characteristic of more humid climate, developed, the material of which is for instance, far more weathered. The differences in the frequency of irrigation, regularity, intensity and as a consequence of this the differences in the vegetation are reflected in the divergence of the soils, too. Dam-system built up for water regulation and smaller dams for protection against deflation make the soil cover more heterogenous and complex, as well as mosaic-like. The eroding effect of the flooding water is also a significant factor.

Common properties of the soils found on the territory of the Project Area as follows /excepting the salt affected soils/:

/1/ Chemical reaction of the soils is alkaline, the pH ranges between 8,0 and 8,4 /Table 2, of Appendix 5/. The reason of the relatively high pH value is partly the $CaCO_3$ content of colloidal dispersion in the soils, partly the Na-content of the weathered feldspars of volcanic rocks. The chemical reaction is similar in the whole soil profile indicating only an insignificant fluctuation. Because of the strongly alkaline chemical reaction alkali hazard has to be taken into consideration.

/2/ The soils are calcareous, their $CaCO_3$- content varies between 1.5 and 1.7 per cent averaging around 5 per cent /Table 2, of Appendix 5/. The $CaCO_3$- content of the individual layers often differ but is not the consequence of soil forming processes /leaching Ca-redistribution/, but it is the result of the differences of the original $CaCO_3$- content of the deposits. The main reason of the small amount of $CaCO_3$-migration is that the CO_2-production of the roots, and thus the CO_2-concentration of the soil solution and soil air is small. The majority of the $CaCO_3$ is present in the soil in fine distribution, e.g. the lime cutans covering with white coat the structural elements of the soil layer under the cultivated horizon or the pseudomycelium developing in the canals of dead roots. Lime nodules, however, occur only rarely.

/3/ The water soluble salt content of the soils is low. The total salt content of the saturated soil paste is 0,1 per cent, the electrical conductivity of the saturation extract measured on C^o 25 is 1 mmhos/cm /Table 4, of Appendix 5/. The quantity of soluble salts in 1:5 water extract is 1-2 mEq 100 g soil, among the cations, besides Na^+ /0,2--0.9 mEq/ there is a considerable quantity of Ca^{2+}

/0,1-0.5 mEq/, Mg^{2+} is less/ 0,1 mEq/ and only a small quantity of K^{+} /0,1 mEq was found/ Table 5, of Appendix 5.

The cation exchange capacity of the soils /CEC/ depending on the particle-size distribution is 10-30 mEq/100 g, the extent of Na^{+} -saturation /ESP/ is small / 7 per cent /Table 5, of Appendix 5/.

/4/ Humus content of the soils is very low, it is below one per cent, generally 0,4-0,5 per cent /Table 2, of Appendix 5/. The cause of the low humus content evenly distributed in the soil profile is the scarce vegetation producing a small quantity of roots, and that organic matter produced under the richer vegetation of the irrigated areas is quickly decomposed under the given conditions. The soil has no other sources of organic matter. The manure of the scarce livestock is not used for manuring either, and the organic matter producing effects of repeated silt coverages have been only partly proved by our tests. The low organic matter content is also one of the causes that the structure of the soils is generally not well developed, the soil surface becomes silted after the rains and irrigations and subsequently forms cracks and soil crust while drying, the water capacity of the soil, the infiltration and permeability is less than it could be expected on the basis of the particle-size distribution.

/5/ N-content of the soils is also low, 0,01-0,04 per cent and changes generally parallel with the humus content. Thus the C: N proportion is around 10 /Table 2, of Appendix 5/. It is remarkable that despite the low N-content the vegetation of the irrigated territories does not show symptoms of N-deficiency, moreover it is often bright green, rich and has abundant growth and, according to some of our experimental experiences, the one-sided N-fertilization /30 kg N/ ha urea/ causes lodging. Whereas in other experiment executed within the frame of the Project, 30 kg/ha N active substance of urea and ammoniumnitrate has had a rather favourable effect on the development of sorghum, maize and millet. Presumably - as other authors have also reported about this fact-in some place the N-content of irrigation water that is not negligible and easily available, covers, the comparatively low nitrogen needs of the plant species grown in Yemen at present as in the case of using big doses of irrigation water this quantity is significant /counting with 500 mm water dose it is e.g. 25-50 kg N /ha/. There is no artifical fertilization in Yemen at present moreover, all kinds of experiences in this matter are completely lacking. But it is obvious that in the case of up-to-date agricultural production, the introduction of suitable species and harmonious use of nutrients the adequate N-supply of the plants will be one of the key questions, as under the present humus conditions natural N-release cannot be expected and with the decrease of the irrigation water doses this N-source will also decrease.

/6/ Aqua regia soluble P_2O_5-content of the soil is low it is between 0,6-0,28 per cent but generally under 0,1 per cent /Table 2, of Appendix 5/. Its distribution in the soil profile does not show any definite tendency. The very high values of profile 165 are remarkable and they can only be explained by certain local accumulation and cannot be taken as characteristic of larger territories, Aqua regia soluble K_2O-content is moderate, fluctuating between 0,3-0,6 per cent /Table 2, of Appendix 5/. Its distribution in the soil profile is even, there are no significant differences among the values measured in the case of soils with different texture.

/7/ The soluble P_2O_5-content - defined by Al-method /Egner-Riehm-Domingo/ of the soils in the Project Area is remarkably high, ranging between 30-90 mg/100 g soil. In some cases it is very close to the "total" aqua regia soluble P_2O_5 quantity. In the upper layers of the soil the values measured are usually higher, P_2O_5-content generally decreases with depth. Though according to the European limit-values these soils are considered to be well supplied with phosphorus without exception, but is should be taken into consideration that under the present conditions the AL-method measures also part of the Ca-silicate-phosphates, the aluminium and Fe-phosphates that are found in the soil, though these can only be taken up by the plants to a limitedextent. As the soils under consideration have never received artificial P-supply, it is possible, that - despite the high P_2O_5 values measured - a favourable phosphorus - effect will be experienced particularly in the case of adequate N-supply. But analytical data regarding this are not available.

/8/ It can be stated on the basis of the elemental analysis of the soils /Table 6, of Appendix 5/, that in the various layers of the different soils the element composition of the soils is rather similar. The quantity of SiO_2 is 45-50 per cent, Al_2O_3 - content is 13-18 per cent, the quantity of CaO is 4-9 per cent, MgO is 3-8 per cent, the amount of K_2O is 1,2-2,0 per cent, the quantity of Na_2O is 0,1-1,5 per cent, that of P_2O_5 is 0,2-0,4 per cent. This refers to the similar origin of the soils and parent material and supports our geological observations and examinations of the fine structure. It should be noted here, that the particle density of all the soils examined is remarkably high: 2,8-2,9 /Table 3, of Appendix 5/. This is caused by the significant quantity of magnetite present in the material of the soils, therefore the Fe_2O_3-content measured is rather high. Al_2O_3- content is also significant /aluminium silicates with different degrees of weathering and also the MgO content /Al-Mg silicates/. On the other hand the quantity of SiO_2 is comparatively low.

3.2 THE SOIL MAP

The classification of the soils found on the territory of the Project Area is summarized in Table I, Appendix 3, Table II of Appendix 3 indicates the territorial extension of the individual units of soil classification whereas in Table III of Appendix 3 it is indicated what kind of laboratory examinations were carried out on the different soil profiles. The data of the laboratory examinations are given in Tables 1-10 of Appendix 5 as it has already been indicated in the introduction. The geographycal extension of the soils is indicated on the soil map at a scale 1:20000.

A more detailed description of the occurring soils is given below.

3.3 DESCRIPTION OF THE SOILS CLASSIFICATION UNITS

Alluvial soils /1/

According to the classification of the FAO/ UNESCO World Soil Map: Calcaric fluvisols /Jc/, /6,19/. According to the 7th Approximation 1960: Entisols-Orthic orthustents, and 7th Approximation issued in 1966 /17/. Entisols - Calcaric torrifluvents.

On the territory of the Project Area alluvial soils are found in the response regions of the main /Wadi Zabid/ and the canals Canal al-Ain, Canals Al-Bira, Canal al-Buney, Canal al-Mawi, Canal al-Jusfi

Canal al-Rayyan/and on the "lower part" of the from field-to-field irrigated territories where the erosion deposit of the flooding water is sedimented. Raw /young/ alluvial soils cover also the islands of the actual Wadi-bed and its terraces I and II. In the southeastern parts of the Project Area older gravel alluvial soils are found often with shallow soil profile that were developed in the past due to more intensive wadi-activities and from the upper portion of the huge detrital cone of the Wadi Zabid. /These soils from and extremely big territory beyond the Project Area up to the slopes of the foot of the hills, they are covered by scarce, scrubby vegetation and are only less suited for agricultural cultivation/.

The common characteristic of the alluvial soils is that because of the seasonal floods and repeated sedimentation soil forming processes could not begin, thus the specific diagnostic soil horizons do not occur, or at the most, a pallid A-horizon can be found on the surface, with low organic matter content. Different layers stratified one after the other in the profile - having different particle-size distribution and $CaCO_3$ - content- derive from the transported material of the Wadi, or more often from the sediment of the flood irrigation water, thus the soil can be considered as

"irrigational soil" /3/

The alluvial soils are generally fertile, their fertility is primarily determined by their water management properties which mainly depend of their texture and stratification. Therefore their lower units of classification have been chosen as follows:

Calcareous shallow alluvial soils /1.1/

The original gravel bed of the Wadi is only covered with thinner sediment layer, moreover, gravel occurs sporadically on the surface and /or in soil layers near the surface. The gravel layer near the surface limits the development of roots and also the water capacity of the soils, it increases the infiltration losses and makes the soils particularly sensitive to aridity /drought-sensitive/.

The fertility and capability /utilization/ of these soils is primarily defined by the depth of the occurence of the gravel layer, therefore this factor consitutes the basis of further classification /see Table I. of Appendix 3./. The morphological description of profile 2 is presented here as an example.

It can be observed in general that soils with gravel layer near the surface /1.11, 1.12/have coarser texture /coarse and moderately coarse - textured soils/, whereas soils, the gravel layer of which is deeper, /1.13/ are medium - textured.

Mapping unit No.	Silt %	Clay %	Hygr.moist %	SP	CEC mEq/ 100 g	Field capac. mm/50 cm	Infiltr. rate mm/h	Perme- ability mm/h
1.11,1.12	20-25	10-15	2,0-3,5	30-40	15-20	-	-	-
1.13	40-50	20-25	3,0-5,0	40-50	17-25	180	30	20

Calcareous deep alluvial soils /1.2/

In their profile there is no gravel layer to the depth of 150 cm. Their fertility and water management properties are partly influenced by their particle-size-distribution partly by the number and the sequence of the silt belts to be found in the profile /thickness, distance from the surface, etc./. Whereas surface silt cover is disandvantageous from the point of agriculture /cracking, soil crust formation on the surface, hard cultivability, etc./, silt belts stratified into alluvial matter with coarse texture improve their water capacity, and water regime of the soils. But silt belts bedded in medium-textured soils are disadvantagous as they decrease the infiltration rate and permeability.

The morphological description of profile 102. is presented here as an example.

The main soil-physical and water management parameters of the soils are as follows:

Mapping unit No.	Silt %	Clay %	Hygr.moist %	SP %	CEC mEq 100/g	Field capa-city mm/50 cm	Infiltr. rate mm/h	Perme-mm/h
1.21	20-25	10-15	2,5-3,5	30-40	15	-	-	-
1.22	25-30	10-15	2,5-3,5	30-35	15	130	50	20
1.23	35-50	15-20	3,0-4,5	35-45	15-20	150	40	15-35
1.24	45-55	30-35	4,0-6,0	40-60	25-30	-	-	-

Silt accumulation on the surface /1.25/ occurs in micro-depressions, in the deeper parts of irrigated fields and only rarely extends to bigger regions. In these depressions silt layer may reach quite often a thickness of 30-60 cm and make plant cultivation difficult.

Soils affected by wind erosion /2/

Such soils occur in the western part of the project Area extending into the desert, between Zabid and Tuheita, and Zabid and El-Tureibah, and also in the south western regions bordering the desert. Here a thinner or thicker layer of desert sand has covered alluvial soils, or tropical arid brown soils, or the deposit layers differ often quite considerably/ in the particle size distribution, in the $CaCO_3$-content , in their origin, etc./. The wind blown sand mantle is in some cases coarse, desert dunesand, but more often the so-called pseudo-sand dune/silt-aggregate cemented with $CaCO_3$ of the size of sand granules/. Fertility of the soils in this region is primarily determined by the thickness of the sand cover, and by the extent of deflation, but also by the texture of the buried soil. The detailed classification of the soils grouped under this heading was carried c t in accordance with these facts. The field morphological description of profile 49 is given here as an example. Some soil-physical and water-management parameters of the soils are as follows:

Mapping unit	Silt %	Clay %	Higr. moist %	SP %	CEC mEq/ 100 g	Field capa-city mm/ 50 cm	Infiltr. rate mm/h	Perme-ability mm/h
2.21	35	15	2,0-3,5	30-40	10-15	140	60	20-35
2.22	35-50	15-20	2,5-4,5	35-45	18-23	170	50	17
2.31	-	-	-	35	-	-	-	-
2.32	40-50	15-20	2,0-4,0	35-45	18-23	-	-	-

In the case of thick sand cover /2.1/ the characteristics of the sand, in the case of thin sand cover /2.3/ those of the buried soils become dominant. Therefore the territory was characterized by the buried soil if the sand cover was thinner than 10 cm. Deriving from the nature of wind erosion the sand cover observed during the field study naturally can change quite quickly and markedly, therefore it is rather intended to express with the classification employed here the degree of the deflational activity and also its intensity.

In the northern region of the Project Area, between Zabid and El Turaibah such soils occur to a smaller extent which have a layerof intensive lime accumulation, though it is not cemented into hard pan /2.4/. But their characteristics are only partly influenced by this phenomenon.

Tropical arid brown soils /3/

According to the classification of the FAO/UNESCO World Soil Map: Haplic Xerosols /Xh/ /6,19/. According to the 7th Approximation: Aridisols - Orthic and Mollic Camborthids /17./.

They cover extensive territories. South on the Zabid, between the alluvial soils of the wadis and the territories damaged by wind erosion, primarily their varieties with coarse texture /3.1, 3.2/ occur, in the region of the Al-Garrahi and Al-Turaibah it is their medium textured varieties /3.3/ and in the eastern part of the Project Area/ on the two sides of the alluvial territories of the Wadi/ the variety with fine texture prevails /3.4/.

In the regions, where the erosion or sediment forming activity of the Wadi or the flood water and the effects of wind erosion have no consequence or they are negligible, but artifical water supply facilitates the existence of richer vegetation, a rather modest soil forming process has begun. This process is not accompanied by a major formation of humus and accumulation as the organic matter of the dead roots quickly decomposes. Structure forming is not noticable either, and no significant clay movement and $CaCO_3$-migration can be observed in the profile. Therefore no sombric, or melanic A-horizon develops, only a more or less developed pallid A-horizon occurs /Ochric epipedon/: with pàle colour and low organic matter content. No salic, calcic, or gypsic horizons develop either, at the most a weakly developed cambic B-horizon appears /transition layer, with a thin lime coatings/. As this initial soil formation itself only takes place under irrigated conditions the tropical arid brown soils found on the territory of the Project Area can be considered as the artifical outcome of the century old human activities /Irrigational soils /3/. Under natural conditions /without irrigation/ this soil type can only develop on territories with a climate of more precipitation.

As soil formation is at its early stage the parent materials mainly characterize the soils. This in this case, is chiefly of aeolian origin a loess-like matter, colluvial-proluvial sediment or alluvium.

The fertility of the tropical arid brown soils occurring is primarily determined by their water management properties as in other respects they are similar. Water management properties on the other hand are determined by structural conditions and texture. On the basis of the latter feature the tropical arid brown soils were separated and divided into the following categories:

Coarse and moderately coarse-textured soils /sand, sandy loams and loamy sand/ /3.1/

are found on a relatively small territory. Their permeability is good, but their field capacity is low.

Their fertility is moderate.

Medium-textured soils /loams, silty loams/ /3.2/

cover extensive territories. Their permeability and field capacity is good. Their great potential fertility is by no means well exploited. Their present fertility can be successfully increased by introducing a more up-to-date agro-technique fertilizers, suitable soil cultivation, intensive species, etc./ and irrigation systems.

The morphological description of profile 147 is given as an example in Appendix 4.

Moderately fine-textured soils /clay loam, silty clay loam with less than 35 % of clay, sandy clay loam /3.3/.

are found extensively mainly in the eastern part of the Project Area. These soils have a fairly good permeability and field capacity. Their fertility can be characterized by the same features as given at the previous type /3.2/. But their soil cultivation may cause difficulties.

Fine textured soils/clay, clay loam, silty clay loam with more than 35 % of clay /3.4/

are found in the eastern part of the Project Area. /The tendency can be generally observed that the soil texture becomes finer from west to east/. These soils have moderate or low permeability and high field capacity. Their potential fertility is moderate. Their irrigation requires great care/ suitable doses of water, even distribution of water, over-irrigation should be avoided/, their soil cultivation is difficult.

The morphological description of profile 227 is given as an example in Appendix 4.

Some soil-physical and water management parameters of the above categories are as follows:

Mapping unit No.	Silt %	Clay %	Hygr.moist %	SP %	CEC mEq 100 g	Field capa-city mm/50 cm	Infilt. rate mm/h	Permea-bility mm/h
3.1	25-35	15-20	2,5-3,0	30-40	15-20	130	50	25
3.2	35-55	15-30	2,7-4,5	35-50	18-28	150	40	18
3.3	40-55	25-35	4,0-5,5	45-55	23-30	170	35	15
3.4	35-45	35	5,0	50	28-32	180	25	8

Salt affected soils /4/

Salt affected soils only occur in the westernmost parts of the Project Area in the region of the Tuheita, on the territory which is characterized by profiles 17 and 18. But a moderate salt accumulation and alkalinization can be observed on the territory of the Experimental farm characterized by profiles 12 and 9 and also in the deeper layers of profiles 8 and 13. As the territorial extension of salt affected soils is small, they are important as they call attention to the potential possibility and hazard of salt accumulation and alkalinization and this has to be taken into consideration by all means in the future at the agricultural utilization and irrigation of the region.

As it has been stated at the description of the soil forming processes the possibility of salinization and alkalinization from the ground water is partically non-existent on the territory of the Project Area. It is also proved by fact that on the territories where thereis no irrigation no salt accumulation and alkalinization can be observed. The major sources of the salts are/or the accumulated products of local weathering and the irrgation water. Here the effects of the two factors are realized jointly:

a. Irrigation, the repeated seasonal processes of moistening and drying, the richer vegetation, the more intensive growth of roots, the bigger CO_2-production, etc., all result in the intensification of weathering and particularly the chemical one on the regions under consideration, which leads to the production of a certain. quantity of soluble Na-compounds and the appearance of Na^{+} ions in the solid and/or liqued phases of the soils depending upon the mineral composition of the given parent material of the soils/andesite, basalt, and olivin, ortholcase feldspars, etc./.

b. Irrigation water /either the water of the Wadi or ground-water/ also gives Na-salts, Na^{+} ions to the soils and often not of a negligible quantity. /Table 8, of Appendex 5/.

On the territories where Na-salts deriving from the above sources and the leaching of Na^{+} - ions through ground-water and their transport from the field are hindered, they accumulate and result in salinization and alkalinization processes. As the majority of the Project area has very favourable natural drainage conditions /soils of coarse texture, gravel subsoil, deep water table horizontal flow of ground-water/such accumulation processes have not occurred under the present practice of flood irrigation, using high dose of water because the leaching requirement of the soil is abundantly guaranteed by the big quantity of water. The situation is different if the drainage conditions of the profile are unfavourable /poor water permeability, impermeable layers in the profile etc./, or the quantity of water used is not enough for leaching of the accumulated Na-salts. In such cases specially on territories where the water accumulates debris from bigger regions, processes of salt accumulation and alkalinization can be observed. These unfavourable processes can be prevented by the improvement of the water management properties of the soils /deep loosening, growth of crops with deep roots etc./ by the even distribution of water and the continuous quality control of the irrigation water and irrigated soils. The morphological description of profile 17 is given here for the characterization of the saltaffected soils in the Project Area.

As it can be seen from the description of the profiles, in the profiles of the salt affected soils of the region, characterized by profiles 17 and 18, a B horizon /solonetz horizon/ with columnar structure can be observed, thus they can be classified according the Subcommision of Salt Affected Soils of the ISSS as "Alkali soils with structural B horizon" type.

These soils have a strongly alkaline chemical reaction, their pH value reaches and even exceeds 9/Table 2 of Appendix 5/. Their water soluble salt content is not high: total salt content measured in the saturated soil paste is 0.10-0,15 per cent, the electrical conductivity of the saturation extract on

^{o}C 25 is 1-1,5 mmhos/cm. The Na^{+}-content of the saturation extract is also low: 4-8 mEq/lit /0,2-0,3 mEq/100 g soil /Table 4 of Appendix 5/. The electrical conductivity of the 1:5 water extract is /EC 25°C/ 0,2-0,3 mmhos/cm, its salt content is low 1-2 mEq/100 g soil. Of the cations Na^{+} is dominant /1-1,5 mEq/, Ca^{2+} and K^{+} are insignificant. Of the anions HCO_3^{-} is dominant /1-1,2 mEq/ and the quantity of the chlorides /0,1-0,3 mEq/ and particularly of the sulphates is small /0,1 mEq Table 5 of Appendix 5/.

Contrary to the low water soluble salt content of the soil the salt-affected soils with 18-20 mEq/100 g cation exchange capacity are strongly saturated with Na, their ESP values reach and even exceed 20 per cent. The quantity of the water soluble salts is the highest in the deeper soil layers, the quantity of exchangeable Na^{+} is the maximum in the B-horizon. The texture differentation /illuvial B horizon/ that is characteristic of the solonetzes occurs primarily in the silt fraction. Their water management characteristics are unfavourable, available moisture content that can be utilized by plants is low, permeability is weak.

Profiles 9-12-13-8 of the Experimental farm have a decreasing tendency of salt accumulation and alkalinization in this order of listing.

In profiles 9 a significant salt accumulation can be observed, water soluble salt content increases with depth. The total salt per cent of the saturated soil paste is 0,2-0,5 %, the saturation extract has EC 1,5-6,5 mmhos/cm, the Na^+-content of the saturation extract reaches and even exceeds the 30 mEq/lit/1-3 mEq/100 g soil/. The 1:5 water extract exceeds EC ^{o}C 25 2 mmhos/cm, the quantity of salts in mEq 100 g soil exceeds 10. Of the cations Na^+ is dominant, whereas of the anions HCO_3^- dominates in the upper soil layers /with lower salt content/, and deeper/ with the increase of salt content/chlorides and sulphates occur in the biggest quantity. The ESP value in the upper soil is 6,6 per cent, increasing with the depth up to 20 per cent. The chemical reaction is only moderately alkaline and decreases with the increase of salt content.

In profile 12 salt content is the biggest at about one meter's depth: the total salt content of the saturated soil paste is 0,25 per cent, the saturation extract EC ^{o}C25 is 2,5 mmhos/cm, the Na^+content is 14 mEq/lit. The composition of the salts can be characterized by the tendency observed at profile 9. The Na-saturation reaches its 15 per cent maximum at 80-100 cm depth.

Na saturation is small in profile 13, a moderate accumulation of salts can be observed in the deeper layers /0,24 per cent - 2,2 mmhos/cm - 15 mEq/lit. On the other hand in profile 8 a mild process of solonetization can be observed ESP 13 per cent in the deeper layers, but the salt content remains low in the whole profile. Soils that are sodic and alkaline to varying degrees in the Experimental farm, offer good opportunities for collecting data for continuously observing the changes, of the salt dynamism and balance of the irrigated soils of the Tihama Plain. Such data do not exist at present, but to the survey of the agricultural potential of the Tihama Plain in Yemen, to the exploration of the possibilities of agricultural development and irrigation and to the forecast of the salt accumulation and alkalinization processes to be expected as the consequence of irrigation and also for the elaboration of the preventive measures, such information is indispensable.

Chapter 4

THE LAND CAPABILITY

4.1 LAND CAPABILITY CRITERIA

The survey of the agricultural potential and land capability of the region was executed is accordance with the regulations of the "United States Department of the Interior Bureau of Reclamation Manual, Volume V Irrigated Land Use, Part 2 Land Classification /24/". Thus, besides the direct soil factors /physical, water management, physicochemical, chemical, biochemical properties/ other natural factors /relief, its articulation and undulation drainage conditions, etc./ and certain economic points/ water supply and the facilities of distribution, cultivability, potential fertility, expected yield of the crops, etc./ have also been taken into consideration.

4.2 LAND CAPABILITY CLASSIFICATION

The geographical situtation of the land capability classes is indicated on the attached map at scale 1:20000. Soil types belonging to the individual land capability classes and their territorial distribution have been summarized in Table IV of Appendix 3.

Before giving the detailed description of the individual land capability classes it is necessary to state the following:

a./ On the territory of the Wadi Zabid Project Area irrigation has been carried out for centuries. The farmers have tried to retain the possible greatest amount of water during the times of the brief floods of the Wadi all without machines, structures and technical skill, and to supply the water to the plants. This effort has developed the specific practice of flood irrigation and the characteristic system of water rights, management, and distribution of water. The fundamental characteristic of this system is that canals are usually taking the water from the upper stream of the Wadi Zabid at Ma'ath or near to Mahwi Matea /ramification of canals/ aimed at leading the irrigation water to a certain place, then fields are irrigated by the so-called "from field to field" methods, when the irrigation rate is regulated by special spillways built up from bricks and cements, or by simply cutting the dykes through. The fields are surrounded by high banks, reaching the height of 7 metres, which can be called dams. If the level is further increased by adding more water, then the water reaches the upper "lands" through the opened dams spillways. Consequently, on the irrigated fields of the Project Area an intricate network of dams has developed and the difference of the level of neighbouring land is often rather considerable /depending upon the origin of its water/. On the other hand it means that turning the regions under flood irrigation culture into fields suitable for large-scale farming and up-to-date surface irrigation, would require extremely great land levelling work than is not only expensive but its economy is also a matter of dispute. This naturally does not mean than the irrigation practice of the regions discussed here could not be modernized /e.g. by the implementation of mechanized water lifting, distribution canals, or by the distribution of smaller quantities of water on bigger territories, etc/ but, no doubt, it represents a hindrance in the way of up-to-date large-scale farming. From this point the conditions are somewhat more favourable in regions /e.g. on the western part of the Project Area, etc./ which can be supplied with water from the Wadi to a rather limited extent and where the irrigation water is mainly obtained from wells. In these regions the fields are larger, there is no, or only a small difference of level among them and the dams are lower /often not serving water control but protection against deflation/.

b./ Under the given climatic conditions /high temperature and potential evaporation, few precipitation/ and irrigated conditions the potential salinity and alkalinity hazard prevail all over the territory of the Project Area, Processes of salt accumulation and alkalinization can only be avoided if the leaching of Na-salts deriving from the local products of weathering and/ or from irrigation water is artificially guaranteed. Therefore when introducing up-to-date irrigated cultivation and extending the size of irrigated territory it is necessary to control continuously the water used and the soil irrigated, to define the changes of the soil, to forecast the expected changes and subsequently to take the necessary measures with the view of preventing harmful processes in the soil. Without this irrigation might become hazardous.

The characterization of the land classes may be briefly summarized as follows:

Class 1-Arable lands /Excellent for irrigated cultivation/.

No found on the territory of the Project Area. The causes are not primarily in pedogological but rather geomorphological and economical at ones the marked geographic sturcture undulation of the region /the systems of dams mentioned earlier, the small size of the fields, with a big difference of level among them, etc./, the difficulties of introducing up-to-date, large scale irrigation/ demanding significant land regulation, etc. /and large-scale mechnaized cultivation.

Class 2-Arable lands /Suitable for irrigated cultivation/.

Approximately 50 per cent of the territory of the Project Area may be classified under this heading. Soils with the best water management properties and with the greatest potential fertility belong to this class: the medium-textured, deep layered alluvial soils /1,23, 1,24/, deep alluvial soils with coarse texture but with several silt accumulation layers /1,22/ and the majority of the medium textured and fine textured tropical arid brown soils /3,2, 3,3, 3,4/ provided their irrigation water supply comes from the Wadi and their economic conditions /distance from the road facilities of transport to and from, etc./ are not unfavourable.

In the case of alluvial soils the potential fertility is limited by the silt-layers that are bedded into the medium textured alluvial matter and decrease the drainage conditions of the soil profile, whereas in the case of the tropical arid brown soils with fine texture the difficult cultivability is the limiting factor.

We have classified under this heading some of the tropical arid brown soils with coarse texture /1.21/ and of the alluvial soils with silt cover on the surface /1.25/ as their water supply and economic conditions are favourable.

The difficulties of up-to-date large-scale mechnaized cultivation and irrigation prevail here as well as in the earlier cases, due to the undulation of the region. The land under consideration is suitable for the irrigated production of all agricultural crops that may occur in the region. Because of the advantageous supply of irrigation water and the good water management properties of the soils it is advisable however to give preference to the cultivation of plants that require more water /vegetables, maize, sugar-cane cotton, banana, etc/, that are more difficult to grow elsewhere. These field do not require ameloirative interference /besides land levelling/. The high potential fertility of the soils can be realized by irrigation, by the introduction of suitable species, by a harmonious use of organic manure and artificial fertilizer /primarily by application of N/ and by up-to-date deep cultivation. Because of the high water capacity of the soils and their good water holding capacity the number and frequency of irrigation can be successfully reduced by using higher doses of water for irrigation.

Class 3-Arable lands /Suitable for irrigated cultivation/

Approximately 27 per cent of the territory of the Project Area may be classified under this heading.

Such soils belong to this class which have good water mangement properties and great potential fertility /1,22, 1,23, 3,2, 3,3, 3,4/, but their water supply from the Wadi is difficult, are distantly situtated from the road and from inhabited regions, thus their economic conditions are relatively disadvantageous.

Deep alluvial soils with moderate water management properties and moderate potential fertility, with coarse texture and one silt-accumulation layer /1,13, 1,21/, some of the alluvial soils with surface silt cover /1,25/ the majority of medium-textured soils slightly affected by wind erosion and covered with thin sand mantle /2,32/, the majority of tropical arid brown soils with coarse texture /3,1/, and also the neighbourhood of soil profiles 12 and 13 that are salt affected and solonethic respectively in their deep layers, also belong to this class.

The potential fertility of the soils is decreased by the gravel layers occurring deeper in the soil profile of alluvial soils /1,13/, by the low field capacity and the danger of deflation /2,32/ in the case of soils with coarse texture /1,21, 3,1/ and the slight accumulation of salts and the tendency of turning solonetzic in the deeper layers of soils in the region characterized by soils profiles 12 and 13.

The difficulties of up-to-date large-scale mechanized cultivation and irrigation prevail here as well as in the earlier cases due to the undulation of the region. The lands under consideration are suitable for the irrigated production of all agricultural crops that may occur in the region but because of the difficulties of water supply and the less advantageous water management properties of the soils it is recommended to give preference to the cultivation of crops that demand less water /durra, uha, sesame, etc/. In regions exposed to sand storm, protection against deflation is important /to surround the land by dams, the fixation of moving sand/. Other ameliorative intervention/ besides the levelling of land/ is not required. During the course of cultivation the disturbance of silt layers that improve the water properties of the soil profile of alluvial soils should be avoided. Deep cultivation /mixing deeper soil layers with the upper ones/ can be particularly successful in soils having silt or sand cover on the surface. The increased supply of organic matter would be important for these soils. When using mineral fertilizers the application of N-is of particular significance and medium doses can be recommended. In the neighbourhood of profiles 12 and 13 particular attention should be paid to the continuous control of the salinity and alkalinity status of irrigation water and irrigated soils.

Class 4-limited arable lands of special use /Suitable for irrigated cultivation only tentatively/.

Approximately 7 per cent of the territory of the Project Area may be classified under this heading.

Medium deep alluvial soils /1,12/, soils moderately damaged by wind erosion and covered by a moderately thick sand mantle /2,21, 2,22/, soils of coarse texture and only slightly damaged by wind erosion /2,31/, and salt affected soils around the soil profile 17, solonetzic soils and soils solonetzic in their deep layers, occuring around profiles 9 and 8 respectively, belong to this class.

In the case of alluvial soils potential fertility is limited by the gravel layer occurring in the profile, by the low water capacity and the danger of deflation of the soils covered with sand mantle, the Na-salt accumulation, the Na-saturation of the exchange capacity of the soil and the unfavourable water management properties have the same effect in the salt affected soils.

At the irrigation of moderately deep soils the infiltration losses are high and water held in the relatively thin soil layer can provide the water supply of plants only for a short time, therefore smaller doses of water and more frequent irrigation is recommended. Of the plants preference should be given to crops that have shallow roots.

In regions damaged by wind erosion the prerequisite of succesful cultivation is protection against deflation. Against the damage caused by sand storm coming from the nearby desert suitable earth dams culisses of plants with thall growth may render sufficient protection, whereas the fixing of sand can be achieved by keeping the surface moist and having permanently a dense growth of crops. It also can be of good results if by deep cultivation the thinner surface cover of sand is mixed with the deeper soil layers that have a heavier texture. Of the plants preference should be given to those that are less sentitive to sand storms and offer more permanent and denser vegetative cover.

In salt affected soils the leaching of the accumulated salts should be guaranteed. For this purpose permeability of the soils has to be improved /deep loosening/ and water necessary to the leaching of salts provided. The cultivation and irrigation of these soils should be done with special care and the necessary measures to limit the strengthening, deepening and spread of salinity and alkalinity should be elaborated. The cultivation of crops sensitive of salts should be avoided.

The use of organic matter and moderate doses of mineral fertilizers can be recommended in the case of soils belonging to Class 4.

Class 5-Tentatively non-arable lands /At present not suitable for irrigated cultivation/. Approximately 10 per cent of the territory of the Project Area may be classified under this heading.

Gravel alluvial soils with shallow profile /1,11/, soils covered with thick sand mantle and strongly deteriorated by wind erosion and soils at the border of the desert /2,1/ belong to this class.

The prerequisite of the agricultural utilization of the latter ones are: the protection against deflation and a suitable amount and quality of irrigation water. The water that may be obtained is primarily from tube wells is not always of good quality particularly in the western part of the Project Area /in the region of Tuheita/.

Class 6-Non-arable lands and inhabited areas.

Approximately 2 per cent of the territory of the Project Area may be classified under this heading.

The Wadi-beds covered with deposits, the stondy lands with trees, bushes and thickets lands turned into desert /sand-dunes/, inhabited and other lands not used for agricultural purposes /cemetry, caravan road, etc/ belong to this class.

Not suitable for agricultural cultivation.

Chapter 5

EXPERIMENTAL FARM

The aim of the Experimental farm is to offer indication of the possibilities and methods of the agricultural development of the Project Area and in a broader sense to the whole Tihama Plain with the help of the experimental data obtained and to serve as a model of-up-to-date large-scale irrigated farming. The Experimental farm offers facilities for a more substantial and continuous study of the effects of irrigation on the soils, for the analysis of the harmful process of salt accumulation and alkalinization, for the clarification of its causes and circumstances and for the elaboration of preventive measures. The Experimental Farm besides presenting and publishing the results that may be achieved in agricultural development, may function as the basis of a network of agricultural advisery service in Yemen.

In accordance with these the Experimental farm can successfully achieve its aims if its own climatic, geological geo-morphological, hydrological, relief and soil conditions well represent the conditions of the Project Area and the whole Tihama Plain of Yemen.

The Experimental farm is situated on the south eastern part of the Project Area some 700 m south of the

Wadi Zabid, and some 300 m north of the FAO Camp. Its area is about 20 hectares.

Its soil conditions and land capabilities are presented on the attached map at scale 1:1000. It should be noted that six intermediary borings were made on the Experimental Farm and 15 soil profiles were dug of which ten have been characterized by detailed laboratory tests. In the case of three profiles field tests of water management /field capacity, infiltration rate, permeability/ have also been executed.

The bigger scale of the maps has made the more detailed classification and marking of the various soils are possible. Types of soil, their territorial extension, the land classes and their territorial distribution have been summarized in Table V., of Appendix 3.

The characteristics of the types of soils occurring in the land of the Experimental farm can be briefly summarized as follows.

Calcareours shallow alluvial soils /1.1/

Cover about 18 per cent of the territory of the Experimental Farm. Detailed description is given in the Chapter 3.3 of the present Report.

Of the soils belonging to this group about 30 per cent have shallow, 15 per cent medium and 55 per cent moderately deep soil profile. This region-bordering the Project Area and characteristic of very big territories -

offers facilities to the elaboration of the systems of cultivation, organic and mineral fertilization and irrigation of gravel soils with shallow soil profile and also to estimation of the facilities and economy of large scale irrigated farming.

Alluvial soils with shallow profile /1.11/ have been grouped under land class 5, alluvial soils with medium deep profile /1.12/ into land class 4, alluvial soils with moderately deep profile /1.13/ into land class 3, in accordance with their potential fertility.

Tropical arid brown soils /3/

Cover about 74 per cent of the land of the Farm. Their detailed description is given in the Chapter 3.3 of the present Report.

Of the soils belonging to this class about 62 per cent have medium /3.3/, 38 per cent /3,4/ fine texture. These soils are characteristic of extensive regions of the Project Area and of other Wadis of the Tihama Plain. They offer facilities to the elaboration of the methods and possibilities of up-to-date irrigated cultivation to be introduced on the soils of the highest potentital fertility of the region.

The soils under consideration have been grouped under land class 2 in accordance with their high potential fertility.

Salt affected soils /4/

Cover about 8 per cent of the territory of the Farm. Detailed description is given in the Chapter 3,3 of the present report.

The larger scale of the map made it possible to classify more detailed the soils affected by differenc degrees of salinization and to plot their boundaries as well. The classes are as follows:

Soils with moderate alkalinity in deeper layers /profile 8/ /4.1/.

The salt-content of the soil is low in the whole profile: total salt percentage of the saturated soil paste is 0,1 % $EC^{o}25$ of saturation extract is 1 mmhos/cm. The Na-saturation /ESP/ grows with the depth and below one metre reaches its maximum with 13 per cent /Table 4 of Appendix 5/. Alkaline medium-textured soils /pH 8,3-8,4/ their B-horizon is not developed.

These soils have been classified under land class 4. Amelioration is not needed but their irrigation requires special care.

Soils with moderate salinity in the deeper-layers /profile 13/ /4.2/

The salt-content of the soil increases with the depth in the profile and at one metre the total salt content of the saturated soil pasta is 0,24 per cent, the saturation extract $EC^{o}25$ is 2,2 mmhos/cm, Na^{+}-content is 14 mEq/lit/0,8 mEq/100 g of soil/. Of the cations Na^+, of the anions HCO_3^- are dominant but the quantity of chlorides is also significant, whereas sulphates occur only in smaller quantities. Their Na-saturation is low /ESP 7 %. /. Alkaline pH 8,3 - 8,6/, moderately fine textured soils. Their B-horizon is not developed. These soils have been classified under land class. Amelioration is not needed but their irrigation requires special care.

Soils with moderate salinity and alkalinity in the deeper layers /profile 12/ /4,3/

Their salt-content and salt composition are similar to the earlier one /4.2/ but their Na-saturation up to 60 to 100 cm reaches almost 15 per cent /Table 4 of Appendix 5/. Strongly alkaline pH 8,4-8,6/, medium textured soils. Their B-horizon is not developed.

These soils have been grouped under land class 3. Amelioration is not needed but their irrigation requires special care.

Soils with medium salinity and alkalinity /profile 9/ /4.4/

Their salt content increases with the depth in the profile and lower than 80 cm it is more than 0,3 per cent / 3 mmhos/cm/. Of the cations HCO_3^- in the upper layers, in the lower ones it is chlorides followed by the sulphates that occur in bigger quantity. The ESP value is 6,6 per cent in the upper soil horizon increasing up to 20 per cent downswards in the soil. Chemical reaction is only moderately alkaline and with the increase of salt content the pH value decreases. Their B-horizon is not developed.

These soils are grouped under land class 4. It is rather fortunate that a great variety of the soils with different degrees of salinity and alkalinity are found in the territory of the Experimental Farm as it ensures farm facilities to study the effects of irrigation and agrotechnique on the salt dynamism and balance and to draw conclusions that are valid for the whole land of the Project Area and also for the whole Tihama Plain regarding the expected effects of irrigation on the soils.

On the territory of the Experimental farm land levelling has been carried out for the sake of large scale irrigated cultivation following the field soil survey. The existing smaller dams and microrelief differences have been levelled and the land has been equipped for surface irrigation. Ground-water obtained by tube wells is utilized for irrigation. The quality of the irrigation water is favourable: its dry residue is 450 mg/lit, electric conductivity on °C 25 is 0,7 mmhos/cm. Its chemical reaction is moderately alkaline pH 8,3-8,4/, its soda content is low / 0,5 m mEq/lit/, its Na per cent remains below 50 and the SAR-value is also hardly above 2. According to the USA standard for water quality classificiation the water belongs to category C_2S_1/ medium salinity low sodium water/ and as such it can be utilized without special salinity control particularly if the drainage conditions of the soil are suitable. As the salinity and alkalinity conditions and water management properties of the soils in the Experimental farm are different valuable experience can be obtained by the utilization of this water regarding the limit values on the Tihama Plain.

Summing up it can be stated that the Experimental Farm represents the natural and soils conditions of the region properly and thus offers facilities to establish the best ways of the agricultural utilization of different soils and to the elaboration of agrotechnique and also the methods of irrigation to be used.

Chapter 6

RECOMMENDATIONS

On the basis of a semi-detailed soil survey the following consolidated recommendations are made to establish investment feasibility and permit the development of a more up-to-date irrigated agriculture:

1 The pre-conditions of implementation of large-scale irrigated farming on the project area is the levelling, the formation of fields of proper size and configuration. Levelling on the areas of present, intensive irrigation is uneconomic, because of the high banks. The problem is simpler on territories /for instance in the western part of the project area, etc/, supplied by water not from the Wadi but from ground-water /tube well irrigation/. Here the fields are larger, the topographic differences between the fields are smaller and the banks are lower. The deeper strata can come up to the surface after levelling /aeolian fluviatile sediments/ have favourable physical and chemical properties, neither saline nor alkaline.

2 Cultivation on the soils does not need application of any special measures, but the large-scale mechanized soil cultivation is hindered by the uneven relief of the area, small size of the fields and their irregular configuration.

In course of tillage of alluvial soils the disturbance of the silt accumulation layers, improving the water management properties of the soil profile, should be avoided. The deep ploughing /mixing the subsoil layer with the top horizons/ might be especially promising on the soils with silt accumulation or sand cover on their surface. The deeper tillage and subsoil loosening can be recommended for the soils of fine texture.

3 The water erosion control of the area can be provided through exchanging the wild flooding and the so-called "from field to field" irrigation methods by more up-to-date methods of irrigation. On the areas damaged by wind erosion pre-conditions of the agricultural crop production is the deflation control. Proper earthbanks, cullisees of high growing, wind-protective plants can serve as a protection against the demage caused by sand storms coming from the adjacent desert area. Fixation of the shifting sand can be reached by maintenance of the soil surface all time wet and providing suitable dense and permanent crop-stand on the soil surface. Among the plants preference should be given to the more sand storm-resistant varieties and to those plants able to give more permanent and denser cover on the respective lands.

4 At the present time soils of the area do not require any kind of amelioration methods except the levelling. Small salt-affected spots can be reclaimed by supplying the leaching requirement and simultaneously by the improvement of vertical drainage of soils /deep ploughing, subsoil loosening, cultivation of deep-rooted crops/. The production of the salt-sensitive plants should be avoided on

these soils.

5 As the total organic matter and plant nutrient content of the soils are very low, elaboration of the system of organic and mineral fertilization is of great importance. Increasing the amount of organic manure is possible only through the development of the livestock and modernization of keeping animals, as well as using the increased farmyard manure output directly for manuring /not for fuel/. But these possibilities, because of forage problems, are the function of the general development of irrigated crop production.

Besides the good water supply of plants the other key-problem of increasing soil fertility is the proper and harmonious plant nutrient supply. In addition to the application of N-fertilizers of vital importance the phosphorus and-in special cases /for instance cultivating potassium-consumptive crops, like vegetables fruit trees, etc/ - the potassium are important, as well. Concerning the optimal assortment and application rate of the fertilizers more detailed data will be obtained by observations and field experiments /supported by soil laboratory tests/ being carried out on the Experimental farm of the Wadi Zabid Project.

6 The kind and sort of the cultivated plants first of all depend on the possibilities of water supply. On the areas of good water supply and on soils having favourable water management properties /Land capability class - 2/it is reasonable to grow water consumptive plants/ vegetables, corn, sugar-cane, cotton, banana, etc./,

the production of which is more difficult on the other territories. On soils with less favourable water management properties and on areas of insuffiecient water supply it is recommended to cultivate less water-consumptive crops/durra, duha, sesame etc/. On soils having shallow profile the cultivation of deep-rooted crops and .. the salt-affected spots the growing of salt-sensitive plants should be avoided.

7 The two sources of irrigation water are the Wadi-water and the ground water.

a. The wadi-water is a medium salinity-low sodium water, can be used for irrigation without any special practices for salinity control, especially if the drainage conditions are favourable and the cultivated crops are not salt- /or sodium/ sensitive.

b. The ground-water under the project area is "medium-salinity-low sodium" or "high salinity-los sodium" water and can be used for irrigation of not salt-sensitive crops, on well drained territories and on permeable soils. In some cases a special management for salinity control may be required. The natural drainage conditions of the project area are favourable /deep ground-water table,gravelly subsoil etc/, therefore especially on coarse textured soils the extension of tube well irrigation is recommended. By this way the irrigated area can be enlarged to a great extent in the Tihama Plain. The water supply can be stabilized and establishment of agriculture on huge farms can be set up. In addition, the fertilizer, effect of N-content of the ground-water cannot be neglected.

8 First the irrigation of territories classified into the Land capability class - 2 and 3 is recommended/ covering about 50 and 27 per cent of the total area-respecitvely/. Here the potential fertility of the soil and the efficiency of irrigation water are high and the economic conditions are favourable as well. On the soils of high field capacity and relatively good permeability /land class - 2/ usage of high dosage of irrigation water makes it possible to diminish the number and frequency of irrigation, which ultimately results in economic farming. On soils of low field capacity, low permeability, or shallow soil profile /Land class 4 and 5/ more frequent irrigation is advisable with smaller doses of irrigation water. The most effective irrigation method can be selected on the basis of the practical experience of the Experimental farm of the project. Instead of sprinkler irrigation /high investment requirement and evaporation losses/ the border system of flooding or furrow irrigation are recommended.

9 Though there is no actual danger of salinization and alkalinization due to the ground-water and the natural drainage conditions are favourable, the salinity and alkalinity hazard due to irrigation water cannot be neglected. The present wild-feeding provides the leaching requirements of soils, but the more modern irrigation practice /less irrigation water rate- reasonable from viewpoint of economy and water management/ will not provide it so unanimously.

That is why permanent and regular quality control of irrigation water and irrigated soils/at least in the first period of the new water management practice/ required. At the same time, the improvement of the water management properties of soils and uniform distribution of irrigation water are necessary. The Experimental farm and the Soil science laboratory of the project provide good possibilities for obtaining data regarding the salt regime of irrigated soils and quality of irrigation water /not available at present/ in the Tihama Plain, which are indispensable for surveying the agricultural potential, exploration of the development possibilities of the modern irrigated farming, for predicting the salinization and alkalinization processes due to irrigation and for the elaboration of proper preventive measures against harmful soil processes.

Appendix 1

LABORATORY METHODS FOR SOILS AND WATER ANALYSES

/1/ pH determinations were done electormetrically with Metrohm E-366 apparatus, with EA 12X-type glass electrods in 1:2,5 soil suspension, in saturation extract, in 1:5 water extract and in waters /10/.

/2/ $CaCO_3$ content was determined by Scheibler's /volumetric calcimeter /method /10/.

/3/ The particle-size distribution of the soil was determined by the pipette method of Robinson-Katsinsky. NaOH was used as dispersive matter after HCl processing of $CaCO_3$. Coarse skeletal parts /gravel/ and coarse sand fraction /1-0,25 mm/ were separated by dry sieving, fine sand /0,25-0,05 mm/, silt /0,002-0,05 mm/, and clay / 0,002 mm/ fractions by sedimentation /2/. Simultaneously the particle density and hygroscopic moisture content of the soil were also determined.

/4/ SP/saturation percentage/, electrical conductivity and the total salt content of the saturated soil paste were measured with portable transistor apparatus. On the basis of these determinations saturation extracts were prepared from the soil samples containing considerable quantity of salt their pH and electrical conductivity /with a OK-104 conductometer made in Hungary by Radelkis, and OK-902 type platinum bellelectrode/were measured. Na-content of samples with the electrical conductivity higher than 1 mmhos/cm was determined with flame photometer.

/5/ The exchangeable Na^+-content of the soil was determined by Richards'method /7/ as the difference between the Na^+-content extractable with 1 n pH-7 ammonium-actate solution and the Na^+- content of the saturation extract.

Cation exchange capacity /CEC/ was measured by Richards' method. ESP value was calculated from the data of the above two determinations.

/6/ 1:5 water extracts of 7 soil samples were analysed to characterize water soluble salt content. Dry and ignition residue, pH/electrometrically/, electrical conductivity /with conductometer/, and CO_3^{2-} /acidimetrically/, with titration with sulphuric acid against phenolphthalein, HCO_3^- /acidimetrically/, with titration, with sulphuric acid against methlyred, Cl^- /argentometrically, with precipitation titration with silver nitrate against pottassium-chromate/, SO_4^{2-} / gravimetrically in the form of $BaSO_4$ /Ca^{2+} and Mg^{2+}/ EDTA titration against murexid and Eriochrome black, T, Na^+ and K^+/ with flame photometer/ content of the extracts were determined.

Similar methods were applied for determining the dry residue, the pH, the electrical conductivity, the carbonate, the hydrocarbonate, chloride, sulphate, calcium, magnesium, sodium and potassium content of the waters as well. Besides, the total hardness of the waters /with EDTA titration against Eriochrome black T/ in German degrees of hardness /N°/ 1 N°= 1mg CaO/lit or 7,19 MgO/lit/, the carbonate hardness of waters/ with acidic titration against methyl-red/, the residual hardness/ total hardness minus carbonate hardness/, the soda-equivalent = $\frac{\text{carbonate-hardness-total hardness}}{2,8}$

$$\text{Na per cent} = \frac{Na^+}{Na^+ + K^+ + Ca^{2+} + Mg^{2+}} \quad \text{mEq/lit}$$

$$\text{SAR value} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{mEq/lit}$$

/7/ Total N-content /with Kjedahl's method/ were also determined.

/8/ The total humus content of soils was determined with Tyurin's method /2/ from digestion with chromic acid, with Kjeldahl's aqueous vapour distillation.

/9/ The total P_2O_5 and K_2O content was determined from digestion with aqua regia.

/10/ The quantity of available P_2O_5 K_2O with the Egner-Riehm-Domingo Al-method, P_2O_5 content was measured colorimetrically/ with Spektromom-360 spectro photometer, made in Hungary/, K_2O-content was determined with flame photometer.

/11/ In the course of the elemental analysis the hygroscopic moisture content and ignition loss of the air dried soilwere determined. The SiO_2-content was determined in hydrochloric acidic extract after alkali-carbonate fusion /gravimetrically, after repated evaporation to dryness hydrochloric acid/. From the filtrate containing no SiO_2 the following components were determined:

R_2O_3 : gravimetrically, after precipitation with NH_4OH

Fe_2O_3 : colorimetrically with KSCN

P_2O_5 : colorimetrically, based on the molybdenum-blue reaction /Arrhenius-method/

MnO : colorimetrically, with potassium per sulphate

CaO : gravimetrically, from the filtrate after precipitation of R_2O_3 with ammonium oxalate.

MgO : gravimetrially, from the filtrate after precipitation of CaO with NaH_2PO_4

SO_3 : gravimetrially, from the filtrate after precipitation of R_2O_3 in the from $BaSO_4$

Al_2O_3 : calculation /R_2O_3/ Fe_2O_3+P_2O_5+MnO/.

Colorimetric measurings were carried out with Hungarian made Spektromom-360 spectro-photometer. The quantity of alkalis /K_2O, Na_2O/ was determined with the Lawrance-Smith method /22/ after digestion by $CaCO_3$+NH_4 Cl with flame photometer.

Appendix 2

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Appendix 3

TABLES OF DETAILS ON THE SOIL AND LAND CAPABILITY CLASSIFICATION

Contents:

Appendix 3 /cont'd/

Table I

Classification of the Soils for the Soil Map

1. Alluvial Soils /Calcaric Fluvisols /Jc/, Entisols - Orthic Orthustens, Entisols - Calcaric Torrifluvents/

1.1 Calcareous Shallow Alluvial Soil

1.11 Gravel at a depth of 0-50 cm, coarse and moderately coarse-textured soils /1, 3, 228, 252, 254, 256, 277/

1.12 Gravel at a depth of 50-100 cm, coarse and moderately coarse textured soils /2, 4, 5, 6, 255, 272/

1.13 Gravel at a depth of 100-150 cm, medium-textured soils /15, 111, 143, 176, 183, 201,235, 243, 253/

1.2 Calcareous Deep Alluvial Soils

1.21 Coarse and moderately coarse - textured soils /sands, loamy sands, and sandy loams /with one silt-accumulation--layer /72, 83, 88, 90, 94, 100, 107, 108, 109, 120, 161, 168, 266, 286, 289, 290, 291, 294, 296, 297, 300/

1.22 Coarse and moderately coarse-textured soils /sands, loamy sands, sandy loams/ with two or more silt-accumulation-layers /36, 50, 79, 82, 101, 102, 118, 131, 133, 135, 142, 160, 180, 190, 268, 281, 282, 285, 287, 299/

1.23 Medium-textured soils with one silt-accumulation-layer /75, 76, 77, 104, 105, 144, 148, 152, 167, 173, 174, 175, 192, 198, 237, 238, 270, 276, 279/

1.24 Medium-textured soils with two or more silt-accumulation-layers /116, 156, 182, 184, 185, 206, 208, 223, 225, 233, 236, 251, 257, 258, 271, 278/

Appendix 3 /cont'd/

1.25 Soils with silt-accumulation-layer on the surface /84, 117, 134, 137, 146, 153, 204/

2. Soils Affected by Wind Erosion

2.1 Soils covered by recent wind deposits thicker than 50 cm /21, 73, 295/

2.2 Soils covered by recent wind deposits with the thickness of 25-50 cm

2.21 Coarse and moderately coarse-textured soils /23, 25, 30, 34, 35, 38, 41, 43, 42, 47, 48, 53, 61, 71, 74, 86/

2.22 Medium-textured Soils /24, 26, 32, 33, 44, 45, 58, 59, 60, 63, 114, 140/

2.3 Soils covered by recent wind deposits with a thickness of 10-25 cm

2.31 Coarse-textured soils /19, 20, 27, 31, 51, 56, 69, 85, 141/

2.32 Medium-textured soils /29, 39, 46, 49, 62, 70, 96, 97, 98, 127, 128, 129, 166/

2.4 Coarse and moderately coarse-textured soils with a lime-accumulation-layer at a depth of 50-150 cm /87, 112, 113/

3. Arid Brown Soils /Haplic Xerosols /Xh/, Aridisols-Orthic and Mollic Camborthids

3.1 Coarse and moderately coarse-textured soils /sands, sandy loams, and loamy sands /22, 37, 65, 80, 81, 92, 103, 110, 119, 124, 283/

Appendix 3 /cont'd/

3.2 Medium-textured soils /loams, silty loams/ 28, 40, 52, 55, 57, 64, 66, 67, 68, 78, 91, 95, 99, 106, 115, 121, 122, 123, 125, 126, 130, 136, 138, 139, 145, 147, 155, 157, 158, 162, 165, 169, 171, 177, 178, 179, 181, 187, 189, 197, 207, 217, 224, 241, 245, 250, 284, 293, 298, 301/

3.3 Moderately fine textured soils /clay loam, silty clay loam, having less than 35 % of clay; sandy clay loam/ 7, 10, 11, 14, 16, 132, 149, 150, 151, 154, 159, 163, 164, 170, 172, 186, 188, 191, 193, 195, 199, 200, 202, 203, 210, 220, 226, 239, 242, 244, 248, 249, 262, 263, 264, 265, 267, 273, 275, 280, 288, 292/

3.4 Fine-textured soils /clay, clay loam, silty clay loam having more than 35 % of clay/ 194, 196, 205, 209, 211, 212, 213, 214, 215, 216, 218, 219, 221, 222, 227, 229, 230, 231, 232, 234, 240, 246, 247, 259, 260, 261, 269, 274/

4. Salt affected soils /8, 9, 12, 13, 17, 18/

Appendix 3 /cont'd/

Table II

Territorial Distribution of the Soil Types

Symbol of the soil types	in hectares	percentage
1.11	172,0	0,85
1.12	48,4	0,24
1.13	212,0	1,95
1.21	1925,2	9,58
1.22	1231,4	6,12
1.23	1165,8	5,80
1.24	797,6	3,97
1.25	300,6	1,49
2.1	286,4	1,42
2.21	1936,0	9,63
2.22	781,2	3,88
2.31	438,4	2,18
2.32	513,6	2,55
2.4	293,2	1,46
3.1	941,0	4,68
3.2	3518,2	17,50
3.3	2726,8	13,56
3.4	1531,6	7,62
4.	62,0	0,30
Total Netto	18881,4	93,93
Wadi Beds	758,6	3,77
Inhabited Area	281,6	1,40
Non-arable Lands	181,2	0,90
Total Gross	20102,8	100,00

Appendix 3 /cont'd/

TABLE III

Laboratory Analyses

Symbol of the soil types	Profile No.	pH	$CaCO_3$	Total humus	Total N	Aq.regia soluble P_2O_5	Aq.regia soluble K_2O	Al soluble P_2O_5	Al soluble K_2O	Particle density	Hygroscopic moisture c.	Particle size distrib.	SP	Total salt content	Sat.extr.: EC	pH	Na^+	1:5 water extract an.	Exchangeable Na^+	CEC	Elemental analysis
1.12	2.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
1.12	4.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
1.12	5.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
1.12	6.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
1.13	15.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
1.13	176.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
1.22	36.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
1.22	102.	+	+	−	−	−	−	+	+	+	+	+	+	+	−	−	−	+	+	+	−
1.22	135.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−
1.23	77.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−
1.23	173.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−
1.23	198.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	+
1.24	206.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
1.25	153.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	+	−	−
2.21	25.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−	+	−
2.21	86.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	+
2.22	59.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
2.31	19.	−	−	−	−	−	−	−	−	+	+	+	−	−	−	−	−	−	−	−	−
2.31	141.	+	+	−	−	−	−	+	+	−	−	+	+	−	−	−	−	−	−	−	−
2.32	29.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
2.32	49.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+	+	−
2.32	97.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−
3.2	68.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−
3.2	91.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
3.2	147.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	+
3.2	158.	+	+	−	−	−	+	+	+	−	−	−	+	+	−	−	−	−	−	−	−
3.2	165.	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−	+	+	−
3.2	178.	+	+	−	−	−	−	+	+	−	−	−	+	+	−	−	−	−	−	−	−

Appendix 3 /cont'd/

TABLE III /cont'd/

Symbol of the soil types	Profile No.	pH	$CaCO_3$	Total humus	Total N	Aq.regia soluble P_2O_5	Aq.regia soluble K_2O	Al soluble P_2O_5	Al soluble K_2O	Particle density	Hygroscopic moisture c.	Particle size distrib.	SP	Total salt content	Sat.extr.: EC	pH	Na^+	1:5 water extract an.	Exchangeable Na^+	CEC	Elemental analysis
3.2	197.	+	+	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-
3.3	7.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-
3.3	10.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
3.3	11.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-
3.3	14.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
3.3	16.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-
3.3	193.	+	+	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-
3.3	200.	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	+	+
3.4	209.	+	+	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-
3.4	214.	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+	+	-
3.4	227.	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+
4.	8.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
4.	9.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
4.	12.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
4.	13.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
4.	17.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
4.	18.	+	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-

Appendix 3 /cont'd/

Table IV

Territorial Distribution of the Land Capability Classes

Land Classes	Symbol of the soil types	In hectares	Percentage
Class 1	-	-	-
Class 2	1.22, 1.23, 1.24 /partly/		
	3.2, 3.3, 3.4 /partly		
	3.1, 1.21, 1.25 /partly/	9984.4	49,66 %
Class 3	1.22, 1.23 /partly/		
	3.2, 3.3, 3.4 /partly/		
	3.1, 1.21, 1.25 /partly/		
	1.13, 2.32 /partly/	5439,4	27,06 %
Class 4	1.12		
	2.21, 2.22, 2.31, 2.4		
	4, 2.32 /partly/	1459,6	7,26 %
Class 5	1.11,		
	2.1	1998,0	9,94 %
Class 6	-	281,6	1,40 %
Wadi beds	-	758,6	3,77 %
Inhabited area	-	181,2	0,91 %
Total		20102,8	100,00 %

Appendix 3 /cont'd/

Table V

Classification of the Soils on the Experimental Farm

1. Alluvial soils
1.1 Calcareous Shallow Alluvial Soils
1.11 Gravels at a depth of 0-50 cm, coarse and moderately coarse textured soils /254/
1.12 Gravels at a depth of 50-100 cm, coarse and moderately coarse-textured soils /255/
1.13 Gravels at a depth of 100-150 cm, medium-textured soils /15, 253/

3. Arid Brown Soils
3.3 Moderately fine textured soils, clay loam, silty clay loam, having less than 35 % of clay; sandy clay loam, /7, 10, 11, 14, 16/
3.4 Fine textured soils, clay, loam, silty clay loam, having more than 35 % of clay /230, 231, 232/

4. Salt Affected Soils
4.1 Soils with moderate alkalinity in the deeper layers /8/
4.2 Soils with moderate salinity in the deeper layers /13/
4.3 Soils with moderate salinity and alkalinity in the deeper layers /1/
4.4 Soils with medium salinity and alkalinity /9/

Appendix 3 /cont'd/

Territorial Distribution of Soil Types in the Area Surveyed for the Experimental Farm

Symbol of Soil Types	Hectares	Percentage
1.11	1.9	5.5
1.12	1.1	3.1
1.13	3.3	9.5
3.3	16,0	46,0
3.4	9.7	27,8
4.1	0,6	1.7
4.2	0.4	1.2
4.3	0.8	2.3
4.4	1,0	2.9
Total	34.8	100.0

Territorial Distribution of Soil Type within the Experimental Farm

Symbol of Soil Types	Hectares	Percentage
1.11	1.9	8.72
1.12	1.1	5.05
1.13	0.9	4.13
3.3	6.8	31.19
3.4	8.5	38.99
4.1	0.4	1.83
4.2	0.4	1.83
4.3	0.8	3.67
4.4	1.0	4.59
Total	21.8	100.00

Appendix 3 /cont'd/

Territorial Distribution of the Land Capability Classes in the Area Surveyed for the Experimental Farm

Classes	Symbol of Soil Types	Hectares	Percentage
Class 1	-	-	-
Class 2	3.3, 3.4	25.7	74,0
Class 3	1.13, 4.2, 4.3	4.5	12.8
Class 4	1.12, 4.1, 4.4	2.7	7.7
Class 5	1.11	1.9	5.5
Class 6	-	-	-
Total	-	34.8	100.0

Territorial Distribution of the Land Capability Classes within the Experimental Farm

Classe	Symbol of Soil Types	Hectares	Percentage
Class 1	-	-	-
Class 2	3.3, 3.4	15.3	70.18
Class 3	1.13, 4.2, 4.3	2.1	9.63
Class 4	1.12, 4.1, 4.4	2.5	11.47
Class 5	1.11	1.9	8.72
Class 6	-	-	-
Total		21,8	100.00

Appendix 4

DESCRIPTION OF THE REPRESENTATIVE SOIL PROFILES

Appendix 4 /cont'd/

Profile Number: 2

Soil Name: Moderately coarse-textured, calcareous, shallow, alluvial soil /1.1.2/

Higher Category Classification: Alluvial Soils /Calcaric Fluvisols /JC/.

Entisoils-Orthic Orthustens, Entisols-Calcaric Torrifluvents/

Date of Examination: 28 July 1969.

Author: István J. Boros

Location: Y. A. R., Wadi Zabid Project, about 500 m to S from the FAO-Camp. Distance from the profile No 1 is 313,3 m, from the Arge tree in direction of N 82,85 m and to the big bush in direction of NW is 40,4 m.

Land Form:

i. Physiographic Position: Plain divided by the earth banks to irrigated fields.

ii. Surrounding land form: Flat cut up by small water-ways, made by the run-off-water.

iii. Microtopography: Surface of the lands has ridges /4 cm high/ and furrows /about 4 cm deep/ as a result of previous bullocks' cultivation.

Slope on which profile is sited: Gentle slope facing NE.

Vegetation and land-use: Scarce weeds as zegf, nusher, wobel etc. Field is not cultivated because of lack of rainfall.

Parent Material: Gravels and stones, covered with river deposits.

Drainage: Class 4 - well drained.

Moisture condition in profile: Slightly wet throughout the profile.

Presence of surface stones, rock outcrops: None

Evidence of Erosion: Very limited.

Appendix 4 /cont'd/

Presence of salt or alkali: None
Human influence: Very strong expressed in the construction of banks, irrigation canals and other hydrological structures with the aim of utilizing flood irrigation. Irrigation water has plenty of floating deposits.
Brief Description of the Profile: Shallow soil with weakly developed genetic horizons. As the gravels and stones are very near to the soil surface it has a limited suitability for irrigation and agricultural use. These lands are out of intensive irrigation and can be called the rain-fed area. Land capability class - class 5.
Effervescence: From the surface up to 95 cm it is strong. Deeper it becomes weaker. Along the lime-containing stones the reaction to the diluted HCl is very strong.
Profile Description:

0 - 5 cm	Brown /5/2 7.5 YR/, dry, sandy loam, loose, a few plant roots found, it seems to be a plough layer.
5 - 29 cm	Strong brown /5/6 7.5 YR/, slightly wet, sandy loam with a few fine gravels, having the diameter of 2-3 cm, weak angular blocky structure, a few fine dead roots, the layer from 16 cm up to 79 cm is covered with white coatings. Boundary is gradual
29 - 56 cm	Strong brown /5/6 7.5 YR/, wet, sandy loam, angular blocky structure, some fine roots, boundary clear.
56 - 85 cm	Brown /5/2 7.5 YR/, slightly wet, sandy loam, some fragments of gravels, weak angular blocky structure, the aggregates are covered with white coatings and break easily under

Appendix 4 /cont'd/

pressure of fingers, a few fine and very fine dead roots, boundary is well distinct.

85 - 95 cm Dark brown /4/4 7.5 YR/, slightly wet sandy loam, blended with fine gravels, weak platy angular blocky structure, some white coatings, a few very fine roots, plenty of insects, mainly termites, boundary clear.

95 - 150 cm Brown to dark brown /5/2-4/4 7.5 YR/, slightly moist, silt with rounded fine gravels and big stones, having the largest diameter of 15 - 20 cm, the silt particles have platy rectangular structure, the gravels and stones are deeply weathered and crush easily by touching, a few very fine plant roots found.

Sampling from the layers: 0-5 cm, 5-25 cm, 25-29 cm, 29-50 cm, 50-56 cm, 56-79 cm, 79-85 cm, 85-95 cm,

Profile Number: 102

Soil Name: Moderately Coarse-Textured, Calcareous, Deep, Alluvial Soil with Two or More Silt-Accumulation-Layers /1.22/

Higher Category Classification: Alluvial Soils /Calcaric Fluvisols /Jc/, Entisols - Orthic Orthustens, Entisols - Calcaric Torrifluvents/

Date of Examination: 12.11. 1969.

Author: István J. Boros

Location: Y.A.R., Wadi Zabid Project, in the islet of the Wadi Bira, on the southern part of the Project the distance from the profile to the Tamarix sp. tree in direction of SW is 71 m and to the Arge tree in direction of E is 90 m.

Appendix 4 /cont'd/

Land Form:

i. Physiographic Position: Relatively low element of the relief, there is a deep depression in direction of SW, partly planted by Sorghum sp.

ii. Surrounding land form: Plain, fields are surrounded by big earth banks with a great number of bushes on it /soul, arge, sudad, tor, coconut etc.,/

iii. Microtopography: Surface of the land has ridges /4 cm high/ and furrows /about 4 cm deep/, as a result of previous bullocks' cultivation.

Slope on which profile is sited: The gentle slope of the field is facing S.

Vegetation and Land-Use: Recently Sorghum sp. was grown. There are some weeds such as: sourage, mohader, alga, gushrok, kubiz, zekf, towail, labna.

Parent Material: Irrigation Deposits on loess-like materials.

Drainage: Class 4 - well drained.

Moisture Condition in Profile: 0-123 cm dry, 123-184 cm slightly wet.

Presence of Surface Stones, Rock Outcrops: None

Evidence of Erosion: Slight

Presence of Salt or Alkali: None

Human Influence: Very strong, expressed in the construction of banks, irrigation canals and other hydrological structures with the aim of utilizing flood irrigation water. The irrigation water has plenty of floating deposits.

Brief Description of the Profile: Very much stratified soil profile. The silt-accumulation-layers increase the water management properties of the coarse-

Appendix 4 /cont'd/

textured soils. Under the condition of a good water supply this soil is capable of giving High yields of crops. Land capability class - class 2.

Effervescence: Very strong from the surface up to the parent materials, except the horizon, which is at a depth of 115-123 cm.

Profile Description:

0 - 14 cm Brown /5/3 10 YR/, dry loamy sand, loose, dusty unstable structure, some silt-particles are mixed to the loamy sand, many sparkling fragments of mica, plentiful fine dead roots, boundary gradual.

12 - 25 cm Brown /5/3 10 YR/, dry, sandy loam, undisturbed, slightly compact, a few fine dead roots, many sparkling fragments of mica, unstable angular blocky structure, some silt-particles are mixed into the layer, a couple of white coatings, boundary gradual.

25 - 35 cm Brown /5/3 10 YR/, dry, sandy loam, but it is more sandy than the overlaying horizon, which is mixed with some silt-particles, slightly compact, unstable angular blocky structure, many fine dead roots, and sparkling fragments of mica, a few white coatings, boundary well distinct.

35 - 40 cm Brown /5/3 10 YR/, dry, silt-accumulation-horizon, in some parts more sand has been mixed, compact, platy rectangular structure, a few fine dead roots, many sparkling fragments of mica, a few white coatings, boundary clear.

Appendix 4 /cont'd/

40 - 52 cm Brown /5/3 10 YR/, sandy loam, but the medium sand, which is located in the lower part of the horizon has greyish brown /5/2 10 YR/ colour, dry, slightly cemented, unstable angular blocky structure, some silt-particles are mixed to the layer, many fine dead roots and sparkling fragments of mica, boundary clear, but waving.

52 - 59 cm Pale brown /6/3 10 YR/, dry loam, on the right side of this horizon medium sand found, having colour of greyish brown /5/2 10 YR/, in the layer silt is dominant, the latter is very compact and has platy rectangular structure. The sand is loose and has dusty unstable structure. A few fine dead roots, many sparkling fragment of mica, boundary distinct.

59 - 70 cm Greyish brown /5/2 10 YR/ and brown /5/3 10 YR/, dry, sandy loam, medium sand mixed with silty particles, slightly compact, dusty unstable angular blocky structure, a few fine dead roots, many sparkling fragments of mica, boundary gradual.

70 - 115 cm Pale brown /6/3 10 YR/, dry, this horizon is a misture of silt and fine sand as the flood blended upside-down the sediments. In the middle of this horizon the amount of the silt is getting less, while in the end it is increasing, comented, the pure silt has platy rectangular structure, the sandy silt has an unstable angular blocky structure, there is a rusty coating /iron/ on the surface of the silt particles, a certain part

Appendix 4 /cont'd/

of the aggregates are porous, many root-prints, a few fine dead roots, many sparkling fragments of mica, a few fine and medium holes, boundary clear.

115 - 123 cm Greyish brown /5/2 10 YR/, loamy sand, dry, loose, structureless, many sparkling fragments of mica, a few fine dead roots, boundary distinct.

123 - 149 cm Brown /5/3 10 YR/, slightly wet, loam, porous, compact, angular blocky structure, there is a thin layer of silt-accumulation in the horizon, a few white coatings, few very fine dead roots, boundary gradual.

149 -184 cm Brown /5/3 10 YR/, slightly wet, loess-like material, porous, less compact than the overlying horizon, angular blocky structure, a few fine dead roots, thin patchy white coatings.

Sampling from the layers: 0-14 cm, 14-25 cm, 25-35 cm, 35-40 cm, 40-52 cm, 52-59 cm, 59-70 cm, 70-78 cm, 78-87 cm, 87-93 cm, 93-106 cm, 106-115 cm, 115-123 cm, 123-134 cm, 134-149 cm, 149-165 cm, 165-175 cm.

Profile Number: 49

Soil Name: Medium-Textured Soil, Affected by Wind Erosion, Recent Wind Deposit 10-25 cm in Thickness /2.32/.

Higher Category Classification: Soils, Affected by Wind Erosion

Date of Examination: 7. 10. 1969.

Author: István J. Boros

Location: Y.A.R., Wadi Zabid Project, near to the Wadi Al-Sharabi and the willage Mahwa Al-Khelaif. The

Appendix 4 /cont'd/

distance from the profile to the sayal tree on the bank in direction of NW is 46 m and to the bush, being in front of the SW bank is 34 m.

Land Form:

i. Physiographic Position: Higher terrace of the area

ii. Surrounding land form: Plain to depressed and the fields are surrounded by big earth banks

iii. Microtopography: Surface of the lands has ridges /4 cm high/ and furrows /about 4 cm deep/ as a result of previous bullocks' cultivation.

Slope on which profile is sited: The slope of the field faces gently SW. The next terrace beyond this bank is about 2 m lower.

Vegetation and Land-Use: Recently Indian cotton was grown. The plants were in very poor condition, nearly dried out, some plants were blossoming.

Parent Material: Loess-like material.

Drainage: Class 4 - well drained

Moisture condition in profile: Dry throughout the profile

Presence of Surface Stones, Rock Outcrops: None

Evidence of Erosion: Wind erosion considerable

Presence of Salt or Alkali: None

Human Influence: Very strong, expressed in the construction of banks, irrigation canals and other hydrological structures with the aim of utilizing flood irrigation water.

Brief Description of the profile: Originally this profile represented quite a good soil, but later, due to the wind erosion, the fertility of the top horizons was considerably lowered. The wind erosion

Appendix 4 /cont'd/

control is indispensable. The latter combined with water supply and a reasonable irrigation practice gives the prospect of getting enough high yields even of the cash-crops. Land capability class - class 3.

Effervescence: Very strong from the surface up to the botton of the pit.

Profile Description:

0 - 20 cm Brown /5/3 10 YR/, dry, fine sandy loam with a great amount of dust, loose, fine angular blocky structure, many fine dead roots and decomposed residue of cotton, many glittering fragments of mica, boundary gradual.

20 - 48 cm Dark brown /3/4 10 YR/, dry loam, in the lower part of the horizon some leached in tongues of the sand, anough loose, fine angular blocky structure, many fine dead roots, in some parts there is an accumulation of silt, at the end of the horizon thin patchy white coatings scattered, a few groundnut of nusher, some holes made perhaps by the termites, boundary gradual.

48 - 88 cm Brown /5/3 10 YR/, dry silty loam, slightly compact, angular blocky structure, porous, many patchy white coatings, there are some sand-tongues, many fine dead roots a few termites' holes, boundary clear.

88 - 107 cm Dark brown /3/4 10 YR/, dry loam, porous, compact or slightly cemented, angular blocky structure, a few gravels, having the diameter of 1 cm, many glittering fragments of mical troughout the

Appendix 4 /cont'd/

horizons, a few fine dead roots, thin patchy white coatings, boundary distinct.

107 - 160 cm Brown /4/3 10 YR/, dry, loam, angular blocky structure, porous, a few very fine dead roots, thin patchy white coatings, some holes made by insects, a few gravels with the diameter of 1 cm, many glittering fragments of mica.

Sampling from the layers: 0-10 cm, 10-20 cm, 20-35 cm, 35-48 cm, 48-62 cm, 62-76 cm, 76-88 cm, 88-107 cm, 107-122 cm, 122-138 cm, 138-153 cm.

Profile Number: 147

Soil Name: Medium-Textured Arid Brown Soil /3.2/

Higher Category Classification: Arid Brown Soils /Haplic Xeresols /Xh/, Aridisols - Orthic and Mollic Camborthids/

Author: István J. Boros

Location: Y.A.R., Wadi Zabid Project, right side of the Wadi Zabid, 1400 m to North from Wadi Mawi and 2100 m to NE from village Al-Qurrayyah. The distance from the profile to the Arge tree in direction of North 59 m and to the second Arge tree in direction of E is 46 m.

Land Form:

i. Physiographic Position: Relatively high terrace of the area

ii. Surrounding land form: Plain to depressed, fields are surrounded by big earth banks

iii. Microtopography: Surface of the lands has ridges /4 cm high/ and furrows /about 4 cm deep/ as a result of previous bullocks' cultivation.

Appendix 4 /cont'd/

Slope on which profile is sited: The slope of the field is facing gently SW.

Vegetation and Land-Use: Recently Sorghum and sesame sp. were grown. Now after harvesting the field is tilled. No crop-rotation. This field is irrigated from the Wadi Al-Mawi once a year. Some weeds found such as: zegf, wobel, sourage, motein, hassar, arive, nusher, bokem.

Parent Material: Loess-like material

Drainage: Class 4 - well drained

Moisture Condition in Profile: Slightly wet throughout the profile except the external surface.

Depth of Groundwater Table: In the neighbouring well is about 16 m.

Presence of Surface Stones, Rock Outcrops: None

Evidence of Erosion: Very strong on the surface of the fields due to high speed of irrigation water

Presence of Salt or Alkali: None

Human Influence: Very strong expressed in the construction of banks, irrigation canals and other hydrological structures with the aim of utilizing flood irrigation water.

Brief Description of the Profile: The profile is compounded of sandy silt, sandy loam, loam and clayey loam. The colour varies from brown /5/3 10 YR/ through greyish brown /5/2 10 YR/ to brown /4/3 10 YR/. According to the result of the particle size distribution analysis this soil can be called as a medium-textured loamy soil. Its potential fertility is good, but the agricultural use is

Appendix 4 /cont'd/

limited by want of irrigation water supply. Because of these engineering and marketing as well as of economical considerations this soil is classified as a class 3 in the land capability groups.

Effervescence: Very strong from the surface up to the parent materials.

Profile Description:

0 - 15 cm Brown /5/3 10 YR/, dry, silty loam, loose, from dusty to crumb structure, some sparkling fragments of mica, a few leaves of Sorghum ploughed into the soil, a few dead roots, clear boundary.

15 - 44 cm Brown /5/3 10 YR/, slightly wet, loam, slightly compact angular blocky structure, a few fine dead roots, gradual boundary.

44 - 63 cm Brown /5/3 10 YR/, slightly wet, sandy loam, slightly compact, unstable angular blocky structure, in the middle of this horizon there is a thin layer of silt, some sparkling fragments of mica, a few holes made by insects, clear boundary.

63 - 75 cm Brown /4/7 10 YR/, slightly wet, clayey loam, but contains a notable amount of silt-fractions, compact, angular blocky structure, a few fine dead roots, some sparkling fragments of mica, distinct boundary.

75 - 87 cm Brown /5/3 YR/, slightly wet, loam, compact, angular blocky structure, porous, a few fine dead roots, some sparkling fragments of mica, thin patchy white coatings, many rootprints and rootcanals, gradual boundary.

Appendix 4 /cont'd/

87 - 114 cm Greyish brown /5/2 10 YR/ to brown /5/3 10 YR/, slightly wet, medium to fine sandy loam, slightly compact, unstable angular blocky structure, thin patchy white coatings, a few fine gravels with the diameter of 2 cm, some holes of different size made by insects, clear boundary.

114 - 180 cm Brown /5/3 10 YR/, slightly moist loess, compact, porous angular blocky structure, thin patchy white coatings, a few holes of different sizes, many termites' mounts with wormcasts in it, a few very fine dead roots.

Sampling from the layers: 0-15 cm, 15-29 cm, 29-44 cm, 44-63 cm, 63-75 cm, 75-87 cm, 87-102 cm, 102-114 cm, 114-129 cm, 129-144 cm, 144-159 cm.

Profile Number: 227

Soil Name: Fine-Textured Arid Brown Soil /3.4/

Higher Category Classification: Arid Brown Soils /Haplic Xerosol /Xh/, Aridisols - Orthic and Mollic Camborthids/

Date of Examination: 20. 1. 1970.

Author: István J. Boros

Location: Y.A.R., Wadi Zabid Project, 1000 m to S from the Wadi Zabid, 1600 m to W-SW from the Experimental Farm and 2000 m to NW from the FAO-Camp. Distance from the profile to the Arge tree in direction of N is 55 m and to the Athle bush in direction of S is 65 m.

Land Form:

i. Physiographic Position: Medium high element of the relief

Appendix 4 /cont'd/

ii. Surrounding land: Plain to depressed, fields are surrounded by the medium high earth banks

iii. Microtopography: Surface of the lands has ridges /about/ 5 cm high /and furrows/ about 5 cm deep/ as a result of previous bullocks' cultivation

Slope on which Profile is Sited: The gentle slope of the field is facing NE.

Vegetation and Land-Use: Recently Sorghum sp. /durra/ was grown. It was harvested 2 months ago. This field was irrigated half a year before. There are some weeds such as: wobel, sanfa, nusher, kurena.

Parent Material: Loess-like deposits

Drainage: Class 4 - well drained

Moisture Condition in Profile: Upper 30 cm is dry, deeper slightly wet.

Presence of surface stones, rock outcrops: None

Evidence of Erosion: Slight water and wind erosion detected.

Presence of Salt or Alkali: None

Human Influence: Very strong expressed in the construction of banks, irrigation canals and other hydrological structures with the aim of utilizing flood irrigation water, which has plenty of floating deposits.

Brief Description of the Profile: Fine-textured soil, which is getting heavier dependent on the depth. In spite of the heavier mechanical composition and the compactness, the potential fertility of the soil is high dependent on adequate water supply. The fine texture needs application of the subsoil loosening and the heavy doses of organic matter /farmyard manure/. Land capability class - class 2.

Effervescence: Very strong from the surface up to the parent material

Appendix 4 /cont'd/

Profile Description:

0 - 10 cm	Brown /5/3 10 YR/, dry, clayey loam, medium subangular blocky structure, compact, plentiful roots, some sparkling fragments of mica, gradual boundary.
10 - 28 cm	Brown /5/3 10 YR/, dry, clay, very compact, angular blocky structure, the soil particles are easily friable, many holes of different size, a few patchy white coatings, some sparkling fragments of mica, a few fine dead and alive roots, many termites' holes with wormcasts, some silt particles scattered, clear boundary.
28 - 106 cm	Brown /5/3 10 YR/, slightly wet, clayey loam, compact, angular blocky structure, many holes of different size with wormcasts, they are perhaps termites' mounts, some sparkling fragments of mica, a few fine and medium dead and alive roots, a few thin and patchy white coatings, gradual boundary.
106 - 123 cm	Dark brown /4/3 10 YR/, slightly wet, silty clay loam, compact, angular blocky structure, many fine holes with some wormcasts, the aggregates areeasily friable, some sparkling fragments of mica, gradual boundary.
123 - 170 cm	Dark brown /4/3 10 YR/, slightly wet, silty clay, more compact than the overlying horizon, angular blocky structure, the soil particles are hardly friable, many holes, a few very fine dead roots, some sparkling fragments of mica, many fine gravels with the diameter of 1-2 cm

Appendix 4 /cont'd/

are scattered.

Sampling from the layers: 0-10 cm, 10-19 cm, 19-28 cm, 28-43 cm, 43-58 cm, 58-74 cm, 74-90 cm, 90-106 cm, 106-123 cm, 123-138 cm, 138-154 cm, 154-170 cm.

Profile Number: 17

Soil Name: Alkali soil with structural "B" horizon.

Higher Category Classification: Salt-affected soils /4/.

Date of Examination: 24 August 1969.

Author: István J. Boros

Location: Y.A.R., Wadi Zabid Project, 1300 m to S from Tuheita village and 300 m to N from the pumping station.

Land form:

i. Physiographic Position: The profile sited in the field, being on the 4-5 m high loess-like deposition, which is located on the left side embankment of the ancient flow of the Wadi Zabid about 100 m away from the point of contact of the desert sand hills and shrubs with the agricultural lands.

ii. Surrounding land form: Nearly levelled fields surrounded by medium high banks:

iii. Microtopography: Ridges and furrows on the soil surface as a result of previous bullocks' cultivation. In some parts of the lands small irrigation furrows are made.

Slope on which profile is sited: Gentle slope towards south-southwest.

Vegetation and land-use: Sorghum stubble, on the Eastern half of the field second growth of the sorghum green. Weeds: arive, sourage, feswa, waika, arayn. Irrigation cropping by means of pumping station. Certain croprotation is used. After sorghum cotton

Appendix 4 /cont'd/

was planted.

Parent material: Loess-like deposits.

Drainage: Class 4 - well drained.

Moisture condition in profile: top 50 cm of profile dry, below it slightly wet.

Presence of surface stones, rock outcrops: None

Evidence of Erosion: Very limited, mainly wind erosion.

Presence of salt and alkali: Moderate alkalinity.

Human influence: Very strong expressed in the construction of banks and irrigation activity.

Brief description of the Profile: The profile belongs to the medium-textured soils. As it is moderately alkaline the formation of structural "B" horizon is observeable. The presence of silt shows that previously here was flood irrigation from the Wadi Zabid. Now use of pumping irrigation has certain danger because the quality of the water is not satisfactory enough. But through the application of the necessary rate of irrigation water and modern agricultural management practice all these problems can be solved. Land capability class - class 4, but in spite of it the farmers get adequate yields of crops because of pumping irrigation. By lowering the land capability class we tried to point out the possibility of further deterioration of the soil fertility status.

Effervescence: Very strong from the surface up to the parent materials.

Appendix 4 /cont'd/

Profile description:

A_p	0 - 11 cm	Brown /5/3 10 YR/, dry, loam, compact, angular structure, the particles are very porous, plentiful alive and dead roots, boundary distinct.
B_1	11 - 22 cm	Brown /4/3 10 YR/, dry, silty loam, more compact than the overlying horizon, subangular blocky structure, vertical cracks, the particles are very porous, small scatered patches of cutan on ped faces, plentiful roots. The compactness and columns formed by vertical cracks resemble the B_1 horizon of alkaline soils /solonetz type/. Boundary gradual.
B_2	22 - 56 cm	Dark yellowish brown /4/4 10 YR/, slightly wet, loam, medium prismatic and columnar structure, very compact, very porous, plentiful fine dead roots, moderate patchy cutans, boundary clear.
B_3	56 - 118 cm	Dark brown /3/4 10 YR/, slightly, wet, loam, coarse prismatic structure, more compact than the overlying horizon, thick broken cutans, many holes, rootcanals and termite mounts, frequent dead and alive fine roots, boundary clear.
C	118 - 154 cm	Dark yellowish brown /3/4 10 YR/, slightly wet, silty loam, loam, which looks like loess, fine prismatic and columnar structure, compact and very porous, thin patchy white coatings

Appendix 4 /cont'd/

continuously getting less than in the overlying horizon, a few very fine roots.

Sampling from the layers: 0-11 cm, 11-22 cm, 22-39 cm, 39-56 cm, 56-71 cm, 71-89 cm, 89-118 cm, 118-136 cm, 136-150 cm.

Appendix 5

RESULTS OF SOIL AND WATER ANALYSES

Appendix 5

RESULTS OF SOIL AND WATER ANALYSES

TABLE 1.

HORIZONS AND SAMPLING DEPTHS
WADI ZABID PROJECT

Profile No.	Horizon cm	Sampling depth cm	Profile No.	Horizon cm	Sampling depth cm	Profile No.	Horizon cm	Sampling depth cm
1	2	3	1	3	2	1	2	3
2.	0— 5	0— 5	9.	0— 16	0— 16	13.	0— 5	0— 5
	5— 29	5— 29		16— 86	16— 31		5— 14	5— 14
	29— 56	30— 50			31— 46		14— 67	14— 32
	56— 85	56— 79			46— 61			32— 17
	85— 95	85— 94			61— 76			47— 67
					76— 86		67—105	67— 85
4.	0— 6	0— 6		86—124	86—101			85—105
	6— 22	6— 22			101—116		105—150	105—125
	22— 63	22— 42			116—124			
		42— 63		124—154	124—139	14.	0— 12	0— 12
	63—150	93—104			139—154		12— 48	12— 30
								20— 48
5.	0— 10	0— 10	10.	0— 15	0— 15		48— 85	48— 61
	10— 35	10— 35		15— 30	15— 30			61— 73
	35— 58	35— 56		30— 63	30— 45			73— 85
	58— 81	60— 80			45— 63		85—150	85—100
	81—125	80—100		63— 98	63— 78			100—115
					78— 98			
6.	0— 10	0— 10		98—150	98—115	15.	0— 16	0— 16
	10— 55	10— 30			115—130		16— 42	16— 30
		30— 50			130—150			30— 42
	55— 70	55— 70					42— 58	42— 58
	70—150	70—150	11.	0— 12	0— 12		58— 92	58— 75
				12— 25	12— 25			75— 92
7.	0— 16	0— 16		25—150	25— 40		92—150	
	16— 26	16— 26			40— 55			
	26— 80	26— 43			55— 70	16.	0— 16	0— 16
		43— 59			70— 85		16— 33	16— 33
		59— 80					33—106	33— 48
	80—154	80— 98	12.	0— 18	0— 10			48— 63
		98—115			10— 18			63— 79
		132—152		18— 96	18— 33			79— 92
					33— 48			92—106
8.	0— 10	0— 10			48— 63		106—150	106—122
	10— 23	10— 23			63— 78			122—140
	23— 78	23— 32			78— 96			
		32— 52		96—111	96—111	17.	0— 11	0— 11
		52— 78			111—126		11— 22	11— 22
	78—110	78— 95			126—141		22— 56	22— 39
		95—110						39— 56
	110—150	110—127		111—155			56—118	56— 71
		127—150						71— 89
								89—118
							118—154	118—136
								136—150

TABLE 1.

HORIZONS AND SAMPLING DEPTHS — Continued
WADI ZABID PROJECT

Profile No.	Horizon cm	Sampling depth cm
1	2	3
18.	0— 10	0— 10
	10— 18	10— 18
	18— 47	18— 32
		32— 47
	47— 92	47— 63
		63— 79
		79— 92
	92—120	92—106
		106—120
	120—154	120—140
19.	0— 24	0— 12
		12— 24
	24— 48	24— 36
		36— 48
	48— 86	48— 62
		62— 74
		74— 86
	86—137	86—101
		101—118
		118—137
	137—150	137—150
25.	0— 3	0— 3
	3— 24	12— 24
	24— 66	39— 54
	66— 98	66— 79
	98—119	98—106
	119—193	119—134
29.	0— 12	0— 12
	12— 20	12— 20
	20— 35	20— 35
	35— 45	
	45— 64	45— 64
	64— 92	81— 92
	92—115	107—115
	115—120	115—120
	120—150	120—140
36.	0— 12	0— 12
	12— 23	12— 23
	23— 51	23— 51
	51— 57	51— 57
	57— 64	57— 64
	64— 78	64— 78
	78—133	93—108
	133—143	133—143
	143—160	143—158

Profile No.	Horizon cm	Sampling depth cm
1	2	3
49.	0— 20	0— 10
	20— 48	20— 35
	48— 88	62— 76
	88—107	88—107
	107—160	138—153
59.	0— 13	0— 13
	13— 25	13— 25
	25— 51	25— 38
		38— 51
	51— 83	51— 67
	83—137	83— 99
		115—125
	137—160	137—152
68.	0— 7	0— 7
	7— 27	7— 17
	27— 42	27— 42
	42— 94	42— 56
		71— 82
	94—155	94—100
		115—130
77.	0— 10	0— 10
	10— 31	10— 21
	31— 57	31— 44
	57— 87	57— 72
	87— 94	87— 94
	94—133	107—120
	133—155	133—144
86.	0— 10	0— 10
	10— 32	10— 16
		16— 32
	32— 81	32— 47
		47— 62
	81—107	81— 94
	107—117	107—117
	117—139	128—139
91.	0— 12	0— 12
	12— 39	12— 27
		27— 39
	39— 54	39— 54
	54— 95	65— 80
	95—110	95—110
	110—175	128—150
97.	0— 13	0— 13
	13— 22	13— 22
	22— 50	22— 37
	50— 64	50— 64
	64— 80	64— 80
	80—111	80— 95
	111—126	111—126
	126—155	141—155

Profile No.	Horizon cm	Sampling depth cm
1	2	3
102.	0— 14	0— 14
	14— 25	14— 25
	25— 35	25— 35
	35— 40	35— 40
	40— 52	40— 52
	52— 59	52— 59
	59— 70	59— 70
	70—115	78— 87
		93—106
	115—123	115—123
	123—149	134—149
135.	0— 12	0— 12
	12— 21	12— 21
	21— 34	21— 34
	34— 61	34— 50
	61— 84	61— 73
	84— 98	84— 98
	98—112	98—112
	112—124	112—124
	124—137	124—137
	137—142	137—142
141.	0— 11	0— 11
	11— 21	11— 21
	21— 37	21— 37
	37— 68	37— 53
	68—100	68— 83
	100—116	100—116
	116—136	116—136
	136—165	136—153
147.	0— 15	0— 15
	15— 44	15— 29
	44— 63	44— 63
	63— 75	63— 75
	75— 87	75— 87
	87—114	87—102
	114—180	114—129
		114—159
153.	0— 6	0— 6
	6— 23	6— 23
	23— 43	23— 43
	43— 65	43— 65
	65—106	80— 92
	106—134	106—121
	134—153	134—153
158.	0— 10	0— 10
	10— 24	10— 24
	24— 57	24— 40
	57— 87	57— 73
	87—115	87—101
	115—127	115—127
	127—147	127—147

TABLE 1.

HORIZONS AND SAMPLING DEPTHS — Continued
WADI ZABID PROJECT

Profile No.	Horizon cm	Sampling depth cm
1	2	3
165.	0— 9	0— 9
	9— 35	9— 23
		23— 35
	35— 68	35— 52
	68— 99	68— 83
	99—142	99—113
		128—142
	142—167	154—167
173.	0— 10	0— 10
	10— 21	10— 21
	21— 45	21— 30
	45— 72	45— 58
	72— 90	72— 90
	90—110	90—110
	110—155	125—140
176.	0— 7	0— 7
	7— 43	7— 22
		22— 32
		32— 43
	43— 68	43— 57
	68— 82	68— 82
	82—108	82— 95
	106—115	108—115
178.	0— 8	0— 8
	8— 29	8— 17
	29— 40	29— 40
	40— 57	40— 57
	57— 77	57— 67
	77—106	77— 93
	106—128	106—119
	128—155	128—140
193.	0— 9	0— 9
	9— 21	9— 21
	21— 61	21— 35
		49— 61
	61— 94	67— 94
	94—165	110—130
		150—165
197.	0— 14	0— 14
	14— 48	14— 25
		36— 48
	48—162	63— 78
		108—123
		138—153

Profile No.	Horizon cm	Sampling depth cm
1	2	3
198.	0— 13	0— 13
	13— 31	13— 31
	31— 44	31— 44
	44— 65	44— 65
	65— 80	65— 80
	80— 99	80— 99
	99—121	114—121
	121—152	121—152
200.	0— 6	0— 6
	6— 26	6— 16
		16— 26
	26— 47	26— 36
	47— 61	47— 61
	61— 99	73— 86
	99—150	99—114
		129—144
206.	0— 11	0— 11
	11— 22	11— 22
	22— 75	22— 39
		39— 58
	75— 86	75— 86
	86—109	95—109
	109—117	109—117
	117—131	117—131
	131—156	144—156
209.	0— 15	0— 15
	15— 35	15— 35
	35— 53	35— 53
	53—132	53— 70
		90—110
	132—166	132—148
214.	0— 16	0— 16
	16— 34	16— 34
	34— 57	34— 45
		45— 57
	57—131	57— 73
		90—110
	131—145	131—145
220.	0— 10	0— 10
	10— 31	10— 20
	31— 42	31— 42
	42— 61	42— 51
	61—136	61— 76
		90—105
	136—182	136—151

Profile No.	Horizon cm	Sampling depth cm
1	2	3
227.	0— 10	0— 10
	10— 28	10— 19
		19— 28
	28—106	28— 43
		58— 74
		90—106
	106—123	106—123
	123—170	138—154

TABLE 2.

ANALYTICAL DATA OF SOILS
WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble			Total				Soluble	
			CaCO₃ %	P_2O_5 %	K_2O %	N %	Humus %	C %	C:N	P_2O_5 mg/100 g of soil	K_2O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10	11	12
2	0— 5	8,18	2,48	0,087	0,387	0,022	0,525	0,302	14,5	47,6	21,2
	5— 25	8,10	1,64	0,075	0,356	0,022	0,345	0,200	9,1	42,3	11,2
	30— 50	8,10	2,48	0,049	0,362	0,030	0,470	0,273	9,1	33,6	10,0
	56— 79	8,10	3,20								
	85— 94	8,10	1,75								
4	0— 6	8,20	2,17	0,120	0,368	0,024	0,396	0,229	9,5	60,4	27,2
	6— 22	8,20	1,86	0,083	0,334	0,032	0,637	0,370	11,5	49,6	13,4
	22— 42	8,15	2,38	0,083	0,331	0,034	0,628	0,362	10,6	34,8	9,0
	42— 63	8,15	1,94								
	93—104	8,00	1,34								
5	0— 10	8,35	2,57	0,099	0,344	0,029	0,426	0,242	8,3	61,2	23,0
	10— 35	8,25	2,46	0,086	0,359	0,020	0,325	0,187	9,3	47,6	12,0
	35— 56	8,05	2,47	0,056	0,281	0,022	0,382	0,222	10,0	40,4	9,0
	60— 80	8,20	2,67								
	80—100	8,30	1,54								
6	0— 10	8,10	1,76	0,104	0,425	0,031	0,640	0,369	11,9	61,6	32,0
	10— 30	8,35	5,80	0,096	0,494	0,017	0,160	0,092	15,3	64,0	16,2
	30— 50	8,05	1,87	0,062	0,293	0,019	0,358	0,195	10,2	26,8	9,0
	55— 70	8,00	3,01	0,082	0,312	0,032	0,745	0,433	13,5	19,6	8,8
	70—150	8,00	1,75								
7	0— 15	8,25	4,12	0,104	0,500	0,046	0,572	0,331	7,2	72,0	42,4
	15— 26	8,25	5,04	0,091	0,544	0,035	0,483	0,279	7,9	68,8	34,8
	26— 43	8,20	2,16	0,118	0,515	0,034	0,549	0,317	9,3	52,0	33,0
	43— 59	8,20	5,25	0,091	0,544	0,023	0,451	0,261	11,3	49,6	25,0
	59— 80	8,15	5,89								
	80— 98	8,20	5,25								
	98—115	8,30	6,90								
	115—132	8,25	8,94								
	132—152	8,30	7,17								
8	0— 10	8,45	4,73	0,154	0,475	0,012	0,148	0,085	7,1	74,0	28,4
	10— 23	8,30	5,15	0,065	0,418	0,022	0,606	0,352	16,0	49,6	14,8
	23— 32	8,40	6,10	0,126	0,412	0,020	0,501	0,289	14,4	55,2	23,0
	32— 52	8,30	6,83	0,078	0,365	0,041	0,869	0,502	12,2	46,8	24,0
	52— 78	8,25	6,34								
	78— 95	8,40	4,42								
	95—110	8,35	5,78								
	110—127	8,30	7,34								
	127—150	8,45	7,17								
9	0— 16	8,40	4,74	0,113	0,456	0,047	1,005	0,580	12,3	82,8	36,4
	16— 31	8,35	5,78	0,162	0,412	0,030	0,463	0,267	8,9	77,6	24,6
	31— 46	8,30	5,55	0,143	0,406	0,027	0,501	0,289	10,7	74,0	22,4
	46— 61	8,30	5,76	0,086	0,450	0,036	0,629	0,363	10,0	70,4	24,0
	61— 76	8,35	5,02								
	76— 86	8,30	6,25								
	86—101	8,30	6,97								
	101—116	8,20	7,48								
	116—124	8,10	6,45								
	124—139	8,00	7,27								
	139—154	7,95	7,07								

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble			Total					Soluble	
			$CaCO_3$ %	P_2O_5 %	K_2O %	N %	Humus %	C %	C:N		P_2O_5 mg/100 g of soil	K_2O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10		11	12
10	0—15	8,30	4,51	0,157	0,412	0,038	0,478	0,276	7,2		88,0	37,4
	15—30	8,25	4,82	0,158	0,462	0,017	0,427	0,247	14,5		91,2	36,8
	30—45	8,35	5,02	0,145	0,389	0,018	0,328	0,189	10,5		91,2	37,3
	45—63	8,30	4,81	0,150	0,453	0,019	0,419	0,242	12,7		80,8	37,6
	63—78	8,30	5,33									
	78—98	8,45	5,43									
	98—115	8,30	4,71									
	115—130	8,30	5,12									
	130—150	8,25	5,64									
11	0—12	8,30	4,81	0,082	0,359	0,039	0,647	0,374	9,5		71,6	31.6
	12—25	8,40	5,44	0,155	0,384	0,018	0,322	0,186	10,3		63,2	28.8
	25—40	8,40	6,59	0,128	0,412	0,022	0,480	0,277	12,5		49,6	24,6
	40—55	8,40	6,50	0,138	0,375	0,016	0.331	0,191	11,9		48.0	35,6
	55—70	8,40	6,09									
	70—85	8,35	5,68									
12	0—10	8,45	4,88	0,127	0,381	0,039	0,716	0,413	10,5		70,0	20,3
	10—18	8,50	5,09	0,190	0,359	0,022	0,504	0,291	13,2		70,4	26.4
	18—33	8,40	5,69	0,161	0,368	0,038	0,695	0,401	10,5		57,2	21,2
	33—48	8,40	5,69	0,148	0,359	0,025	0,565	0,328	13,1		50,8	16.8
	48—63	8,40	5,39	0,108	0,406	0,038	0.758	0,438	11,5		43,6	15,6
	63—78	8,40	6,30									
	78—96	8,50	7,12									
	96—111	8,55	7,73									
	111—126	8,15	6,41									
	126—141	8,55	6,20									
13	0—5	8,40	4,27	0,106	0,406	0,030	0,486	0,280	9,3		79,6	38,0
	5—14	8,45	4,27	0,107	0,474	0,028	0,466	0,269	9,6		77,6	30,4
	14—32	8,30	5,70	0,177	0,609	0,032	0,435	0,251	7,8		77,2	28,8
	32—47	8,20	6,51	0,205	0,594	0,028	0,601	0,347	12,3		74,0	25,2
	47—67	8,15	5,29	0,117	0,564	0,034	0,561	0,324	9,5		68,8	23,2
	67—85	8,20	4,89									
	85—105	8,15	5,19									
	105—125	8,60	7,34									
14	0—12	8,35	3,36	0,108	0,466	0,025	0,427	0,246	9,8		74,0	29,2
	12—30	8,30	4,28	0,133	0,511	0,021	0,246	0,142	6,7		68,8	25,2
	30—48	8,25	5,30	0,142	0,511	0,017	0,297	0,172	10,0		57,2	20,0
	48—61	8,20	5,02	0,184	0,466	0,019	0,361	0.208	10,9		48,4	16.40
	61—73	8,30	4,70									
	73—85	8,05	2,64									
	85—100	8,30	4,28									
	100—115	8,40	4,59									
15	0—16	8,40	6,25	0,168	0,474	0,016	0,409	0,236	14,7		68,4	26,0
	16—30	8,35	3,74	0,214	0,534	0,019	0,391	0,227	11,9		66,0	25.4
	30—42	8,30	3,96	0,302	0,526	0,010	0,475	0,274	27,4		57,2	22,8
	42—58	8,35	5,82	0,146	0.368	0,022	0,427	0,246	11,1		34,4	17,6
	58—75	8,30	6,75									
	75—92	8,30	4,47									
	92—120	8,30	2.49									

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued

WADI ZABID PROJECT

Pro-file No.	Sampling depth cm	pH	Aqua regia soluble: $CaCO_3$ %	Aqua regia soluble: P_2O_5 %	Aqua regia soluble: K_2O %	Total: N %	Total: Humus %	Total: C %	Total: C:N	Soluble: P_2O_5 mg/100 g of soil	Soluble: K_2O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10	11	12
16	0— 16	8,45	4,15	0,178	0,444					70,4	22,8
	16— 33	8,25	5,19	0,186	0,481	0,033	0,455	0,262	7,9	66,8	29,2
	33— 48	8,30	5,31	0,288	0,537	0,029	0,507	0,294	10.0	60,8	27,0
	48— 63	8,30	7,72	0.286	0.526	0,029	0,609	0,354	12.2	62.0	25,2
	63— 79	8,30	5,42								
	79— 92	8,20	5,31								
	92—106	8,25	4,59								
	106—122	8,25	4,90								
	122—140	8,25	6,05								
17	0— 11	8,55	5,63	0,228	0,474	0,041	0,588	0,339	8,2	59,6	25,6
	11— 22	8,90	5,05	0,210	0,493	0,027	0,633	0,365	13,5	54.8	18,4
	22— 39	9,05	6,05	0,270	0,466	0,014	0,357	0,206	14,7	57,2	15,8
	39— 56	9,00	6,57	0,196	0,459	0,027	0,323	0,186	6.8	50,8	19.3
	56— 71	9,00	6,49								
	71— 89	8,95	5,84								
	89—118	9,00	5,42								
	118—136	9,00	5,42								
	136—150	8,95	4,90								
18	0—10	8,45									
	10—18	8,55									
	18— 32	9,00									
	32— 47	9,05									
	47— 63	9,00									
	63— 79	8,90									
	79— 92	9,05									
	92—106	9,05									
	106—120	8,85									
	120—140	8,50									
25	0— 3	8,35	3,57	0,107	0,426	0,051	1,02	0,59	11,6	57,2	23,6
	12— 24	8,45	3,16	0,085	0,318	0,043	0,82	0.48	11,2	52,0	23,2
	39— 54	8,40	3,31	0,074	0,456	0,049	0,95	0,55	11,2	42,4	14.0
	66— 79	8,45	4,27								
	98—109	8,40	5,10								
	119—134	8,45	4,89								
29	0— 12	8,55	3,57	0,073	0,546	0,026	0,45	0,26	10,0	49,2	22.8
	12— 20	7,95	4,07	0,080	0,528	0,047	0,80	0,46	9,8	53,2	26,0
	20— 35	8,10	6,31	0,090	0,516	0,033	0,56	0,33	9,9	48,4	26,0
	45— 64	8,20	5,31	0,225	0,558	0,058	0,94	0,55	9.4	40.0	18.0
	81— 92	8,15	5,31								
	107—115	8,40	4,28								
	115—120	8,45	4,79								
	120—140	8,20	5,51								
36	0— 12	8,00	5,08	0,115	0,624	0,045	0,85	0,49	10,8	56.4	34,6
	12— 23	8,10	4,08	0,080	0,540	0,053	1,06	0,62	11,7	46,6	26,4
	23— 51	8,30	3,98	0,085	0,472	0,031	0,56	0,32	10,3	51,6	19,4
	51— 57	8,25	5,10	0,122	0,564	0,052	0,87	0,50	9,6	46,6	22.4
	57— 64	8,35	4,59	0,097	0,558	0,040	0,85	0,50	11.5	52,0	23.0
	64— 78	8,35	5,10								
	93—108	8,40	3,66								
	133—143	8,35	6,63								
	143—158	8,35	5.51								

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued

WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble			Total				Soluble	
			$CaCO_3$ %	P_2O_5 %	K_2O %	N %	Humus %	C %	C:N	P_2O_5 mg/100 g of soil	K_2O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10	11	12
49	0— 10	8,05	5,73	0,237	0,516	0,078	1,20	0,69	8,8	61,6	50,2
	20— 35	8,35	4,49	0,150	0,492	0,030	0,54	0,31	10,3	49,2	34,6
	62— 76	8,30	6,12	0,187	0,660	0,033	0,58	0,33	10,0	61,6	30,0
	88—106	8,35	5,31								
	106—122	8,35	5,59								
	138—153	8,35	6,63								
Silt-1		8,10	7,12	0,130	0,648	0,149	1,74	1,01	6,8	34,4	29,4
		8,10	7,02	0,155	0,636	0,146	1,68	0,99	6,7	30,4	28,0
59	0— 13	8,20	5,14	0,067	0,399	0,026	0,40	0,23	8,8	30,0	18,3
	13— 25	7,90	6,26	0,096	0,433	0,072	1,08	0,62	8,6	34,6	27,6
	25— 38	8,10	5,54	0,091	0,405	0,029	0,42	0,24	8,4	38,2	25,1
	38— 51	8,20	8,22	0,070	0,390	0,019	0,37	0,22	11,4	32,4	21,4
	51— 67	8,20	5,85								
	83— 99	8,25	5,54								
	115—126	8,30	5,65								
	137—152	8,30	5,85								
68	0— 7	8,20	5,03							36,4	44,0
	7— 17	8,10	8,00							30,0	36,2
	27— 42	8,25	5,95							28,4	17,5
	42— 56	8,20	6,57							43,8	22,3
	71— 82	8,20	5,64							43,8	22,3
	94—100	8,20	6,15								
	115—130	8,20	6,15								
77	0— 10	8,10	6,77							52,4	47,4
	10— 21	8,00	4,62							51,8	44,6
	31— 44	8,20	4,51							44,8	34,0
	87— 94	8,20	5,84								
	107—120	8,25	5,32								
	133—140	8,20	5,02								
86	0— 10	8,25	3,51	0,078	0,424	0,013	0,30	0,17	13,4	51,0	34,0
	10— 16	8,10	3,92	0,083	0,424	0,025	0,45	0,26	10,4	57,8	40,0
	16— 32	7,90	6,19	0,133	0,467	0,036	0,54	0,31	8,8	55,8	39,0
	32— 47	8,00	5,98	0,102	0,462	0,029	0,58	0,34	11,7	55,4	40,0
	47— 62	8,20	4,83	0,091	0,525	0,031	0,52	0,30	9,8	55,4	37,0
	81— 94	8,10	5,12								
	107—117	8,20	2,77								
	128—139	8,15	2,77								
91	0— 12	8,10	6,45	0,091	0,438	0,069	1,05	0,61	9,7	39,6	23,9
	27— 39	8,10	5,21	0,071	0,395	0,042	0,80	0,46	11,1	37,2	21,2
	39— 54	8,20	6,02	0,071	0,381	0,027	0,55	0,32	11,8	39,6	21,2
	65— 80	8,30	8,06								
	95—110	8,25	7,04								
	128—150	8,25	7,55								
97	0— 13	8,35	4,60							63,2	41,8
	13— 22	8,20	2,47							67,2	37,0
	22— 37	8,30	3,70							62,4	29,2
	50— 64	8,30	2,77							37,4	17,0
	64— 80	8,30	5,25							37,4	17,0
	80— 95	8,30	5,46								
	111—126	8,30	4,40								
	141—155	8,30	4,39								

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble			Total				Soluble	
			CaCO$_3$ %	P$_2$O$_5$ %	K$_2$O %	N %	Humus %	C %	C:N	P$_2$O$_5$ mg/100 g of soil	K$_2$O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10	11	12
102	0— 14	8,10	4,40							42,2	40,0
	14— 25	7,95	5,75							39,2	33,2
	25— 35	7,95	6,29							27,2	24.8
	35— 40	7,90	6,70							28,0	23,7
	40— 52	8,10	3,71							23,6	17,4
	52— 59	8,20	4,54							26,0	19,7
	59— 70	8,20	5,92							26,0	19,7
	78— 87	8,20	7,54								
	93—106	8,20	4,69								
	115—123	8,30	4,49								
	134—149	8,25	5,20								
135	0— 12	8,20	5,10							37,6	28,8
	12— 21	8,15	4,81							37,2	25.3
	21— 34	8,10	7,98							28,8	26,0
	34— 50	8,15	4,14							21,2	23,6
	61— 73	8,10	5,17								
	84— 98	8,25	4,66								
	98—112	8,25	4,55								
	124—137	8,20	6,00								
	137—142	8,25	4,24								
141	0— 11	8,20	3,72							50,0	35,8
	11— 21	8,25	3,62							44,4	32,0
	21— 37	8,35	4,97							43,4	23.4
	37— 53	8,35	3,10							42,2	20,0
	68— 83	8,30	3,30								
	100—116	8,10	3,20								
	116—136	8,00	3,52								
	136—153	7,95	3,10								
147	0— 15	8,10	4,97	0,060	0,419	0,063	0,89	0,52	8,3	43,4	39,0
	15— 29	8,20	5,17	0,065	0,409	0,051	0,90	0,56	11,0	41,6	32,4
	44— 63	8,20	5,98	0,028	0,399	0,013	0,19	0,11	8,8	18,6	12,8
	63— 75	8,20	5,16								
	75— 87	8,20	5,36								
	87—102	8,20	4,54								
	114—129	8,20	6,19								
	144—159	8,15	5,78								
153	0— 6	7,90	5,67							31,4	32,0
	6— 23	7,90	5,88							28,4	29,2
	23— 43	8,00	5,36							30,0	24,2
	43— 65	8,05	5,57							25,6	20,6
	80— 92	8,20	4,54								
	106—121	8,25	5,57								
	134—153	8,25	5,36								
158	0— 10	7,95	5,36							35,8	44,6
	10— 24	5,15	6,60							34,2	24,6
	24— 40	8,20	4,74							31,4	23,4
	57— 72	8,20	5,57							23,6	24,6
	87—101	8,20	5,78								
	115—127	8,15	5,88								
	127—147	8,20	4,74								

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble			Total					Soluble	
			CaCO3 %	P2O5 %	K2O %	N %	Humus %	C %	C:N	P2O5	K2O	
										mg/100 g of soil		
1	2	3	4	5	6	7	8	9	10	11	12	
165	0— 9	8,10	4,74	0,102	0,429	0,045	0,75	0,43	9,7	88,0	48 8	
	9— 23	8,20	4,11	0,125	0,409	0,036	0,62	0,36	10,0	92,0	41,4	
	23— 35	8,20	3,49	0,500	0,650	0,038	0,69	0,40	10,6	496,0	117,0	
	35— 52	8,20	4,62	0,449	0,520	0,040	0,85	0,49	12,4	377,0	78,0	
	68— 83	8,30	3,90									
	99—113	8,30	3,80									
	128—142	8,25	3,90									
	154—157	8,20	4,77									
173	0— 10	8,15	5,18							34,2	32,4	
	10— 21	8,20	4,15							28,8	25,1	
	21— 30	8,15	6,22							34,8	23,0	
	45— 58	8,20	5,29							34,2	17,9	
	72— 90	8,25	6,22									
	90—110	8,30	5,67									
	125—140	8,30	6,62									
176	0— 7	8,05	7,04	0,129	0,419	0,112	1,61	0,92	9,4	34,7	37,0	
	7— 22	8,15	6,21	0,097	0,405	0,086	1,46	0,85	9,9	28,8	28,4	
	22— 32	8,05	6,22	0,104	0,376	0,088	1,31	0,76	8,7	28,0	19,1	
	32— 43	8,05	6,22	0,107	0,371	0,087	1,46	0,85	9,8	31,6	24,4	
	43— 57	8,05	5,18	0,117	0,284	0,038	0,64	0,37	9,8	16,8	12,6	
	58— 82	7,90	4,97									
	82— 95	7,90	4,97									
	108—115	8,15	3,11									
178	0— 8	8,05	5,47							42,0	36,2	
	8— 17	8,20	5,47							38,4	34,0	
	29— 40	8,15	5,15							29,2	20,0	
	40— 57	8,20	5,68							34,2	17,5	
	57— 67	8,10	5,05									
	77— 93	8,20	4,42									
	106—119	8,20	4,73									
	128—140	8,20	4,84									
193	0— 9	8,20	3,68							59,2	37,0	
	9— 21	8,25	3,78							56,8	31,2	
	21— 35	8,30	3,99							65,2	29,2	
	49— 61	8,25	4,52							56,2	22,1	
	68— 94	8,00	5,26									
	110—130	7,90	5,47									
	150—165	8,05	5,68									
197	0— 14	8,00	5,89							38,4	37,0	
	14— 25	8,10	5,68							36,2	29,2	
	36— 48	8,20	5,47							34,6	22,6	
	63— 78	8,25	5,68									
	108—123	8,15	4,63									
	138—153	8,20	5,26									
198	0— 13	8,00	5,47	0,054	0,289	0,031	0,53	0,31	9,9	19,8	17,5	
	13— 31	8,10	5,99	0,038	0,352	0,080	1,28	0,75	9,4	28,4	28,0	
	31— 44	8,15	4,84	0,035	0,332	0,028	0,40	0,23	8,4	22,8	15,2	
	44— 65	8,85	5,89	0,075	0,472	0,030	0,44	0,25	8,6	58,8	22,1	
	65— 80	8,20	5,05									
	80— 99	8,15	5,78									
	114—121	8,20	5,89									
	121—152	8,00	6,52									

TABLE 2.

ANALYTICAL DATA OF SOILS — Continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	pH	Aqua regia soluble $CaCO_3$ %	Aqua regia soluble P_2O_5 5	Aqua regia soluble K_2O %	Total N %	Total Humus %	Total C %	C:N	Soluble P_2O_5 mg/100 g of soil	Soluble K_2O mg/100 g of soil
1	2	3	4	5	6	7	8	9	10	11	12
200	0— 6	8,10	5,89	0,053	0,347	0,062	1,12	0,70	11,3	34,6	32,0
	6— 16	8,00	5,78	0,053	0,409	0,072	0,98	0,57	8,0	38,4	37,8
	16— 26	8,15	5,47	0,068	0,366	0,048	0,81	0,47	8,4	30,4	46,8
	26— 36	8,15	4,94	0,068	0,371	0,046	0,74	0,43	9,4	30,4	25,3
	47— 61	8,20	5,47	0,042	0,347	0,036	0,61	0,35	9,7	27,8	18,1
	73— 86	8,20	5,89								
	99—114	8,20	5,89								
	129—144	8,30	5,89								
206	0— 11	7,95	4,94	0,200	0,376	0,083	1,28	0,75	9,0	36,4	42,4
	11— 22	8,10	4,20	0,095	0,352	0,073	1,24	0,72	9,8	28,2	32,4
	22— 39	8,05	5,05	0,125	0,366	0,069	1,14	0,66	9,6	25,0	26,2
	39— 58	8,10	5,36	0,098	0,356	0,078	1,12	0,65	8,4	27,8	21,8
	75— 86	8,10	4,63								
	95—109	8,15	5,89								
	109—117	8,10	6,41								
	117—131	8,15	5,57								
	144—156	8,10	5,47								
209	0— 15	8,10	5,05							41,6	36,2
	15— 35	8,20	4,84							36,8	22,1
	35— 53	8,30	5,89							51,0	20,0
	53— 70	8,35	5,68								
	90—110	8,80	6,35								
	132—148	8,95	6,45								
214	0— 16	8,20	3,54	0,096	0,399	0,026	0,42	0,25	9,6	63,6	36,2
	16— 34	8,25	3,94	0,125	0,409	0,029	0,40	0,23	9,6	60,0	30,4
	34— 45	8,15	3,94	0,076	0,462	0,027	0,42	0,25	9,2	59,2	27,4
	45— 57	8,20	3,33	0,133	0,467	0,025	0,38	0,22	8,8	59,6	26,2
	57— 73	8,35	4,78								
	90—110	8,15	5,62								
	131—145	8,20	4,99								
220	0— 10	8,05	5,41							66,0	44,8
	10— 20	8,15	5,41							50,2	26,0
	31— 42	8,25	5,62							26,4	14,0
	42— 51	8,15	5,62							27,2	13,2
	61— 76	8,10	5,83								
	95—105	8,25	4,99								
	136—151	8,30	5,83								
227	0— 10	8,30	6,14	0,049	0,385	0,030	0,45	0,26	8,8	36,0	13,6
	10— 19	8,30	6,35	0,077	0,347	0,031	0,48	0,28	9,1	34,6	12,6
	19— 28	8,23	6,76	0,083	0,364	0,038	0,55	0,32	8,8	27,0	12,6
	28— 43	8,15	7,07	0,062	0,351	0,039	0,82	0,48	12,3	23,6	11,2
	58— 74	8,20	5,83								
	90—106	8,40	5,20								
	106—123	8,20	6,03								
	138—154	8,30	5,93								

TABLE 3.
PARTICLE SIZE DISTRIBUTION OF SOILS
WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Hygr. moist %	Particle density	Loss in HCl processing %	Particle size in mm: 1—0,25 %	0,25—0,05 %	0,05—0,002 %	<0,002 %	Gravel* <1 mm %
1	2	3	4	5	6	7	8	9	10
2.	0— 5	2,17	2,80	4,63	6,11	50,22	24,62	14,42	3,77
	5— 25	2,76	2,80	4,64	10,14	43,48	25,09	16,65	9,41
	30— 50	3,29	2,84	5,07	14,80	36,47	23,67	19,99	17,60
	56— 79	3,88	2,84	7,01	17,74	31,69	22,12	21,44	57,19
	85— 94	3,42	2,83	4,95	25,06	34,22	20,03	15,74	54,82
4.	0— 6	2,03	2,80	4,84	5,03	50,29	27,76	12,08	4,75
	6— 22	2,73	2,81	4,47	7,04	44,53	29,77	14,19	6,11
	22— 42	3,18	2,81	5,05	14,43	37,48	24,36	18,68	6,65
	42— 63	3,48	2,81	4,93	12,25	43,76	20,49	20,57	11,16
	93—104	2,53	2,85	4,14	39,42	35,39	11,86	9,19	62,51
5.	0— 10	2,23	2,82	4,71	7,57	51,20	23,04	13,48	6,54
	10— 35	2,94	2,83	5,49	9,44	38,74	30,37	15,96	7,00
	35— 56	2,55	2,80	5,30	10,63	44,91	24,31	14,75	9,22
	60— 80	2,30	2,80	4,65	12,09	50,50	21,55	11,21	11,10
	80—100	1,97	2,89	4,02	40,44	33,33	12,67	9,54	69,65
6.	0— 10	2,51	2,82	4,28	5,75	54,58	21,97	13,42	3,59
	10— 30	4,18	2,83	9,78	1,28	18,64	45,54	24,76	3,13
	30— 50	2,82	2,83	4,34	10,73	50,93	18,95	15,05	12,95
	55— 70	3,71	2,87	5,86	16,75	35,30	19,67	22,42	87,26
	70—150	3,22	2,84	4,18	35,74	32,57	16,23	11,18	84,02
7.	0— 16	3,21	2,83	8,08	0,99	30,59	38,46	21,88	1,27
	16— 26	4,14	2,86	10,08	0,79	18,08	43,93	27,12	1,09
	26— 43	4,55	2,86	9,82	1,03	15,59	44,94	28,62	0,87
	43— 59	4,63	2,84	10,91	1,13	13,02	45,22	29,72	0,69
	59— 80	5,14	2,81	10,82	0,68	8,05	49,07	30,58	2,32
	80— 98	5,07	2,87	10,35	0,83	7,38	46,42	35,02	0,79
	98—115	5,25	2,85	11,23	0,89	11,28	45,67	30,93	0,40
	115—132	5,46	2,79	13,21	0,96	3,50	43,62	38,75	1,11
	132—152	5,21	2,75	12,46	1,02	7,29	43,79	35,44	0,92
8.	0— 10	2,88	2,77	7,78	0,57	36,03	37,85	17,77	1,01
	10— 23	3,86	2,85	8,72	3,35	35,04	24,50	28,39	4,01
	23— 32	4,53	2,85	10,67	0,69	15,06	45,46	28,12	0,30
	32— 52	5,48	2,87	11,79	0,48	11,32	43,61	32,80	
	52— 78	5,46	2,89	11,43	0,36	7,89	45,78	34,54	
	78— 95	4,80	2,86	8,84	1,88	20,84	40,45	27,99	3,51
	95—110	5,12	2,88	10,48	1,02	12,32	46,22	29,96	3,51
	110—127	4,19	2,86	12,15	0,64	15,84	48,55	22,82	
	127—150	3,97	2,86	11,32	0,23	21,19	50,68	16,58	
9.	0— 16	3,77	2,78	8,74	0,27	25,84	42,07	23,08	
	16— 31	5,00	2,86	9,47	0,22	15,70	39,99	34,62	
	31— 46	4,80	2,86	9.51	0,23	17,39	38,38	34,49	
	46— 61	5,70	2,83	7,31	0,21	13,29	44,74	34,45	
	61— 76	5,50	2,84	9,41	0,28	12,40	39,80	38,11	
	76— 86	5,35	2,85	11,02	0,38	10,19	43,32	35,09	
	86—101	5,61	2,85	9,51	0,30	14,08	40,93	35,18	
	101—116	5,41	2,86	11,96	0,39	7,73	48,22	31,70	
	116—124	4,48	2,84	11,27	0,57	12,10	46,97	29,09	
	124—139	5,49	2,86	12,25	0,26	3,49	45,52	38,48	
	139—154	5,81	2,88	12,44	0,23	5,33	40,41	41,79	
10.	0— 15	3,51	2,81	8,43	0,32	23,61	50,05	17,59	
	15— 30	3,75	2,83	8,70	0,42	18,77	48,95	23,16	
	30— 45	4,10	2,84	9,10	0,70	14,53	50,21	25,46	
	45— 63	4,55	2,84	9,48	0,55	10,37	52,97	26,63	
	63— 78	4,13	2,84	9,65	0,34	16,27	49,13	24,61	
	78— 98	4,65	2,86	10,70	1,09	17,25	50,23	20,73	
	98—115	3,90	2,84	8,75	0,33	18.95	50.16	21,81	
	115—130	5,10	2,84	10,04	0,48	7,84	51,64	30,00	
	130—150	4,71	2,83	10,75	0,35	7,60	56,61	24,69	

Note: *Gravel percentage (in this case the finer fractions expressed in the % of gravel-free material)

TABLE 3.

PARTICLE SIZE DISTRIBUTION OF SOILS — continued
WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Hygr. moist %	Particle density	Loss in HCl processing %	Particle size in mm 1—0,25	0,25—0,05	0,05—0,002	<0,002	Gravel* <1 mm
					%				
1	2	3	4	5	6	7	8	9	10
11.	0— 12	3,35	2,80	9,26	0,35	22,47	48,34	19,58	
	12— 25	3,85	2,83	9,63	0,37	20,92	49,16	19,92	
	25— 40	4,32	2,84	10,33	0,46	14,85	46,12	28.24	
	40— 55	4,38	2,83	10,41	0,46	14,90	46,83	27,40	
	55— 70	4,56	2,82	10,79	0,45	12,16	48,47	28,13	
	70— 85	4,94	2,86	10,73	0,41	6,53	48,75	33,58	
12.	0— 10	3,51	2,81	8,70	0,58	26,00	40,60	24,12	
	10— 18	3,74	2,83	7,70	0,57	23,86	43.02	24,85	
	18— 33	4,74	2,85	10,18	0,50	13,35	43,36	32,61	
	33— 48	5,42	2,82	10,47	0,10	7,31	47,87	34,25	
	48— 63	5,60	2,84	11,10	0,28	4,35	46,43	37,84	
	63— 78	6,07	2,86	10,91	0,18	1,66	41,44	45.81	
	78— 96	4,58	2,84	10,83	0,60	9,31	47,35	31.91	
	96—111	3,86	2,82	12,77	0,83	8.11	48,05	30.24	
	111—126	4,30	2,81	9,99	0,42	9,01	45,62	34,96	
	126—141	3,14	2,81	9,89	2,48	17,68	51,75	18.20	
13.	0— 5	2,99	2,79	7,72	0,93	34,26	39,04	18,05	
	5— 14	3,22	2,81	7,89	0,89	29,26	41,75	20,21	
	14— 32	4,83	2,82	9.64	0,26	11.24	45.26	33,60	
	32— 47	5,01	2,82	9,93	0,24	7,47	48,17	34,19	
	47— 67	5,32	2,84	9,82	0,34	9,21	43,65	37,98	
	67— 85	5,07	2,81	9,72	0,22	8,98	45,75	35.33	
	85—105	4,93	2,83	9,81	0,45	10,09	45,93	33.72	
	105—125	4,25	2,81	11,29	0,60	15,33	53,19	19,65	
14.	0— 12	2,64	2,85	7,16	0,67	34,16	41,96	16,05	
	12— 30	3,57	2,83	8,23	0,83	24,88	43,44	22,62	
	30— 48	2,90	2,81	9,36	3,38	23,11	44,68	19,47	
	48— 61	3,56	2,84	8,55	4,54	23,37	42,65	20,89	
	61— 73	3,96	2,83	9,22	1,92	22,71	43,73	22.42	
	73— 85	3,83	2,80	4,24	7,38	39,35	31,37	17,66	
	85—100	3,63	2,81	9,06	1,35	27,70	41,74	20,15	
	100—115	4,58	2,80	8,25	1,78	19,60	41,50	28.87	
15.	0— 16	2,42	2,79	6,71	1,54	36,17	42,39	13,19	
	16— 30	3,81	2,83	7,75	1,53	21,96	44,80	23,96	
	30— 42	3,62	2,82	7,68	1,73	24.85	42,61	21,13	
	42— 58	3,22	2,85	10,12	3,87	25,10	41,15	19,76	
	58— 75	3,36	2,80	10,78	1,68	21,06	47,67	18,81	
	75— 92	3,24	2,84	8,35	0,75	24,97	45,42	20.51	
16.	0— 16	3,21	2,86	8,36	1,08	27,73	43,81	19.02	
	16— 33	4,15	2,82	10,31	0,47	19,02	55,69	23,61	
	33— 48	3,95	2,87	9,68	1,21	16,84	46,91	25,36	
	48— 63	4,18	2,84	9,87	1,18	15,00	46,31	27,64	
	63— 79	5,20	2,87	10,67	0,81	8,93	44.15	35,44	
	79— 92	5,49	2,83	10,58	0,59	8,55	41,61	38,32	
	93—106	5,18	2,83	9,94	0,94	11,98	42,86	34.28	
	106—122	4,05	2,83	9,32	2,35	18,24	44,32	25,77	
	122—140	4,23	2,81	10,55	1,82	12,84	47,24	27,55	
17.	0— 11	3,23	2,88	11,37	0,63	27,59	38,65	21,76	
	11— 22	4,15	2,87	10,57	0,15	10,52	56.01	22,75	
	22— 39	3,18	2,89	9,66	0,11	19,06	54,18	16,99	
	39— 56	3,05	2,83	10,82	0,10	15,63	54,97	18.48	
	56— 71	3,68	2,85	10,29	0,13	18,24	49,08	22.26	
	71— 89	3,57	2,87	9,89	0,17	22.25	45,31	22,38	
	89—118	3,42	2,85	9,33	0,53	28.52	41,92	19.70	
	118—136	3,54	2,88	9,22	0,21	23,95	49.86	16.76	
	136—150	2,80	2,85	8,78	0,73	33,81	40,13	16,55	
18.	0— 10	2,57	2,78	8.69	1,73	45,96	27.19	16.43	
	10— 18	2,72	2,82	8,68	1,83	46,42	29.91	14.16	
	18— 32	4,36	2,84	10,70	0,41	17,31	43.90	27.68	
	32— 47	4,12	2,82	10,20	0,18	21,36	38,79	29,47	
	47— 63	3,91	2,83	10,04	0,61	29,16	35,24	24.95	
	63— 79	4,36	2,87	9,15	1,25	28,41	30,63	30.56	
	79— 92	3,13	2,82	9,33	3,39	34,31	30,69	22.28	
	92—106	2,43	2,81	9,01	6,69	48,00	25,37	16,93	
	106—120	2,76	2,82	8,78	6,56	37,61	30,80	16.16	
	120—140	3,30	2,81	9,86	3,31	31,19	34,30	21,34	

TABLE 3.

PARTICLE SIZE DISTRIBUTION OF SOILS — continued
WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Hygr. moist %	Particle density	Loss in HCl processing %	Particle size in mm				
					1—0,25	0,25—0,05	0,05—0,002	<0,002	Gravel* <1 mm
					%				
1	2	3	4	5	6	7	8	9	10
19.	0— 12	1,87	2,82	6,90	6,57	66,13	10,91	9,49	
	12— 24	1,86	2,82	6,95	12,87	59,08	10,91	10,19	
	24— 36	2,88	2,83	8,42	9,01	38,82	26,30	17,45	
	36— 48	2,81	2,81	8,52	12,70	35,66	25,68	17,44	
	48— 62	2,12	2,82	7,96	6,85	45,26	27,44	12,49	
	62— 74	2,76	2,84	8,87	4,19	32,50	39,40	15,04	
	74— 86	3,03	2,85	9,61	4,03	24,75	42,07	19,54	
	86—101	3,67	2,84	9,32	5,23	27,53	33,08	24,84	
	101—118	4,03	2,85	9,63	5,94	26,41	30,29	27,73	
	118—137	3,04	2,77	8,78	10,76	35,49	23,75	21,22	
	137—150	3,02	2,81	7,98	14,54	33,23	24,61	19,64	
25.	0— 3	1,68	2,81	6,83	16,38	55,37	12,25	9,17	
	12— 24	1,42	2,80	6,29	18,00	64,84	3,12	7,25	
	39— 54	2,31	2,85	10,65	0,53	52,18	31,01	5,65	
	66— 79	2,22	2,79	8,31	0,59	59,75	24,34	7,05	
	98—106	2,78	2,83	9,89	0,57	37,43	34,41	17,70	
	119—134	2,50	2,83	10,00	0,28	36,74	40,76	12,22	
29	0— 12	2,10	2,84	7,11	11,16	41,20	27,98	12,55	
	12— 20	2,85	2,82	8,57	1,02	33,64	43,65	13,12	
	20— 35	2,88	2,82	10,58	9,39	23,74	42,24	14,05	
	45— 64	4,55	2,85	11,59	0,19	9,11	57,80	21,31	
	81— 92	3,81	2,84	9,75	2,82	21,92	46,38	19,13	
	107—115	3,01	2,82	6,84	2,66	49,46	24,92	16,12	
	115—120	3,10	2,81	8,25	4,92	44,31	25,03	17,49	
	120—140	4,05	2,82	10,18	1,63	15,95	58,23	13,97	
36.	0— 12	2,81	2,83	9,19	0,89	57,67	23,25	14,00	
	12— 23	1,93	2,81	8,19	1,99	61,56	19,32	9,04	
	23— 51	1,92	2,84	7,54	0,07	69,32	15,35	7,72	
	51— 57	3,41	2,83	9,81	0,02	24,25	51,67	14,25	
	57— 64	2,65	2,82	8,47	0,01	54,13	24,75	12,64	
	64— 78	3,97	2,85	9,94	0,05	30,18	38,35	21,48	
	93—108	2,47	2,85	7,66	2,42	52,77	25,03	12,12	
	133—143	4,08	2,86	11,53	0,19	8,59	64,49	15,20	
	143—158	3,27	2,85	9,56	0,34	25,02	54,45	10,63	
49.	0— 10	2,19	2,81	10,36	1,60	56,93	22,91	8,20	
	20— 35	2,74	2,86	9,50	2,20	26,97	45,75	15,58	
	62— 76	3,81	2,83	11,03	0,74	14,00	50,86	23,37	
	88—107	2,50	2,80	9,11	6,38	30,67	42,46	11,38	
	107—122	3,19	2,84	9,60	1,81	27,96	42,14	18,49	
	138—153	3,87	2,81	11,52	6,39	13,55	47,72	20,82	
Silt-1.		5,13		13,44	0,10	0,04	56,24	30,18	
Silt-2.		5,05		13,39	0,03	1,28	59,15	26,15	
59.	0— 13	2,39	2,84	7,6	—	48,4	31,3	12,7	
	13— 25	2,92	2,82	8,6	—	33,6	41,3	16,5	
	25— 38	3,24	2,83	7,2	—	37,6	36,7	18,5	
	38— 51	2,86	2,83	7,4	—	34,5	45,3	12,8	
	51— 67	4,21	2,82	9,3	—	21,7	38,4	30,6	
	83— 99	3,86	2,84	7,9	—	33,3	40,1	18,7	
	115—125	4,32	2,85	9,0	—	17,1	52,8	21,1	
	137—152	4,48	2,85	8,7	—	16,9	54,6	19,8	
86.	0— 10	2,18	2,79	6,2	—	74,8	12,0	7,0	
	10— 16	2,69	2,79	4,3	—	60,1	25,7	9,9	
	16— 32	2,98	2,80	4,9	—	54,3	31,0	9,8	
	32— 47	3,75	2,79	8,0	—	40,0	33,5	18,5	
	47— 62	3,90	2,82	4,9	—	36,1	41,3	17,7	
	81— 94	4,23	2,83	9,1	—	35,4	36,2	19,3	
	107—117	2,30	2,85	3,4	17,8	55,6	10,2	13,0	
	128—139	1,91	2,83	5,4	7,0	74,1	13,6	2,9	
91.	0— 12	4,42	2,79	7,6	0,7	10,1	59,6	22,0	
	12— 27	4,63	2,82	7,6	0,7	12,2	50,9	28,6	
	27— 39	4,02	2,82	6,2	—	18,9	47,0	27,2	
	39— 54	3,26	2,81	6,2	—	28,3	46,3	19,2	
	54— 95	4,15	2,84	6,2	—	22,2	42,3	29,3	
	95—110	4,67	2,84	5,6	0,7	27,5	39,9	26,3	
	110—170	3,97	2,83	6,2	—	32,4	38,3	23,1	

TABLE 3.

PARTICLE SIZE DISTRIBUTION OF SOILS — continued

WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Hygr. moist %	Particle density	Loss in HCl processing %	Particle size in mm: 1—0,25 %	0,25—0,05 %	0,05—0,002 %	<0,002 %	Gravel* <1 mm %
1	2	3	4	5	6	7	8	9	10
102.	0—14	2,86	2,82	6,2	0,7	49,5	25,4	18,2	
	14—25	3,14	2,82	5,5	0,7	47,8	27,4	18,6	
	25—35	2,23	2,83	6,2	1,4	61.9	16,8	13,7	
	35—40	3,23	2,84	8,2	1,4	31,9	37.7	20,8	
	40—52	2,16	2,81	5,4	4,8	59,2	20,1	10,5	
	52—59	3,12	2,83	6,9	2,8	38,7	35,0	16,6	
	59—70	2,96	2,84	6,2	2,1	45,0	36,3	10,6	
	78—87	4,88	2,83	8,5	—	16,2	50,5	24,9	
	93—106	2,58	2,83	6,9	—	53,7	21,2	18,2	
	115—123	2,22	2,85	6,1	—	69,6	17,5	6,8	
	134—149	4,48	2,83	7,7	—	23,2	43,4	25,7	
147.	0—15	3,73	2,80	7,6	—	20,0	50,7	21,7	
	15—29	4,29	2,81	7,0	—	20,3	45,7	27,0	
	44—63	2,20	2,86	6,8	—	63,2	19,8	10,2	
	63—75	4,53	2,82	7,0	—	22,1	40,4	30,5	
	75—87	3,29	2,82	9,0	2,8	27,1	36,9	24,2	
	87—102	2,53	2,83	7,5	4,8	43,8	38,0	5,9	
	114—129	2,96	2,83	10,3	2,7	34,1	39,0	13,9	
	144—159	2,93	2,82	9,6	6,2	33,1	38,8	12,3	
165.	0—9	2,86	2,78	8,9	2,7	37,2	32,8	18,4	
	9—23	2,89	2,77	8,2	4,1	37,1	31,3	19,3	
	23—35	3,36	2,76	7,0	4,2	34,3	33,5	21,0	
	35—52	2,68	2,81	7,7	11,3	32,4	38,4	10,2	
	68—83	3,29	2,80	6,9	2,8	29,3	42,6	18,4	
	99—113	2,71	2,83	6,4	3,5	44,6	28,8	16,7	
	128—142	2,98	2,82	6,9	3,4	36,1	39,2	14,4	
	154—167	2,38	2,80	6,9	7,6	45,1	24,9	15,5	
176.	0—7	4,78	2,80	11,3	—	20,5	44,5	23,7	
	7—22	4,93	2,80	10,6	—	19,7	50,1	19,6	
	22—32	4,26	2,82	10,5	—	20,2	50,0	19,3	
	32—43	4,60	2,83	10,6	—	17,7	45,5	26,2	
	43—57	3,02	2,83	8,3	—	32,6	50,4	8,7	
	68—82	2,98	2,82	7,5	—	40,7	42,9	8,9	
	82—95	4,34	2,83	9,8	—	12,8	51,6	25,8	
	103—115	1,38	2,85	5,4	12,2	70,9	9,5	2,0	
198.	0—13	2,43	2,81	7,5	—	41,2	46,0	5,3	
	13—31	4,42	2,81	9,8	—	15,7	49,5	25,0	
	31—44	3,08	2,84	7,6	—	47,7	34,4	10,3	
	44—65	5,28	2,85	9,2	—	13,7	55,6	21,5	
	65—80	2,52	2,82	7,5	—	49,5	35,5	7,5	
	80—99	4,39	2,83	10,5	—	17,1	58,0	14,4	
	114—121	3,29	2,81	9,0	—	25,2	49,0	16,8	
	121—152	3,66	2,82	7,6	—	19,0	58,1	15,3	
200.	0—6	4,07	2,83	9,7	—	16,7	48,9	24,7	
	6—16	3,97	2,82	9,7	—	13,5	52.2	24,3	
	16—26	3,97	2,82	9,0	—	18,9	49,9	22,2	
	26—36	4,02	2,77	9,6	—	16,8	51,5	22,1	
	47—61	3,70	2,82	9,6	—	19,4	51,9	19,1	
	73—86	4,27	2,81	9,7	—	14,0	53,1	23.2	
	99—114	4,68	2,80	10,5	—	7,0	43,5	29,0	
	129—144	4,70	2,81	9,8	—	8,1	54,1	28,0	
206.	0—11	4,65	2,82	8,4	—	14,0	43,0	34,6	
	11—22	4,10	2,84	10,5	—	38,2	17,2	34,1	
	22—39	5,55	2,85	9,9	—	4,5	50,9	34,7	
	39—58	5,06	2,86	10,6	—	11,6	47,0	30,8	
	75—86	4,71	2,84	10,5	—	8,1	54,6	26,8	
	95—109	4,56	2,83	10,5	—	15,7	46,3	27,5	
	109—117	5,19	2,85	12,0	—	8,1	48,6	31,3	
	117—131	3,96	2,85	9,0	—	19,2	53,4	18,4	
	144—156	5,35	2,77	11,8	—	7,7	39,7	40,8	

TABLE 3.

PARTICLE SIZE DISTRIBUTION OF SOILS — continued
WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Hygr. moist %	Particle density	Loss in HCl processing %	Particle size in mm 1—0,25 %	0,25—0,05 %	0,05—0,002 %	<0,002 %	Gravel* <1 mm %
1	2	3	4	5	6	7	8	9	10
214.	0— 16	3,30	2,81	6,2	—	31,7	36,4	25,7	
	16— 34	4,04	2,83	6,2	—	21,2	43,7	28,9	
	34— 45	5,34	2,84	7,0	—	15,1	44,8	33,1	
	45— 57	5,72	2,83	6,3	0,7	17,7	37,2	38,1	
	57— 73	5,97	2,86	6,4	0,7	16,3	38,1	38,5	
	90—110	5,76	2,82	8,4	1,1	14,1	37,7	38,7	
	131—145	5,16	2,80	7,0	1,4	12,5	48,9	30,2	
227.	0— 10	6,09	2,82	7,8	0,7	15,2	36,5	39,8	
	10— 19	7,03	2,84	9,2	0,7	18,4	31,4	40,3	
	19— 28	6,17	2,83	12,1	1,1	6,0	38,3	42,5	
	28— 43	5,63	2,84	11,3	0,7	8,4	42,3	37,3	
	58— 74	5,87	2,84	9,9	0,7	12,7	37,4	39,3	
	90—106	5,16	2,84	9,8	1,4	11,5	41,3	36,0	
	106—123	5,17	2,80	9,9	0,7	11,3	42,6	35,5	
	138—154	4,21	2,82	9,0	0,7	20,8	40,7	28,8	

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Total salt %	Saturation extract					Exchange able Na+	CEC	ESP
			SP	EC 25° C mS	pH	Na+		mEq/100 g soil		
						mEq/lit	mEq/100 g			
1	2	3	4	5	6	7	8	9	10	11
2.	0— 5	0,02	31,2	0,43	8,3			0,29	13.55	2,14
	5— 25	0,04	33,2	0,58	8,3			0.41	17,45	2,32
	30— 50	0,04	34,0	0,39	8,3			0,48	21,00	2,27
	56— 79	0,04						0,70	21,58	3,22
	85— 94	0,02						0,58	19,55	2,96
4.	0— 6	0,01	34,4	0,26	8,2			0,35	12,57	2,75
	6— 22	0,02	33,6	0,39	8,2			0,41	13.76	2,94
	22— 42	0,05	36,8	0,57	8,0			0,53	18,83	2,80
	42— 63	0,04	41,3	0.61	8,0			0,55	19.55	2,81
	93—104	0,05						0,74	15.78	4,69
5.	0— 10	0,02	32,8	0,50	8,4			0,35	15,28	2,26
	10— 35	0,03	30,8	0,59	8,3			0,59	18,33	3,23
	35— 56	0,03	32,0	0,44	8,4			0,68	14,27	4,78
	60— 80	0,01	29,6	0,41	8,3			0,66	11,73	5,63
	80—100	0,01						0,74	11.15	6.62
6.	0— 10	0,04	34,0	0,52	8,0			0,49	18.25	2,66
	10— 30	0,08	42,4	0,92	8,2			1,01	24.63	4.08
	30— 50	0,03	34,0	0,43	8,3			0,49	18,68	2,64
	55— 70							0,69	20,28	3,36
	70—150							0,70	18,46	3,76
7.	0— 15	0,06	37,2	0,74	8,2			1,10	18,10	6,08
	15— 26	0,11	47,2	1,20	8,5			1,55	23,90	6,49
	26— 43	0,07	48,9	0,68	8,3			1,39	29,70	4,68
	43— 59	0,07	47,2	0,71	8,2			1,34	24.26	5,50
	59— 80	0,07	50,4	0,74	8,2			0,97	28.25	3,43
	80— 98	0,08	50,8	0,62	8,0			1,34	29,70	4,51
	98—115	0,07	50,8	0,53	8,1			1,32	30.00	4,40
	115—132	0,07	55,2	0,57	8,1			1,59	30.43	5.23
	132—152	0,05	52,2	0,47	8,3			1,12	29,70	3,77
8.	0— 10	0,06	36,0	0,71	8,3			1,21	16.66	7.21
	10— 23	0,06	40,8	0,62	8,2			1,25	21,73	5,73
	23— 32	0,07	45,2	0,59	8,2			1,70	26,80	6,34
	32— 52	0,09	53,2	0,71	8,1			1,99	28,98	6,87
	52— 78	0,08	52,4	0,88	8,0			2,17	30,78	7,05
	78— 95	0,11	46,8	1,37	8,2			1,61	27,16	5,93
	95—110	0,09	47,6	0,92	7,8			2,10	28,25	7,43
	110—127	0,06	44,4	0,74	8,2	3,739	0,166	1,71	18,46	9,25
	127—150	0,07	41,1	0,79	8,2	4,261	0,175	2,58	19,55	13,20
9.	0— 16	0,07	34,8	0,62	8,2	1,304	0,045	1,34	20,28	6,59
	16— 31	0,11	46,0	1,02	8,2	2,782	0,127	2,19	24,26	9,02
	31— 46	0,14	48,4	1,34	8,1	7,217	0,349	2,55	22,45	11,25
	46— 61	0,18	53,2	1,58	7,9	7,936	0,417	3,17	25,00	12,63
	61— 76	0,20	54,6	1,79	7,8	9,993	0,546	4,09	25,08	15,68
	76— 86	0,30	55,4	3,20	8,0	23,212	1,286	4,72	25,71	18,35
	86—101	0,34	53,8	3,82	7,8	26,152	1,406	4,82	28,25	17,06
	101—116	0,40	57,2	3,94	7,8	25,148	1,437	5.00	25,00	20,00
	116—124	0,46	52,8	5,30	7,7	30,675	1,623	4,18	24.26	17,23
	124—139	0,55	58,6	6,41	7,4	34,454	2,019	4.21	26.08	16,14
	139—154	0,50	66,0	5,67	7,9	29,130	1,923	4,89	25,35	19,28
10.	0— 15	0,06	36,8	0,74	8,2	3,740	0,138	0.78	21,00	3,71
	15— 30	0,05	36,8	0,71	8,2	3,910	0,144	0.73	21,73	3.36
	30— 45	0,06	43,1	0,55	8,2	2,390	0,117	0.91	24,63	3,69
	45— 63	0,05	44,1	0,41	8,2	1,950	0,086	1.04	24,63	4.22
	63— 78	0,06	46,0	0,48	8,2			1,12	23.90	4.69
	78— 98	0,06	48,0	0,49	8,1			1,18	27,88	4,24
	98—115	0,06	42,0	0,49	8,2			0,88	24.63	3,57
	115—130	0,07	50,8	0,64	8,2			1,14	27,53	4,14
	130—150	0,07	52,0	0,48	8,1			1,18	28,61	4,12

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS — continued
WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Total salt %	Saturation extract					Exchange-able Na+	CEC	ESP
			SP	EC 25° C mS	pH	Na+		mEq/100 g soil		
						mEq/lit	mEq/100 g			
1	2	3	4	5	6	7	8	9	10	11
11.	0— 12	0,06	36,8	0,52	8,1			0,83	18,83	4,40
	12— 25	0,05	38,4	0,52	8,1			0,98	21,73	4,51
	25— 40	0,06	49,6	0,43	8,0			1,05	23,89	4,39
	40— 55	0,06	47,6	0,42	8,0			1,09	23,89	4,54
	55— 70	0,06	46,8	0,39	8,0			1,16	26,42	4,38
	70— 85	0,06	57,2	0,31	8,2			1,30	31,87	4,08
12.	0— 10	0,06	38,4	0,42	8,2			1,09	21,87	4,97
	10— 18	0,06	42,8	0,59	8,2			1,34	21,87	6,12
	18— 33	00,8	50,4	0,71	8,1			1,85	27,52	6,70
	33— 48	0,11	59,6	1,04	8,2			2,39	25,71	9,29
	48— 63	0,11	61,2	1,11	8,1	5,913	0,372	2,79	29,68	9,40
	63— 78	0,18	62,4	1,60	8,0	8,174	0,510	3,58	30,77	11,63
	78— 96	0,19	58,4	1,97	7,9	9,739	0,568	3,56	25,34	14,04
	96—111	0,25	57,6	2,59	7,9	16,956	0,976	3,51	24,99	14,04
	111—126	0,16	54,4	1,60	7,9	5,478	0,298	1,81	24,99	7,24
	126—141	0,23	48,0	2,28	7,7	13,478	0,647	3,15	21,95	6,96
13.	0— 5	0,06	34,0	0,79	8,0	2,304	0,078	0,79	14,19	5,56
	5— 14	0,06	40,0	0,63	8,0	2,739	0,109	0,83	15,92	5,21
	14— 32	0,11	48,4	1,08	7,9	3,478	0,168	1,35	21,57	6,25
	32— 47	0,13	55,2	1,23	7,9	4,956	0,237	1,49	24,62	6,05
	47— 67	0,14	60,0	1,23	7,8	4,739	0,284	1,52	27,52	5,52
	67— 85	0,14	60,0	1,33	7,8	4,913	0,295	1,63	24,99	6,52
	85—105	0,17	56,0	1,60	7,7	5,826	0,326	1,59	23,17	6,86
	105—125	0,24	54,4	2,22	7,7	14,783	0,804	1,03	17,37	5,92
14.	0— 12	0,084	36,2	0,86	8,0	2,870	0,104	0,54	12,67	4,26
	12— 30	0,050	40,0	0,56	8,1			0,76	16,79	4,52
	30— 48	0,050	41,6	0,53	8,3			0,94	18,09	5,20
	48— 61	0,052	46,4	0,49	8,4			1,01	19,54	5,17
	61— 73	0,048	47,2	0,31	8,4			1,23	20,64	5,96
	73— 85	0,045	37,6	0,53	8,3			0,37	14,47	5,29
	85—100	0,050	44,8	0,47	8,3			1,27	19,91	6,36
	100—115	0,062	51,2	0,52	8,2			1,52	20,99	7,24
15.	0— 16	0,050	37,6	0,64	8,4			0,72	13,03	5,55
	16— 30	0,060	44,4	0,52	8,4			0,98	20,27	4,81
	30— 42	0,065	46,0	0,59	8,4			1,01	20,43	4,95
	42— 58	0,060	46,0	0,63	8,3			0,83	17,01	4,89
	58— 75	0,050	44,4	0,53	8,3			0,83	18,09	4,60
	75— 92	0,065	46,0	0,48	8,3			0,76	17,22	4,41
16.	0— 16	0,050	38,8	0,47	8,2			1,05	15,56	6,75
	16— 33	0,050	53,2	0,42	8,3			1,02	23,90	4,27
	33— 48	0,058	48,4	0,42	8,4			0,90	21,73	4,14
	48— 63	0,065	50,4	0,44	8,4			0,95	22,45	4,23
	63— 79	0,070	60,0	0,59	8,4			0,95	24,56	3,86
	79— 92	0,075	62,0	0,53	8,3			1,16	31,15	2,72
	92—106	0,078	59,2	0,52	8,2			1,16	27,53	4,21
	106—122	0,055	47,2	0,59	8,3			0,88	21,00	4,19
	122—140	0,060	49,6	0,60	8,4			0,88	22,60	3,89
17.	0— 11	0,120	42,0	1,23	8,4	6,261	0,263	1,97	18,83	10,46
	11— 22	0,095	51,6	0,96	8,4	4,287	0,221	2,01	21,00	9,58
	28— 39	0,075	42,4	0,63	8,6	2,956	0,125	4,13	18,09	22,83
	39— 56	0,075	42,0	0,61	8,5	2,956	0,124	4,51	20,64	21,85
	56— 71	0,115	44,0	1,13	8,6	6,608	0,291	4,67	22,45	20,80
	71— 89	0,130	42,0	1,18	8,7	6,608	0,277	4,42	22,72	19.45
	89—118	0,130	42,0	1,18	8,7	6,608	0,277	3,70	18,75	19,73
	118—136	0,090	44,0	1,05	8,6	4,903	0,216	3,76	18,91	19,88
	136—150	0,180	32,0	1,66	8,5	8,478	0,271	3,10	16,60	18,67

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS — *continued*

WADI ZABID PROJECT

Prof. No.	Sampling depth cm	Total salt %	Saturation extract					Exchangeable Na+	CEC	ESP
			SP	EC 25° C mS	pH	Na+ mEq lit	Na+ mEq/100 g	mEq/100 g soil		
1	2	3	4	5	6	7	8	9	10	11
25.	0— 3	0,01	30					0.76	13,78	5,51
	12— 24	0,01	30					0.62	11,58	5,36
	39— 54	0,03	36					0.74	13,50	5,49
	66— 79	0,02	35					1,01	13,80	7,31
	98—106	0,06	39					1.14	15,30	7.43
	119—134	0,06	38					1,00	14.36	6,95
29.	0— 12	0,02	31					0,87	14.85	5,85
	12— 20	0,12	35	1,35	7,8			0,87	18.83	4,65
	20— 35	0,14	37	1,59	7,7			1,52	17.38	8,75
	45— 64	0,06	50					1.12	27.53	4,07
	81— 92	0,11	44	1,23	7,9			1,23	21,36	5,76
	107—115	0,03	34					0,87	17,38	5,01
	115—120	0,05	33					1,08	20,28	5,35
	120—140	0,06	50					1,19	23,55	5,05
36.	0— 12	0,04	35					0,73	15,83	4.62
	12— 23	0.05	32					0,55	11,85	4,63
	23— 51	0,01	30					0,72	12,30	5,85
	51— 57	0,03	43					0,87	19.20	4,56
	57— 64	0,02	35					0,77	16,66	4,59
	64— 78	0,04	43					0,77	20,45	3,79
	93—108	0,02	32					0,58	17,38	3,35
	133—143	0,02	47					0,95	25,33	3.75
	143—158	0,02	39					0,77	18,83	4,07
49.	0— 10	0,10	31	1,06	8,3			0,53	11,26	4,74
	20— 35	0,03	40					0,73	16,50	4,44
	62— 76	0,03	42					0,87	22.45	4,45
	88—107	0,02	36					0,77	16,51	4,63
	107—122	0,02	40					0,78	18,00	4,33
	138—153	0,02	46					1,01	24,63	4,10
Silt-1.		0,08	80					1,11	38,25	3,92
Silt-2.		0,09	76					1,35	37,10	3,64

TABLE 4.
SALINITY AND ALKALINITY STATUS OF SOILS — continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Total salt %	SP	Exchangeable Na+	CEC	ESP
				mEq/100 g soil		
1	2	3	4	5	6	7
59.	0— 13	0,045	34,3	1,15	18,1	6,37
	13— 25	0,090	40,4	1,14	19,6	4,83
	25— 38	0,070	40,9	1,33	21,2	6,29
	38— 51	0,045	36,4	1,29	19,5	6,63
	51— 67	0,080	46,5	1,73	27,4	6,29
	83— 99	0,050	40,5	1,18	23,7	4,99
	115—125	0,055	44,0	1,43	23,7	6,03
	137—152	0,065	48,3	1,66	24,6	6,74
68.	0— 7	0,055	39,1			
	7— 17	0,058	39,0			
	27— 42	0,045	46,0			
	42— 56	0,040	38,7			
	71— 82	0,038	38,6			
	94—100	0,050	49,7			
	115—130	0,058	38,4			
77.	0— 10	0,096	36,6			
	10— 21	0,060	36,0			
	31— 44	0,028	30,4			
	57— 72	0,020	33,4			
	87— 94	0,030	38,8			
	107—120	0,038	38,3			
	133—144	0,038	38,8			
86.	0— 10	0,030	31,0	0,78	11,9	6,58
	10— 16	0,070	32,8	0,73	12,9	5,63
	16— 32	0,110	34,2	0,79	15,3	5,15
	32— 47	0,088	35,1	1,08	19,6	5,52
	47— 62	0,065	39,3	0,85	16,1	5,29
	81— 94	0,065	40,2	0,82	20,5	4,00
	107—117	0,020	29,4	1,09	13,8	7,90
	128—139	0,028	31,9	0,90	14,1	6,38
91.	0— 12	0,080	46,0	1,66	26,8	6,20
	12— 27	0,040	48,0	1,45	28,8	5,04
	27— 39	0,045	41,4	1,27	22,4	5,67
	39— 54	0,035	39,5	1,19	20,2	5,90
	65— 80	0,042	42,7	1,31	23,2	5,65
	95—110	0,045	41,3	1,38	26,1	5,29
	128—150	0,035	38,8	1,43	26,4	5,34
97.	0— 13	0,035	28,9			
	13— 22	0,058	28,0			
	22— 37	0,040	27,0			
	50— 64	0,022	25,7			
	64— 80	0,040	35,4			
	80— 95	0,042	42,3			
	111—126	0,024	31,2			
	141—155	0,010	28,4			
102.	0— 14	0,050	34,2	1,04	16,8	6,19
	14— 25	0,090	35,2	0,71	16,5	4,31
	25— 35	0,080	30,0	0,49	14,2	3,42
	35— 40	0,098	41,5	0,94	23,2	4,05
	40— 52	0,038	32,0	0,65	14,5	4,49
	52— 59	0,034	35,3	0,72	16,2	4,51
	59— 70	0,030	35,6	0,65	17,4	3,74
	78— 87	0,050	44,4	1,11	24,6	4,51
	93—106	0,044	36,6	0,84	20,3	4,13
	115—123	0,030	33,0	0,58	15,2	3,81
	134—149	0,042	48,2	0,99	24,6	4,03

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS — continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Total salt %	SP	Exchangeable Na+	CEC	ESP
				mEq/100 g soil		
1	2	3	4	5	6	7
135.	0— 12	0,046	41,4			
	12— 21	0,038	42,5			
	21— 34	0,022	43,6			
	34— 50	0,005	38,5			
	61— 73	0,030	52,5			
	84— 98	0,020	39,4			
	98—112	0,018	39,1			
	112—124	0,030	44,5			
	124—137	0,030	52,5			
	137—142	0,020	41,2			
141.	0— 11	0,050	31,0			
	11— 21	0,040	34,3			
	21— 37	0,042	34,0			
	37— 53	0,040	29,8			
	68— 83	0,060	36,0			
	100—116	0,080	38,5			
	116—136	0,150	40,8			
	136—153	0,110	38,6			
147.	0— 15	0,058	48,6	1,02	23,0	4,14
	15— 29	0,042	46,5	1,04	24.5	4,25
	44— 63	0,020	33,0	0,51	13.7	3.72
	63— 75	0,052	46,0	0,97	29,7	3,26
	75— 87	0,048	41,0	0,87	25.4	3.42
	87—102	0,030	33,7	0,58	16,2	3,58
	114—129	0,035	40,9	0,62	18.6	3.34
	144—159	0,039	39,5	0,73	18.1	4,04
153.	0— 6	0,115	61,8			
	6— 23	0,105	67,4			
	23— 43	0,055	52,6			
	43— 65	0,055	61,0			
	80— 92	0,018	40,0			
	106—121	0,022	35,3			
	134—153	0,040	45,3			
158.	0— 10	0,070	48,4			
	10— 24	0,025	44,0			
	24— 40	0,025	38,7			
	57— 72	0,020	38,2			
	87—101	0,035	44,5			
	115—127	0,038	47,2			
	127—147	0,035	47,2			
165.	0— 9	0,065	35,5	0,87	20,3	4,24
	9— 23	0,030	36,6	0,73	20.4	3,58
	23— 35	0,050	39,3	1,47	21,4	6.85
	35— 52	0,030	39,0	1,11	20,6	5,40
	68— 83	0,050	40,3	0,93	18.6	5.01
	99—113	0,030	36,6	0,77	19.6	3,94
	128—142	0,035	37,3	0,71	19.1	3.74
	154—167	0,018	34,3	0,60	16,3	3,71
173.	0— 10	0,045	36,0			
	10— 21	0.025	36,0			
	31— 30	0,050	44,6			
	45— 58	0,055	51,2			
	72— 90	0,055	57,7			
	90—110	0,050	50,0			
	125—140	0,052	49,0			
176.	0— 7	0.070	45,6	0,57	24.9	2,27
	7— 22	0,038	52,4	0,82	24.9	3,30
	22— 32	0,038	49,5	0,65	25.9	2.51
	32— 43	0,035	50,7	0,86	29,0	2.95
	43— 57	0,005	38,6	0,75	20.3	3,70
	68— 82	0,001	37,2	0,47	18,8	2,51
	82— 95	0,040	54,2	0,75	30.2	2,48
	108—115	0,001	28,0	0,36	10,5	3,46

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS — continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Total salt %	SP	Exchangeable Na+	CEC	ESP
				mEq/100 g soil		
1	2	3	4	5	6	7
178.	0— 8	0,058	39,4			
	8— 17	0,015	36.5			
	29— 40	0,018	42,0			
	40— 57	0.037	39.0			
	57— 67	0,040	46,6			
	77— 93	0,038	39,4			
	106—119	0,031	38,0			
	128—140	0,038	38,5			
193.	0— 9	0,050	33,0			
	9— 21	0,040	34,6			
	21— 35	0,060	35,4			
	49— 61	0,065	46.0			
	77— 94	0,085	48,3			
	110—130	0,115	45,1			
	150—165	0,090	45,3			
197.	0— 14	0,078	52.8			
	14— 25	0,038	48,8			
	36— 48	0,050	46,5			
	63— 78	0,035	44,4			
	108—123	0,050	45,3			
	138—153	0,065	42,0			
198.	0— 13	0,030	42,0	0,75	15,8	4,76
	13— 31	0,045	48,4	1,04	26,7	3,88
	31— 44	0,018	42,0	0,83	18,0	4,61
	44— 65	0,095	65,0	0,82	31,8	2,57
	65— 80	0,018	40,0	1,01	16,1	6,19
	80— 99	0,030	48,7	1,46	25,2	5,79
	114—121	0.030	41,6	1,29	17,3	7,48
	121—152	0.075	51,2	1,51	21.6	6,98
200.	0— 6	0,055	45,2	1,18	24,2	4,86
	6— 16	0,078	46,4	1,46	24.2	6.03
	16— 26	0,035	43,7	1.33	23.1	5,74
	26— 36	0,045	44,2	1,58	21,6	7,29
	47— 61	0,018	44,4	1,46	21.2	6,87
	73— 86	0,030	45,6	1,43	26.2	5,44
	99—114	0,058	48,7	1,13	26.9	4,20
	129—144	0,055	51,2	1,24	26,0	4,75
206.	0— 11	0,115	51,3	1,06	26.9	3,94
	11— 22	0,055	50,0	0.81	25.7	3.17
	22— 39	0,058	59,2	0,96	33.4	2,87
	39— 58	0,042	57,8	0,96	26,0	3.68
	75— 86	0,025	50,8	0,87	27.8	3,13
	95—109	0,050	50,4	0,98	28.2	3,48
	109—117	0,040	55,1	0.96	31.9	1,59
	117—131	0,032	45,2	0,81	22,4	3.63
	144—156	0,055	56,3	0,95	31,0	3,05
209.	0— 15	0,078	47,2			
	15— 35	0,050	48,0			
	35— 53	0,075	46,2			
	53— 70	0,070	43,8			
	90—110	0,080	48,0			
	132—148	0,105	62,3			
214.	0— 16	0,055	42,0	0.73	21.9	3,34
	16— 34	0,058	46,0	0.92	23.9	3,83
	34— 45	0,070	50,5	1,12	28,6	3,90
	45— 57	0,058	54,6	0.99	29,7	3,33
	57— 73	0,065	55,8	1,09	30,0	3,64
	90—110	0,090	53,3	1,21	30,7	3,94
	131—145	0,075	52,7	1,37	28,2	4,86
220.	0— 10	0,110	48,5			
	10— 20	0,052	45.2			
	31— 42	0,048	49,7			
	42— 51	0,058	55.0			
	61— 76	0,058	48,7			
	90—105	0.065	49,2			
	136—151	0,055	46,1			

TABLE 4.

SALINITY AND ALKALINITY STATUS OF SOILS — continued
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Total salt %	SP	Exchangeable Na+	CEC	ESP
				mEq/100 g soil		
1	2	3	4	5	6	7
227.	0— 10	0,110	51,0	1,89	30,7	6,16
	10— 19	0,095	52,1	1,74	33,1	5,26
	19— 28	0,090	56,5	1,83	32,4	5,65
	28— 43	0,070	57,1	1,67	31,1	5,36
	58— 74	0,070	57,9	1,35	30,1	4,49
	90—106	0,065	54,7	1,45	28,2	5,15
	106—123	0,062	49,8	1,61	29,0	5,54
	138—154	0,055	46,8	1,66	26,1	6,40

TABLE 5.

RESULTS OF THE ANALYSIS OF 1:5 WATER EXTRACT OF SOILS WADI ZABID PROJECT

Profile No.	Sampling depth cm	Dry	Ignition	pH	EC 25 C°	Anions				Cations			
		residue %			mS	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
						% / mEq 100 g soil							
1	2	3	4	5	6	7	8	9	10	11	12	13	14
9.	0— 16	0,068	0,035	7,7	0,25	—	0,0516 0,8459	0,0057 0,1605	0,0025 0,0521	0,0058 0,2894	0,0023 0,1891	0,0155 0,6739	0,0023 0,0588
	16— 31	0,089	0,057	7,8	0,33	—	0,0575 0,9426	0,0078 0,2197	0,0045 0,0937	0,0054 0,2695	0,0015 0,1233	0,0240 1,0434	0,0012 0,0307
	31— 46	0,106	0,060	7,7	0,42	—	0,0567 0,9295	0,0173 0,4873	0,0049 0,1021	0,0050 0,2495	0,0017 0,1398	0,0325 1,4130	0,0013 0,0332
	46— 61	0,134	0,108	7,9	0,51	—	0,0626 1,0262	0,0244 0,6873	0,0107 0,2229	0,0046 0,2295	0,0020 0,1644	0.405 1,7608	0,0015 0,0334
	61— 76	0,162	0,128	7,7	0,64	—	0,0642 1,0524	0,0338 0,9521	0,0205 0,4271	0,0037 0,1846	0,0025 0,2055	0,0520 2,2608	0,0017 0,0435
	76— 86	0,206	0,163	7,9	0,84	—	0,0534 0,8754	0,0529 1,4901	0,0362 0,7541	0,0041 0,2045	0,0015 0,1233	0,0680 2,9565	0,0013 0,0332
	86—101	0,225	0,209	8,0	0,86	—	0,0583 0,9557	0,0580 1,6338	0,0427 0,8896	0,0041 0,2045	0,0017 0,1398	0,0760 3,3043	0,0014 0,0358
	101—116	0,249	0,216	7,9	0,99	—	0,0558 0,9147	0,0639 1,8000	0,0563 1,1729	0,0046 0,2295	0,0025 0,2055	0,0815 3,5434	0,0014 0,0358
	116—124	0,383	0,360	7,7	1,36	—	0,0457 0,7492	0,0710 2,000	0,1401 2,9187	0,0128 0,6387	0,0106 0,8717	0,0985 4,2820	0,0019 0,0486
	124—139	0,468	0,439	7,5	1,54	—	0,0354 0,5803	0,0872 2,4563	0,1833 3,8187	0,0154 0,7684	0,0194 1,5953	0,1060 4,6086	0,0029 0,0742
	139—154	0,700	0,639	7,6	2,28	—	0,0411 0,6738	0,1136 3,2000	0,2889 6,0187	0,0162 0,8083	0,0445 3,6595	0,1330 5,7825	0,0031 0,0792
12.	0— 10	0,067	0,040	7,8	0,12	—	0,0305 0,5000	0,0041 0,1155	0,0033 0,0687	0,0021 0,1048	0,0017 0,1398	0,0110 0,4783	0,0015 0,0384
	10— 18	0,071	0,034	7,7	0,15	—	0,0337 0,5524	0,0044 0,1239	0,0029 0,0604	0,0029 0,1447	0,0012 0,0987	0,0135 0,5869	0,0014 0,0353
	18— 33	0,084	0,045	7,8	0,18	—	0,0391 0,6409	0,0041 0,1155	0,0045 0,0937	0,0021 0,1048	0,0012 0,0987	0,0180 0,7826	0,0010 0,0255

	33— 48	0,054	0,066	7,9	0,25	—	0,0433 0,7098	0,0064 0,1802	0,0097 0,2020	0,0017 0,0848	0,0015 0,1233	0,0230 1,0000	0,0011 0,0281
	48— 63	0,111	0,070	7,9	0,31	—	0,0434 0,7114	0,0119 0,3352	0,0148 0,3083	0,0021 0,1048	0,0012 0,0987	0,0315 1,3695	0,0007 0,0179
	63— 78	0,139	0,111	8,0	0,42	—	0,0477 0,7819	0,0199 0,5605	0,0214 0,4458	0,0021 0,1048	0,0012 0,0987	0,0410 1,7826	0,0010 0,0255
	78— 96	0,120	0,092	8,1	0,46	—	0,0502 0,8229	0,0265 0,7464	0,0189 0,3937	0,0021 0,1048	0,0010 0,0822	0,0440 1,9130	0,0012 0,0306
	96—111	0,158	0,089	7,9	0,52	—	0,0531 0,8704	0,0277 0,7802	0,0267 0,5562	0,0021 0,1048	0,0012 0,0987	0,0495 2,1522	0,0009 0,0230
	111—126	0,123	0,101	7,9	0,33	—	0,0344 0,5639	0,0213 0,6000	0,0197 0,4104	0,0062 0,3092	0,0028 0,2303	0,0255 1,1086	0,0013 0,0332
	126—141	0,157	0,087	8,0	0,49	—	0,0445 0,7295	0,0279 0,7859	0,0296 0,6166	0,0021 0,1048	0,0012 0,0987	0,0480 2,0869	0,0009 0,0230
13.	0— 5	0,063	0,036	7,8	0,17	—	0,0312 0,5114	0,0048 0,1352	0,0045 0,0937	0,0041 0,2045	0,0020 0,1645	0,0100 0,4347	0,0022 0,0563
	5— 14	0,067	0,040	8,0	0,15	—	0,0322 0,5278	0,0040 0,1126	0,0033 0,0687	0,0037 0,1846	0,0012 0,0987	0,0111 0,4826	0,0016 0,0409
	14— 32	0,104	0,061	8,0	0,22	—	0,0334 0,5475	0,0085 0,2394	0,0036 0,1791	0,0041 0,2045	0,0017 0,1398	0,0170 0,7391	0,0014 0,0358
	32— 47	0,085	0,052	7,7	0,20	—	0,0344 0,5639	0,0098 0,2760	0,0135 0,2812	0,0054 0,2894	0,0010 0,0822	0,0165 0,7173	0,0008 0,0202
	47— 67	0,105	0,044	7,8	0,25	—	0,0339 0,5557	0,0153 0,4309	0,0139 0,2895	0,0058 0,2894	0,0010 0,0822	0,0200 0,8695	0,0007 0,0179
	67— 85	0,090	0,067	7,7	0,26	—	0,0349 0,5721	0,0170 0,4789	0,0173 0,3604	0,0050 0,2495	0,0020 0,1644	0,0210 0,9130	0,0008 0,0202
	85—105	0,099	0,081	7,8	0,30	—	0,0349 0,5721	0,0227 0,6394	0,0168 0,3500	0,0058 0,2894	0,0023 0,1891	0,0230 1,0000	0,0007 0,0179
	105—125	0,155	0,093	8,1	0,41	—	0,0546 0,8950	0,0265 0,7464	0,0263 0,5479	0,0071 0,3543	0,0015 0,1233	0,0420 1,8260	0,0003 0,0153
17.	0— 11	0,081	0,054	8,0	0,21	—	0,0472 0,7738	0,0109 0,3070	0,0070 0,1458	0,0021 0,1048	0,0012 0,0987	0,0205 0,8913	0,0008 0,0202
	11— 22	0,089	0,052	8,0	0,23	—	0,0656 1,0754	0,0081 0,2281	0,0057 0,1187	0,0021 0,1048	0,0005 0,0411	0,0270 1,1739	0,0002 0,0051
	22— 39	0,115	0,079	8,1	0,25	—	0,0772 1,2655	0,0106 0,2985	0,0053 0,1104	0,0058 0,2894	0,0015 0,1233	0,0295 1,2826	0,0005 0,0127
	39— 56	0,105	0,067	8,5	0,25	0,0034 0,1133	0,0750 1,2295	0,0087 0,2451	0,0037 0,0771	0,0029 0,1447	0,0002 0,0205	0,0305 1,3260	0,0003 0,0076

TABLE 5.

RESULTS OF THE ANALYSIS OF 1:5 WATER EXTRACT OF SOILS — *continued*
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Dry residue %	Ignition residue %	pH	EC 25 C° mS	Anions CO_3^{2-}	Anions HCO_3^-	Anions Cl^-	Anions SO_4^{2-}	Cations Ca^{2+}	Cations Mg^{2+}	Cations Na^+	Cations K^+
						% / mEq/100 g soil							
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	56— 71	0,100	0,065	8,3	0,23	tr	0,0733 1,2016	0,0088 0,2478	0,0045 0,0937	0,0041 0,2045	0,0002 0,0205	0,0295 1,2826	0,0004 0,0102
	71— 89	0,104	0,063	8,2	0,25	tr	0,0750 1,2295	0,0085 0,2394	0,0029 0,0604	0,0021 0,1048	0,0002 0,0205	0,0295 1,2826	0,0004 0,0102
	89—118	0,109	0,065	8,2	0,25	tr	0,0733 1,2016	0,0069 0,1944	0,0041 0,0854	0,0037 0,1846	0,0005 0,0411	0,0285 1,2391	0,0004 0,0102
	118—136	0,101	0,044	8,3	0,23	tr	0,0735 1,2049	0,0064 0,1803	0,0025 0,0521	0,0017 0,0848	0,0002 0,0205	0,0275 1,1956	0,0004 0,0102
	136—150	0,086	0,035	8,2	0,22	tr	0,0647 1,0606	0,0055 0,1549	0,0049 0,1021	0,0017 0,0848	0,0002 0,0205	0,0255 1,1086	0,0003 0,0076
86.	0— 10	0,051	0,027	7,8	0,10	—	0,0219 0,3589	0,0052 0,1464	0,0025 0,0521	0,0027 0,1350	0,0001 0,0082	0,0078 0,3391	0,0014 0,0358
	10— 16	0,081	0,042	7,6	0,17	—	0,0264 0,4327	0,0080 0,2253	0,0066 0,1375	0,0063 0,3150	0,0015 0,1233	0,0070 0,3043	0,0028 0,0716
	16— 32	0,124	0,071	7,3	0,44	—	0,0424 0,6948	0,0200 0,5632	0,0148 0,3082	0,0130 0,6500	0,0040 0,3290	0,0150 0,6520	0,0062 0,1586
	32— 47	0,110	0,071	7,7	0,37	—	0,0512 0,8392	0,0160 0,4506	0,0124 0,2582	0,0136 0,6800	0,0024 0,1974	0,0152 0,6608	0.0052 0,1330
	47— 62	0,065	0,035	7,9	0,14	—	0,0227 0,4540	0,0044 0,1239	0,0033 0,0687	0,0033 0,1650	0,0012 0,0987	0,0071 0,3086	0,0020 0,0511
	81— 94	0,069	0,049	7,9	0,16	—	0.0274 0,4491	0,0056 0,1577	0,0033 0,0687	0,0037 0,1850	0,0020 0,1645	0,0069 0,2999	0,0015 0,0384
	107—117	0,043	0,028	7,9	0,09	—	0,0217 0,3557	0,0048 0,1352	0,0008 0,0166	0,0037 0,1850	0,0015 0,1233	0,0032 0,1391	0,0011 0,0281
	128—139	0,060	0,033	8,0	0,10	—	0,0201 0,3294	0,0052 0,1464	0,0008 0,0166	0.0033 0,1650	0,0012 0,0987	0.0040 0,1739	0,0009 0,0230

102.	0— 14	0,070	0,034	7,7	0,14	—	0,0217 0,3557	0,0072 0,2028	0,0062 0,1291	0,0063 0,3150	0.0007 0,0576	0,0060 0,2608	0,0031 0,0793
	14— 25	0,101	0,047	7,7	0,24	—	0.0217 0,3557	0.0124 0,3492	0.0157 0,3271	0,0105 0,5250	0.0015 0,1233	0,0080 0,3477	0.0030 0.0767
	25— 35	0,080	0,040	7,8	0,22	—	0,0235 0,3852	0,0124 0,3492	0,0132 0,2750	0,0104 0,5200	0,0015 0,1233	0,0070 0,3043	0,0025 0,0639
	35— 40	0,102	0,055	7,7	0,29	—	0,0305 0,5000	0,0199 0,5605	0,0148 0,2083	0,0099 0,4950	0,0016 0.1316	0.0175 0,7607	0.0018 0,0460
	40— 52	0,050	0,029	7,8	0,12	—	0,0193 0,3163	0,0052 0,1464	0,0025 0,0521	0,0045 0,2250	0,0008 0,0658	0,0045 0,1953	0,0012 0,0307
	52— 59	0,055	0,030	8,0	0,10	—	0,0235 0,2852	0,0036 0,1014	0,0025 0,0521	0,0033 0,1650	0,0009 0,0740	0,0052 0,2260	0,0010 0,0256
	59— 70	0,055	0,029	8,2	0,09	tr	0,0240 0,3934	0,0032 0,0901	0,0008 0,0166	0,0037 0,1850	0,0007 0,0576	0.0050 0,2174	0,0010 0,0256
	78— 87	0,075	0,040	7,8	0,14	—	0,0337 0,5523	0,0048 0,1352	0,0041 0,0854	0,0052 0,2600	0,0010 0,0822	0,0084 0,3651	0.0009 0,0230
	93—106	0,055	0,037	7,9	0,12	—	0,0290 0,4753	0,0032 0,0901	0,0025 0,0521	0,0043 0,2150	0,0013 0,1039	0,0062 0,2695	0,0008 0,0205
	115—123	0,047	0,031	8,1	0,09	—	0,0222 0,3639	0,0048 0,1352	0,0008 0,0166	0,0037 0,1850	0,0009 0,0740	0,0038 0,1652	0,0007 0,0179
	134—149	0,069	0,042	8,0	0,11	—	0.0306 0,5015	0,0036 0,1014	0.0016 0,0333	0,0052 0,2600	0,0010 0,0822	0,0055 0,2391	0,0009 0,0230
227.	0— 10	0,135	0,081	8,1	0,41	—	0,0477 0,7819	0,0153 0,4309	0,0148 0,3083	0,0058 0,2894	0,0015 0,1233	0,0240 1,0434	0,0012 0,0307
	10— 19	0,104	0,071	8,1	0,30	—	0,0434 0,7114	0,0085 0,2394	0,0139 0,2895	0,0058 0,2894	0,0012 0.0987	0,0200 0,8695	0,0006 0,0153
	19— 28	0,118	0,069	7,9	0,28	—	0,0400 0,6556	0,0096 0,2703	0,0053 0,1103	0,0033 0,1650	0,0008 0,0658	0,0154 0,6694	0,0007 0,0179
	28— 43	0,082	0,041	7,8	0,19	—	0,0345 0,5655	0,0084 0,2365	0,0049 0,1020	0,0035 0,1750	0.0008 0,0658	0,0148 0,6433	0,0008 0,0205
	58— 74	0,091	0,061	8,0	0,22	—	0,0353 0,5786	0,0096 0,2703	0,0062 0,1291	0,0035 0,1750	0,0010 0,0822	0,0160 0,6955	0.0007 0,0179
	90—106	0,076	0,047	8,1	0,14	—	0,0326 0,5343	0,0032 0,0901	0,0053 0.1103	0,0028 0,1400	0.0006 0,0493	0,0122 0,5303	0,0006 0,0153
	106—123	0,066	0,037	7,8	0,13	—	0,0329 0,5392	0,0040 0,1126	0.0049 0,1020	0.0027 0,1350	0.0004 0,0329	0,0120 0,5216	0,0006 0,0153
	138—154	0,061	0,034	8,4	0,11	tr	0,0292 0,4786	0.0040 0,1126	0,0029 0,0604	0,0027 0,1350	0,0004 0,0329	0,0093 0,4173	0,0009 0,0230

TABLE 6.

RESULTS OF THE TOTAL CHEMICAL ANALYSIS OF SOILS
WADI ZABID PROJECT

Profile No.	Sampling depth cm	Hygrosc. moisture %	Ignition residue %	SiO_2 %	R_2O_3 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	SO_3 %	MnO %
86.	0— 10	1,934	4,377	59,550	24,660	17,168	7,203	4,420	3,595	1,300	0,804	0,289	0,412	0,147
	10— 16	2,460	5,355	57,460	24,840	17,278	7,242	4,518	3,443	1,422	0,677	0,280	0,748	0,153
	16— 32	2,845	6,088	56,690	25,180	16,346	8,506	5,458	3,885	1,188	0,585	0,328	0,401	0,138
	32— 47	3,551	7,058	55,150	26,192	16,908	8,982	4,471	3,703	1,357	0,642	0,302	1,241	0,209
	47— 62	3,585	6,903	53,850	26,295	16,476	9,540	4,905	3,625	1,495	0,627	0,279	1,211	0,253
	81— 94	3,917	7,240	51,420	24,470	13,914	10,137	4,545	4,513	1,552	1,030	0,419	1,211	0,255
	107—117	1,906	4,174	56,630	25,246	15,772	9,188	5,217	3,905	0,993	0,526	0,286	1,033	0,360
	128—139	1,474	*3,464*	*59,910*	*24,568*	*15,807*	*8,496*	5,453	3,387	*0,794*	0,355	0,265	0,802	0,291
147.	0— 15	3,132	7,095	50,930	26,400	15,412	10,578	6,372	4,535	1,748	1,031	0,410	0,624	0,258
	15— 29	3,375	7,282	52,280	24,437	14,217	9,896	6,623	4,620	1.665	1,021	0,324	0,445	0,245
	44— 63	1,780	4,259	58,600	24.030	14,815	9,543	6,430	4,875	0,910	0,472	0,242	0,479	0,210
	63— 75	3,290	6,576	50,780	27,969	17,704	9.800	7,083	4,334	1,486	0,906	0,336	0,374	0,215
	75— 87	3,176	6,128	52,190	26,220	17,551	8,325	6,967	4,782	1,202	0,569	0,344	0,868	0,214
	87—102	2,187	5,031	53,770	25,166	13.566	11,030	6,966	4.387	1.038	0,640	0,300	0,400	0,264
	114—129	2,475	5,942	53,030	24,997	14.547	9,902	8.985	4,069	1.017	0,472	0,348	0,770	0,235
	144—159	2,420	5,479	53,660	25,846	13,017	6,505	8,872	3,959	0,946	0,362	0,324	0,749	0,107
176.	0— 7	4,474	9,883	48.970	24,800	15,093	9,315	5,674	5,026	1,875	1,247	0,387	1,874	0.249
	7— 22	4.597	9.107	47,270	27,190	17,646	9,132	6,728	4.957	1,806	1,163	0,412	1,225	0.203
	22— 32	4.008	*8,482*	*49,250*	*24,078*	*14,271*	*9,391*	8,026	5.020	1,591	1.358	0,416	1,001	0.177
	32— 43	4,366	8,808	47,590	25,217	15,998	8,805	8,550	4,515	1,894	0.872	0,414	0.994	0,215
	43— 57	2,468	5,814	52.590	25.377	16.759	8,300	6.884	4.548	1,743	1,402	0,318	0.461	0,146
	68— 82	2,237	5.654	52,490	23,830	15,531	8,033	8,466	4,071	1,841	1.635	0.296	0.350	0,183
	82— 95	3,718	7,771	50,900	24,048	14,661	9,026	7,815	5,299	1,569	0,859	0,361	1.650	0,197
	108—115	1,148	7,204	56,110	22,012	14,078	7,573	7,613	3,598	1,227	0,220	0,361	0,227	0,162
198.	0— 13	2,105	5,379	54.510	21,485	13,214	8.014	8.407	4,145	1,742	1.531	0,257	1,441	0.301
	13— 31	3,589	8,312	49.730	23,172	15,252	7.543	9,973	4,710	1,906	1.209	0,377	1.615	0,267
	31— 44	2,340	5,625	52,210	23,911	15,622	7,900	8.740	5,676	1,546	1.322	0.339	1,350	0.268
	44— 65	4.977	6.670	49,100	25,617	16,825	8,500	6.935	5,383	1,473	0,935	0.292	0,290	0,321
	65— 80	2,163	5,529	52,450	24.220	16,498	7.471	7,268	4,388	1,850	1,048	0,751	0.880	0.234
	86— 99	3.409	7.718	49,660	24.292	14.554	9.024	8,033	5.058	1,732	1,224	0,314	0.339	0,316
	114—121	2,640	5.950	52,890	22.956	14,124	8.551	8.406	4.919	1,787	1.317	0.281	0.398	0,258
	121—152	3,149	7,421	50,240	24,594	13,435	10,846	7,019	4,676	[illegible]	1,235	0.313	0,780	0,321

200.	0— 6	3,277	7,486	51,810	23,307	13.549	9,426	7,656	4,622	1,870	1,147	0,332	0,510	0.318
	6— 16	3,323	7,528	49,630	26.274	16,836	9,076	7,310	4,321	1.680	1,074	0,362	0,660	0,437
	16— 26	3,284	7,104	50.230	25.256	16,342	9,052	7,214	9,960	1,950	1,345	0,362	0,860	0.334
	26— 36	4,078	6,909	50,320	25,344	15,951	9,058	8,122	4,353	1,720	1,250	0,335	0,450	0,310
	47— 61	3.033	6,697	50,690	26,230	17,101	8,800	7,984	4,278	2,147	1,657	0,379	0,230	0,283
	73— 86	3,653	7,525	50.940	25,980	16,466	9,177	7,160	3,922	1,693	0,976	0,337	0,530	0,263
	99—114	3,877	8,200	45,960	27,100	17,260	9,524	7,417	8,171	1.885	1,340	0,316	0.830	0.195
	129—144	3,742	7,976	47,820	25,143	15,380	9,426	7,383	8,150	2,172	1,110	0,337	0,540	0,290
227.	0— 10	4,675	8,092	49,660	24,415	14,900	9,148	7,407	6,464	1.424	0,900	0,367	0,580	0.173
	10— 19	4,777	8,018	49,080	25,440	16,135	9.036	6,880	5,796	1,612	1,011	0,269	0,390	0,264
	19— 28	4.886	8.881	44,930	24,942	15,373	9,193	7,991	7,306	1,513	1,003	0,376	0,880	0,296
	28— 43	4,471	8,663	45,860	26,121	16,863	8,900	8,415	6,984	1,657	0,966	0.358	0,300	0,262
	58— 74	4,467	8,152	48,390	25,943	16,221	9,360	6,485	5,408	1,635	0.957	0,362	0,810	0.360
	90—106	4,150	7,875	49,000	27,415	18,041	8,991	8.052	6,042	1.613	0,791	0,383	1,320	0.331
	106—123	4,441	8,350	48,130	25,360	16,234	8,743	7,850	5,905	1.472	0,997	0,383	0,930	0,261
	138—154	3,540	6,987	51,680	26,067	15,562	10,123	4,515	5,865	1,564	0,818	0,382	0,282	0,339

TABLE 7.

WATER MANAGEMENT PROPERTIES OF SOILS
WADI ZABID PROJECT
(Field measurements)

Soil type No.	Profile No.	Bulk density	Field capacity	Infiltration rate	Permeability mm/hour	Depth of the wetting front cm
		mm/50 cm		mm/hour		
1.11	254.	1,38	124,84	34,4	13,4	90
1.13	176.	1,34	179,55	28,3	17,4	65
1.22	102.	1,33	127,67	48,2	18,6	90
1.23	77.	1,36	125,03	50.0	34.8	130
1.23	198.	1,40	175,74	27,4	16.8	80
2,21	53.	1,42	136,36	70.1	35,4	85
2.21	86.	1,44	148,28	29,3	21,0	100
2.22	59.	1,30	170,77	51,4	17,4	90
3.2	91.	1,38	135,16	39,2	18,0	85
3.2	147.	1.27	163,72	38,8	16.2	85
3.2	165.	1,45	137,90	40,5	18.6	90
3.3	200.	1,35	167,40	38,3	15.6	90
3.4	214.	1,50	162,90	30,1	10,8	80
3.4	227.	1,55	186.60	20.1	8,4	60
3.4	231.	1,52	181,75	29.2	7,2	90
4.3	12.	1,45	147,73	33,2	11,4	75

TABLE 8.

RESULTS OF WATER ANALYSIS
WADI ZABID PROJECT

No.	Dry residue %	pH	EC 25° C mS	Degree of hardness N° total	Degree of hardness N° carbonate	Degree of hardness N° residual	Soda Eq.	CO_3^{2-} g/lit mEq/lit	HCO_3^- g/lit mEq/lit	Cl^- g/lit mEq/lit	SO_4^{2-} g/lit mEq/lit	Ca^{2+} g/lit mEq/lit	Mg^{2+} g/lit mEq/lit	Na^+ g/lit mEq/lit	K^+ g/lit mEq/lit	Sodium percentage %	SAR	Total N mg/lit
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0,704	7,9	1,02	19,92	13,95	5,97	—	—	0,3037 4,9820	0,1340 3,7880	0,0937 1,9520	0,0811 4,0550	0,0365 3,0016	0,0930 4,0434	0,0072 0,1841	35,8 35,8	2,15	6,61
2	0,612	8,0	0,94	13,47	14,63	—	0,42	—	0,3186 5,2250	0,0800 2,2615	0,0773 1,6083	0,0780 2,4000	0,0271 2,2286	0,1200 5,2173	0,0060 0,1534	52,2	3,43	13,04
3	0,674	8,1	0,99	13,30	14,13	—	0,26	tr	0,3078 5,0480	0,0960 2,7138	0,1069 2,2270	0,0407 2,3500	0,0308 2,5320	0,1420 6,1739	0,0044 0,1125	55,4	3,95	12,80
4	0,750	8,1	1,10	16,70	12,77	3,93	—	—	0,2781 4,5610	0,1140 3,2226	0,1118 2,3292	0,0501 2,5050	0,0415 3,4127	0,1350 5,8695	0,0058 0,1483	49,2	3,41	19,65
5	0,660	7,9	0,97	14,94	15,17	—	0,08	—	0,3307 5,4190	0,0840 2,3745	0,0830 1,7292	0,0511 2,5550	0,0321 2,6398	0,1250 5,4347	0,0600 0,1534	50,5	3,38	14,52
6	0,732	8,0	1,05	16,70	13,94	2,76	—	—	0,3078 4,9820	0,1000 2,8269	0,0847 1,7646	0,0428 2,1400	0,0459 3,7746	0,1260 5,4782	0,0037 0,1713	47,4	3,19	17,55
7	0,666	8,1	0,97	15,38	13,88	1,50	—	0,0073 0,2433	0,3024 4,9590	0,0890 2,5159	0,0814 1,6958	0,0417 2,0850	0,0409 3,3634	0,1150 4,9999	0,0067 0,1713	47,0	3,03	15,76
8	0,516	8,1	0,80	9,52	10,04	—	0,19	0,0020 0,0666	0,2187 3,5860	0,0860 2,4311	0,0715 1,4895	0,0240 1,2000	0,0264 2,1710	0,1120 4,8695	0,0071 0,1815	57,9	3,75	8,84
9	0,624	8,2	0,89	14,79	13,76	1,03	—	0,0060 0,1998	0,2997 4,9150	0,0820 2,3180	0,0732 1,5249	0,0376 1,8880	0,0409 3,3634	0,1100 4,7826	0,0052 0,1329	47,0	2,95	11,80
10	0,634	8,1	0,91	14,92	12,89	2,05	—	0,0066 0,2199	0,2808 4,6050	0.0860 2,4311	0,1282 2,6710	0,0417 2,0852	0,0519 4,2680	0,1060 4,6086	0,0067 0,1713	41,6	2,58	14,65
11	0,618	8,1	0,90	14,94	13,64	1,30	—	0,0093 0,3099	0,2970 4,8710	0,0820 2,3180	0,0789 1,6437	0,0376 1,8880	0,0390 3,2072	0,1070 4,6521	0.0072 0,1871	46,8	2,98	11,12
12	0,574	8,0	0,85	14,35	12,34	2,01	—	tr	0,2686 4,4060	0.0780 2,2049	0,0847 1,7649	0,0376 1,8880	0,0377 3,1002	0,0960 4,1739	0,0068 0,1739	44,7	2,65	8,34
13	0,608	7,9	0,93	15,24	15,81	—	0,20	—	0,0342 5,6460	0,0860 2,4311	0,0789 1,6437	0,0386 1,9300	0,0422 3,4703	0,1070 4,6521	0,0092 0,2352	45,2	2,83	10,26

14	0,602	8,1	0,89	14,94	14,63	0,31	—	0,0045 0,1499	0,3186 5,2250	0,0720 2,0353	0,0682 1,4210	0,0521 2,6050	0,0387 3,1825	0,0930 4,0434	0,0084 0,2148	40,4	2,33	10,75
15	0,622	8,2	0,90	15,23	14,01	1,22	—	0,0080 0,2666	0,3051 5,0040	0,0780 2,2049	0,0822 1,7125	0,0501 2,5050	0,0422 3,4703	0,1030 4,4782	0,0058 0,1483	42,3	2,59	11,68
16	0,582	7,9	0,88	14,10	14,75	—	0,23	0,0039 0,1299	0,3213 5,2690	0,0880 2,4876	0,0740 1,5417	0,0365 1,8250	0,0465 3,8240	0,0980 4,2608	0,0058 0,1486	40,3	2,54	4,39
17	0,566	8,2	0,85	13,60	13,02	0,58	—	0,0080 0,2666	0,2835 4,6490	0,0840 2,3745	0,0773 1,6104	0,0459 2,2950	0,0432 3,5525	0,0940 4,0869	0,0056 0,1432	40,6	2,39	6,92
18	0,500	8,2	0,75	13,86	8,55	5,31	—	tr	0,1863 3,0550	0,0820 2,3180	0,0789 1,6437	0,0303 1,5150	0,0415 3,4127	0,0790 3,4347	0,0080 0,2046	40,0	2,18	8,28
19	0,526	7,9	0,79	14,70	13,14	1,56	—	0,0027 0,0899	0,2862 4,6940	0,0720 2,0353	0,0674 1,4042	0,0313 1,5650	0,0447 3,6759	0,0780 3,3913	0,0082 0,2097	37,4	2,09	7,04
20	0,554	7,9	0,81	14,00	12,89	1,11	—	—	0,2808 4,6050	0,0780 2,2049	0,0748 1,5583	0,0334 1,7200	0,0403 3,3141	0,0920 3,9999	0,0067 0,1719	43,4	2,52	8,16
21	0,602	7,9	0,89	14,70	15,37	—	0,24	—	0,3348 5,4910	0,0760 2,1484	0,0773 1,6104	0,0334 1,7200	0,0528 4,3721	0,0940 4,0869	0,0138 0,3529	38,9	2,35	9,64
22	0,584	8,0	0,86	13,60	14,63	—	0,37	0,0080 0,2666	0,3186 5,2250	0,0720 2,0353	0,0732 1,5250	0,0303 1,5150	0,0379 3,1167	0,0960 4,1739	0,0132 0,3375	45,6	2,74	8,28
23	0,594	8,1	0,81	13,60	14,75	—	0,41	0,0099 0,3299	0,3213 5,2690	0,0740 2,0919	0,0764 1,5920	0,0313 1,5650	0,0396 3,2565	0,0980 4,2608	0,0074 0,1892	46.0	2,74	6,98
24	0,618	8,1	0,86	14,20	16,36	—	0,77	0,0139 0,4466	0,3564 5,8450	0,0780 2,2049	0,0814 1,6958	0,0303 1,5150	0,0428 3,5197	0,1000 4,3478	0,0076 0,1943	45,5	2,73	7,72
25	0,578	8,1	0,84	14,70	15,74	—	0,37	0,0080 0,2666	0,3429 5,6230	0,0680 1,9222	0,0799 1,6646	0,0387 1,9350	0,0564 4,6381	0,0930 4,0434	0,0066 0,1687	37,4	2,23	8,59
26	0,622	8,2	0,88	14,70	16,30	—	0,57	0,0086 0,2866	0,3645 5,8230	0,0680 1,9222	0,0764 1,5916	0,0209 1,0450	0,0510 4,1940	0,0950 4,1304	0,0058 0,1483	43,4	2,55	9,83
27	0,610	8,1	0,80	16,26	15,25	1,01	—	0,0097 0,3226	0,3321 5,4442	0,0796 2,2422	0,0838 1,7458	0,0534 2,6646	0,0344 3,1003	0,0960 4,1739	0,0074 0,1892	41,2	2,46	8,59
28	0,640	8,4	0,77	12,87	15,03	—	0,77	0,0266 0,8873	0,3271 5,3622	0.0837 2,3577	0,0887 1,8479	0,0425 2,1207	0,0297 2,4424	0,0980 4,2608	0.0076 0,1943	47,2	2,82	16,99
29	0,602	8,1	0,79	15,79	15,59	0,20	—	0,0242 0,8066	0,3334 5,5639	0,0783 2,2056	0,0764 1,5916	0,0659 3,2884	0,0282 2,3190	0,0980 4,2603	0,0086 0,2199	42,2	2,54	6,55
30	Well is being built																	
31	0,572	8,0	0,80	14,97	12,88	2,09	—	0.0194 0,6453	0,2804 4,5967	0,0891 2,5098	0,0830 1,7291	0,0643 3,2085	0,0256 2,1052	0,0890 3,8695	0,0086 0,2199	41,2	2,38	6,18
32	0,624	8,2	0,80	14,74	14,57	0,17	—	0,0145 0,4840	0,3173 5,2016	0,0918 2,5859	0,0846 1,7625	0,0617 3,0788	0,0261 2,1463	0,0980 4,2408	0,0086 0,2199	43,9	2,63	3,58
33	0,630	8,1	0,86	15,44	14,80	0,64	—	0,0218 0,7260	0,3222 5,2319	0,0999 2,8141	0,1027 2,1395	0,0751 3,7475	0,0211 1,7351	0,0950 4,1304	0,0108 0,2762	41,8	2,50	4,57

TABLE 8.

RESULTS OF WATER ANALYSIS — *continued*

WADI ZABID PROJECT

No.	Dry residue %	pH	EC 25° C mS	Degree of hardness N° total	Degree of hardness N° carbonate	Degree of hardness N° residual	Soda Eq.	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Sodium per-cent-age %	SAR	Total N mg/lit
								g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit	g/lit mEq/lit			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
34	0,536	7,8	0,74	15,09	13,90	1,19	—	—	0,3025 4,9590	0,0823 2,3183	0,0723 1,5062	0,0684 3,4131	0,0236 1,9407	0,0830 3,6086	0,0084 0,2148	39,3	2,21	0,93
35	0,490	8,1	0,69	13,57	13,33	0,24	—	0,0218 0,7260	0,2902 4,7573	0,0634 1,7859	0,0657 1,3687	0,0542 2,7045	0,0256 2,1052	0,0810 3,5217	0,0084 0,2148	41,2	2,43	1,38
36	0,472	8,2	0,76	11,46	9,94	1,52	—	0,0169 0,5646	0,2164 3,5475	0,0850 2,3943	0,0838 1,7458	0,0434 2,1656	0,0231 1,8996	0,0910 3,9565	0,0078 0,1994	48,1	2,78	3,89
37	0,458	8,0	0,64	11,81	10,96	0,85	—	0,0073 0,2420	0,2386 3,9114	0,0769 2,1661	0,0781 1,6270	0,0467 2,3303	0,0226 1,8585	0,0880 3,8260	0,0086 0,2199	46,5	2,65	1,17
38	0,464	8,2	0,72	12,28	10,62	1,66	—	0,0145 0,4840	0,2312 3,7901	0,0729 2,0535	0,0764 1,5916	0,0484 2,4151	0,0236 1,9407	0,0830 3,6086	0,0072 0,1841	44,3	2,45	3,03
39	0,462	8,1	0,74	10,06	8,93	1,13	—	0.0024 0,0806	0,1943 3,1852	0,0864 2,4338	0,0879 1,8312	0,0375 1,8712	0,0206 1,6940	0,0930 4,0434	0,0090 0,2301	51,6	3,03	4,02
40	0,496	8,1	0,76	11,82	10,28	1,54	—	0,0097 0,3226	0,2238 3,6686	0,0891 2,5098	0,0945 1,9687	0,0459 2,2904	0,0231 1,8996	0,0960 4,1739	0,0094 0,2404	48,5	2,88	0,68
41	0,692	7,8	0,80	13,10	11,75	1,35	—	—	0,2558 4,1937	0,0837 2,3577	0,0896 1,8666	0,0484 2,4151	0,0271 2,2286	0,0930 4,0434	0,0084 0,2148	45,4	2,65	2,10
42	0,[illegible]72	8,0	0,74	11,58	9,83	1,75	—	0,0073 0,2420	0,2140 3,5081	0,0850 2,3943	0,0904 1,8833	0,0425 2,1207	0,0241 1,9819	0,0890 3,8695	0,0078 0,1994	47,3	2,69	4,02
43	0,[illegible]72	7,9	0,74	11,58	10,17	1,41	—	—	0.2214 3,6295	0,0837 2,3577	0,0912 1,9000	0,0425 2,1207	0,0241 1,9819	0,0900 3,9130	0,0078 0,1994	47,6	2,72	4,88
44	0,4[illegible]0	8,0	0,74	11,35	9,60	1,75	—	0,0073 0,2420	0,2091 3,4278	0,0810 2,2816	0,0912 1,9000	0,0417 2,0808	0,0236 1,9407	0,0920 3,9999	0,0078 0,1994	48,6	2,82	3,34
45	0,5[illegible]0	8,3	0,68	1[illegible],80	14,46	—	0,23	0,0242 0,8066	0,3148 5,1606	0.0783 2,2056	0,0490 1,0210	0,0578 2.8742	0,0246 2,0230	0,1030 4,4782	0,0189 0.4757	45,5	2,87	3,21
46	0,[illegible]08	8,2	0,74	14,27	14,12	0,15	—	0.0218 0,7260	0.3075 5,0409	0,0729 2,0535	0,0781 1,6271	0,0509 2,5309	0,0307 2,5246	0,0840 3,6525	0,0070 0,1790	41,1	2,29	3,15

47	0,526	8,1	0,80	16,73	13,78	2,95	—	0,0169 0,5646	0,3001 4,9596	0,0972 2,7380	0,0945 1,9687	0,0567 2,8293	0,0377 3,1003	0,0950 4,1304	0,0108 0,2762	39,9	2,40	4,14
48	0,570	8,1	0,92	13,81	12,77	1,04	—	0,0194 0,6453	0,2779 4,5557	0,1458 4,1070	0,0764 1,5916	0,0617 3,0788	0,0221 1,8174	0,1070 4,6521	0,0088 0,2250	47,6	2,98	1,98
49	0,462	8,1	0,78	13,69	13,11	0,58	—	0,0218 0,7260	0,2853 4,6770	0,0756 2,1295	0,0723 1,5062	0,0526 2,6247	0,0271 2,2286	0,0810 3,5217	0,0076 0,1943	41,1	2,26	1,61
50	0,422	8,1	0,72	12,40	10,17	2,23	—	0,0121 0,4033	0,2214 3,6295	0,0783 2,2056	0,0682 1,4208	0,0492 2,4551	0,0236 1,9407	0,0720 3,1304	0,0058 0,1483	40,8	2,12	5,56
51	0,540	7,8	0,86	13,92	13,56	0,36	—	—	0,2952 4,8393	0,0931 2,6225	0,0846 1,7625	0,0567 2,8293	0,0256 2,1052	0,1020 4,4347	0,0088 0,2250	46,2	2,82	6,06
52	0,558	8,2	0,86	13,34	14,69	—	0.48	0,0194 0,6453	0,3198 5,2426	0,1012 2,8507	0,0928 1,9333	0,0434 2,1656	0,0312 2,5657	0,1030 4,4782	0,0252 0,6445	45,4	2,90	0,55
53	0,582	7,8	0,86	14,74	14,12	0,62	—	—	0,3075 5,0409	0,1053 2,9661	0,0781 1,6270	0,0451 2,2505	0,0362 2,9769	0,1030 4,4782	0,0098 0,2506	45,0	2,77	8,09
54	0,554	8,2	0,81	14,51	15,37	—	0,31	0,0169 0,5646	0,3345 5,4836	0,0756 2,1295	0,0772 1,6083	0,0325 1,6217	0,0427 3,5115	0,0890 3,8695	0,0080 0,2046	42,0	2,42	10,44
55	0,600	7,9	0,85	12,75	14,80	—	0,37	—	0,3222 5,2819	0,0796 2,2422	0,0937 1,9520	0,0501 2,5000	0,0246 2,0230	0,1070 4,6521	0,0102 0,2608	49,3	3,08	5,00
56	0,488	8,2	0,76	13,45	14,01	—	0,20	0,0145 0,4840	0,3050 5,0000	0,0742 2,0901	0,0674 1,4041	0,0551 2,7495	0,0246 2,0230	0,0850 3,6956	0,0120 0,3069	42,1	2,39	5,62
57	0,522	8,2	0,79	14,74	15,03	—	0,10	0.0218 0,7230	0,3271 5,3622	0,0810 2,2816	0,0797 1,6604	0,0542 2,7045	0,0307 2,5246	0,0880 3,8260	0,0082 0,2097	41,3	2,30	3,46

TABLE 9.

ORIGIN OF WATER SAMPLES
WADI ZABID PROJECT

No of water samples	Depth of Water Table	Method of use for irrigation	Duration of irrigation	Irrigated area Hectares	Near to the Profile No
1	2	3	4	5	6
1.	20,0 m	Pumping	3 Years	14,6	20
2.	8,0 m	Bullocks	6 ,,	0,73	18
3.	?	Pumping	10 ,,	21,8	21
4.	27,0 m	,,	3 ,,	18,3	22
5.	8,0 m	Bullocks	4 ,,	0,73	19
6.	16,0 m	Pumping	2 ,,	20,1	17
7.	15,0 m	Bullocks	2 ,,	0,11	25
8.	17,0 m	Pumping	1½ ,,	14,6	23
9.	19,0 m	,,	2 ,,	18,3	24
10.	21,0 m	,,	2 ,,	13,1	28
11.	16,0 m	,,	6 Months	18,3	27
12.	25,0 m	,,	1 Year	21,8	31
13.	15,5 m	Bullocks	3 Years	0,11	29
14.	28,5 m	For drink	200 ,,	—	37
15.	22,0 m	Pumping	3 ,,	21,8	40—39
16.	11,0 m	Bullocks	2 ,,	0,11	43
17.	12,0 m	,,	1 Year	0,73	44
18.	20,0 m	Pumping	3 Years	11,0	46
19.	?	For drink	150 ,,	—	52
20.	8,0 m	,,	71 ,,	—	61
21.	7,0 m	Pumping	4 Months	14,6	84
22.	16,0 m	,,	3 Years	14,26	85
23.	15,0 m	,,	1½ ,,	21,8	62
24.	12,0 m	,,	2 ,,	9,1	86
25.	?	,,	1½ Year	7,3	89
26.	?	,,	1 ,,	14,6	107—108
27.	?	Bullocks	12 Years	0,73	111—112
28.	?	Pumping	6 ,,	7,3	112
29.	18,5 m	Bullocks	12 ,,	0,4	114
30.	well is being built.				
31.	21,0 m	Bullocks	1 Month	1,5	211
32.	31,0 m	For drink	20 Years	—	217
33.	28,0 m	,,	30 ,,	—	244
34.	29,0 m	,,	39 ,,	—	263
35.	22,5 m	,,	60 ,,	—	261
36.	From the field irrigated by the water of canal Al-Bunei				
37.					
38.					
39.	From the field irrigated by the water of canal Al-Girba				
40.					
41.					
42.	From the and of the flood in Wadi Zabid				
43.	From the middle of the flood in Wadi Zabid				
44.	From the flood of Wadi Zabid at Ma'ath				
45.	Al-Hima near the road — for drink out of use				113—114
46.	Morshedia nearby the mosque — for drink				
47.	Al-Qurra nearby the mosque — for drink				
48.	Al-Moukher in the center of the village, for drink				
49.	B. Al Said Ahmed well near m. Al-Senif for drink				
50.	Camp well near the road				
51.	Suleyman well near the road of M. Al-Moukher				
52.	Al-Shobaker well 25,5 m for drink			—	214—215—216
53.	M. Al-Nadaah well for drink				
54.	Dahi-Talha well for drink N. from Zabid				
55.	Al-Shugun well for drink				
56.	M. Al Girbeh near small mosque for drink				
57.	Beit Tanka				240

TABLE 10.

RESULTS OF ANALYSIS OF THE WATER SAMPLES TAKEN FROM THE NEWLY DRILLED DEEP TUBE-WELLS WADI ZABIB PROJECT

		1	2	3	4	5	6
Dry residue	g/lit	0,568	0,526	0,468	0,448	0,450	0,460
pH		8,3	8,4	8,4	8,4	8,3	8,4
$EC_{25\,°C}$	mS	0,76	0,74	0,73	0,70	0,69	0,71
Degree of hardness							
Total	N°	14.76	13,72	14,51	15,23	11,96	12,71
Carbonate		12,53	12,34	12,63	12.34	10,47	10,37
Residual		2,23	1,38	1,88	2,89	1,49	2,34
CO_3^{2-}	g/lit	0,0190	0,0226	0,0190	0,0180	0,0148	0,0144
	mEq/lit	0,6320	0,7520	0,6320	0,6160	0,4960	0,4780
HCO_3^-	g/lit	0,2731	0,2689	0,2752	0,2689	0,2282	0,2261
	mEq/lit	4,4777	4,4080	4,5120	4,4081	3,7409	3,7065
Cl^-	g/lit	0,0843	0,0817	0,0621	0,0607	0,0820	0,0789
	mEq/lit	2,4096	2,3368	1,7736	1,7305	2,3447	2,2556
SO_4^{2-}	g/lit	0,0731	0,0550	0,0476	0,0493	0,0583	0,0603
	mEq/lit	1,5312	1,1479	0,9916	1,0279	1,2145	1,2666
Ca^{2+}	g/lit	0,0659	0,0639	0,0601	0.0616	0,0588	0,0592
	mEq/lit	3,2904	3,1886	3,0000	3,0820	2,9371	2,9588
Mg^{2+}	g/lit	0,0239	0,0222	0,0263	0,0283	0,0161	0,0191
	mEq/lit	1,9654	1,8250	2,0806	2,2902	1,3240	1,5707
Na^+	g/lit	0,0740	0,0720	0,0680	0,0660	0,0690	0,0690
	mEq/lit	3,2174	3,1304	2,9565	2,8695	3,0000	3,0000
K^+	g/lit	0,0032	0,0031	0,0034	0,0032	0,0027	0,0026
	mEq/lit	0,0843	0,0818	0,0895	0,0843	0,0690	0,0664
Fe^{2+}		—	—	—	—	—	—
Fe^{3+}		—	—	—	—	—	—
Mn^{2+}		—	—	—	—	—	—
$Na^+ : / Ca^{2+} + Mg^{2+} + Na^+ + K^+ /$ %		37,6	38,1	36,5	34,7	40,9	39,5
SAR		1,96	1,94	1,88	1,76	2,05	1,99
Total N	mg/lit	17,36	16,72	28,77	29,14	20,46	18,11

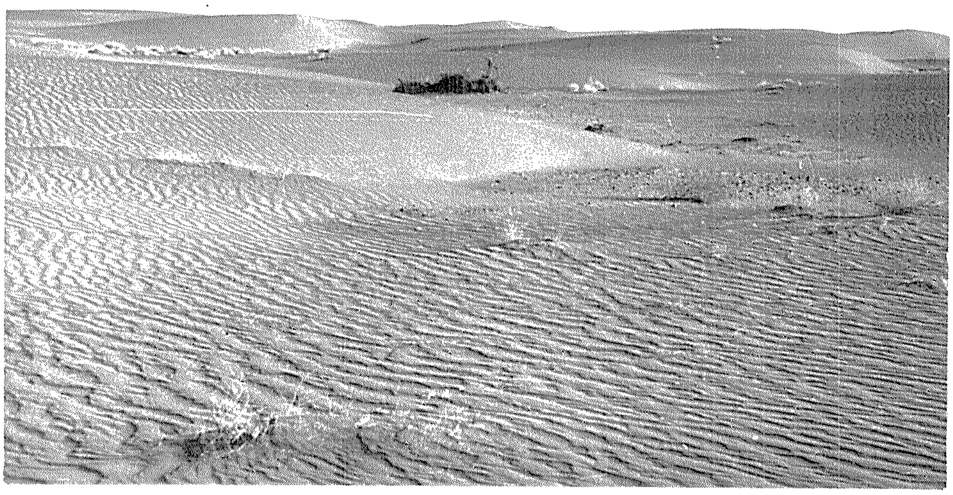
No. 1 = Well No. 3.
No. 2 = Well No. 3.
No. 3 = Well No. 5.
No. 4 = Well No. 5.
No. 5 = Camp-well
No. 6 = Camp-well

Appendix 6

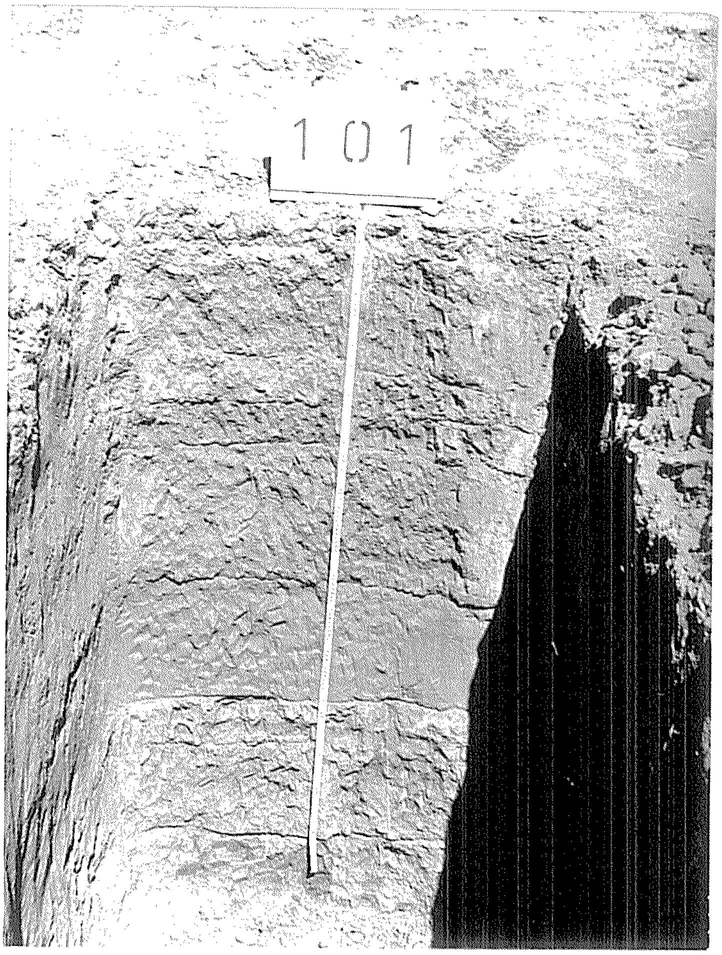
LIST OF MAPS

Appendix 7

LIST OF PHOTOGRAPHS

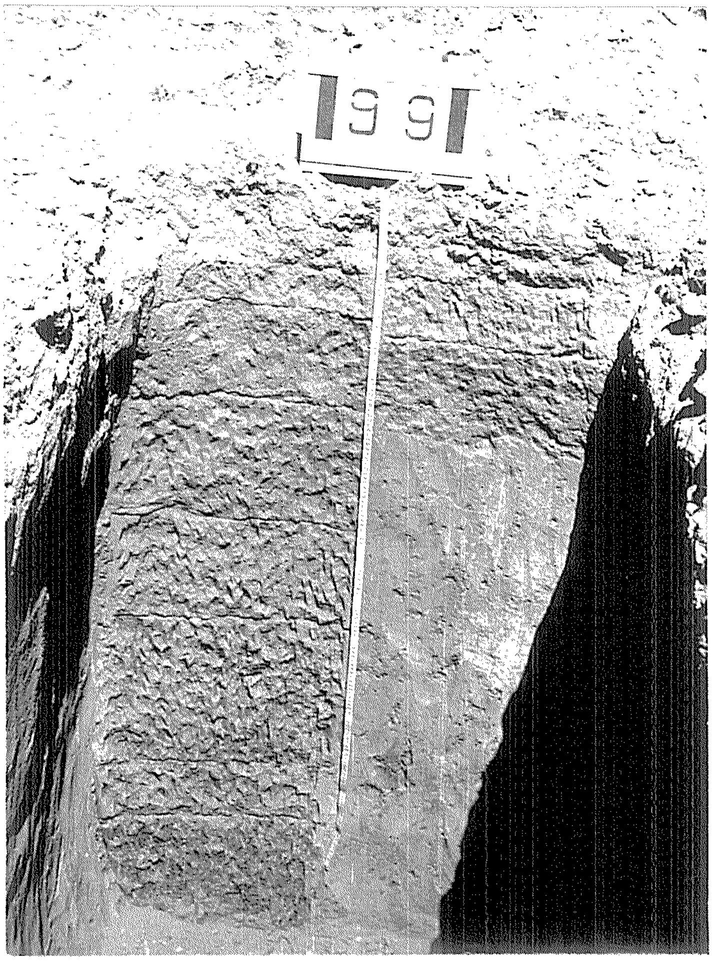


1. Desert with sand hills

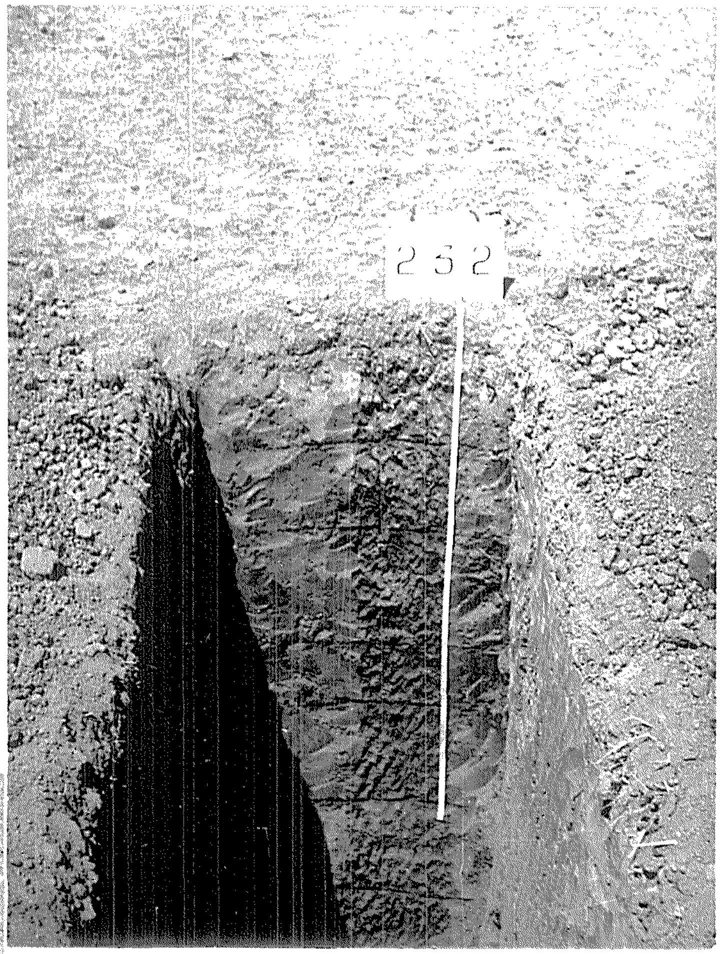


2. Alluvial soil /1.2.2/

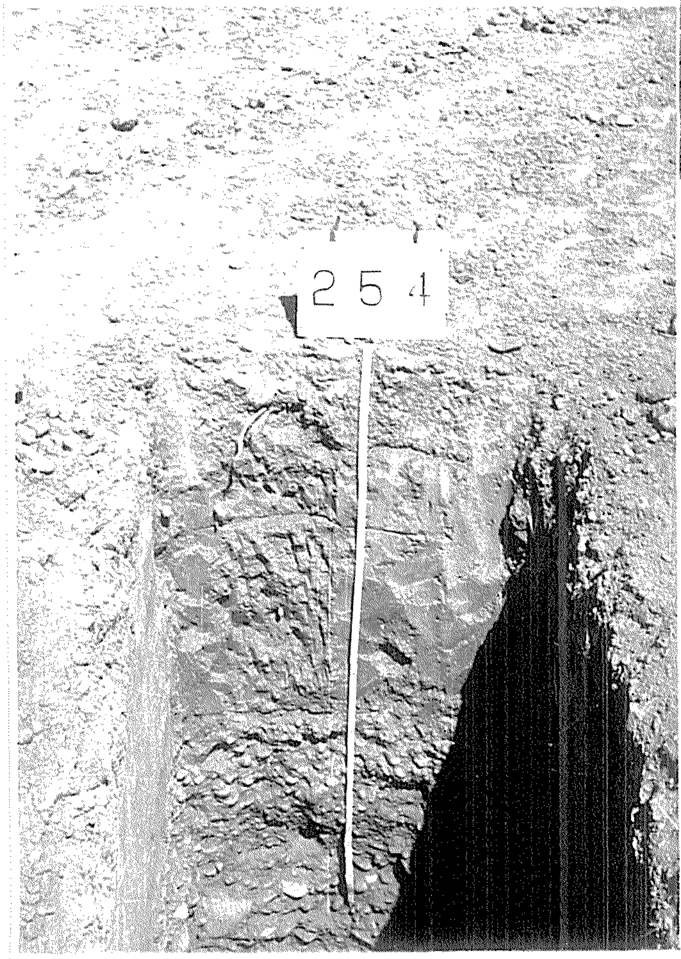
3. The Yemeni counter-part staff in action



4. Arid brown soil /3.2/

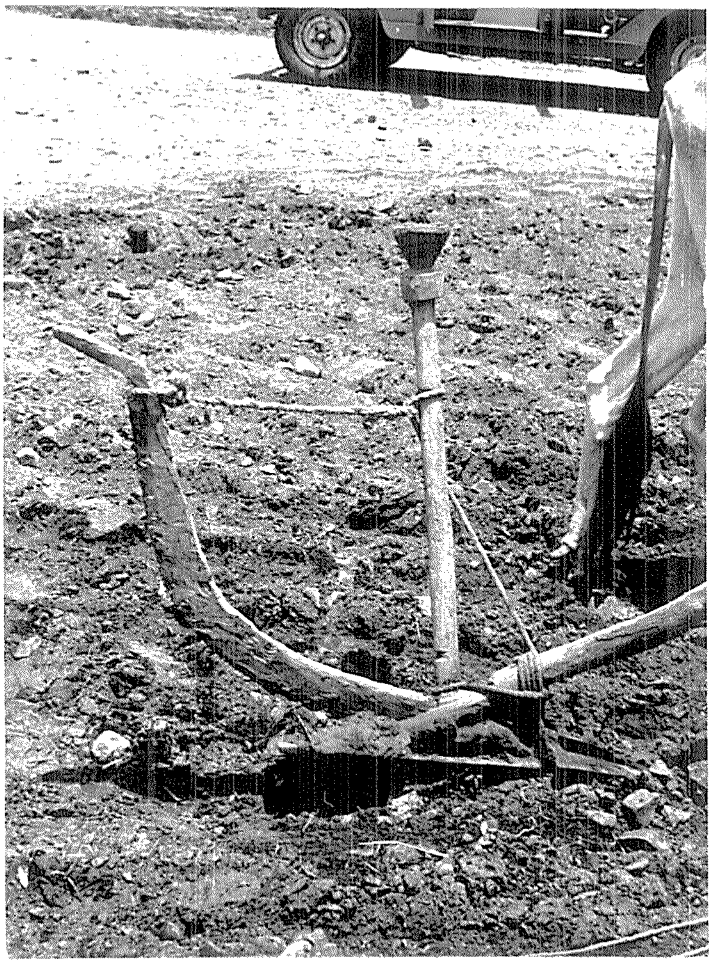


5. Arid brown soil /3.4/

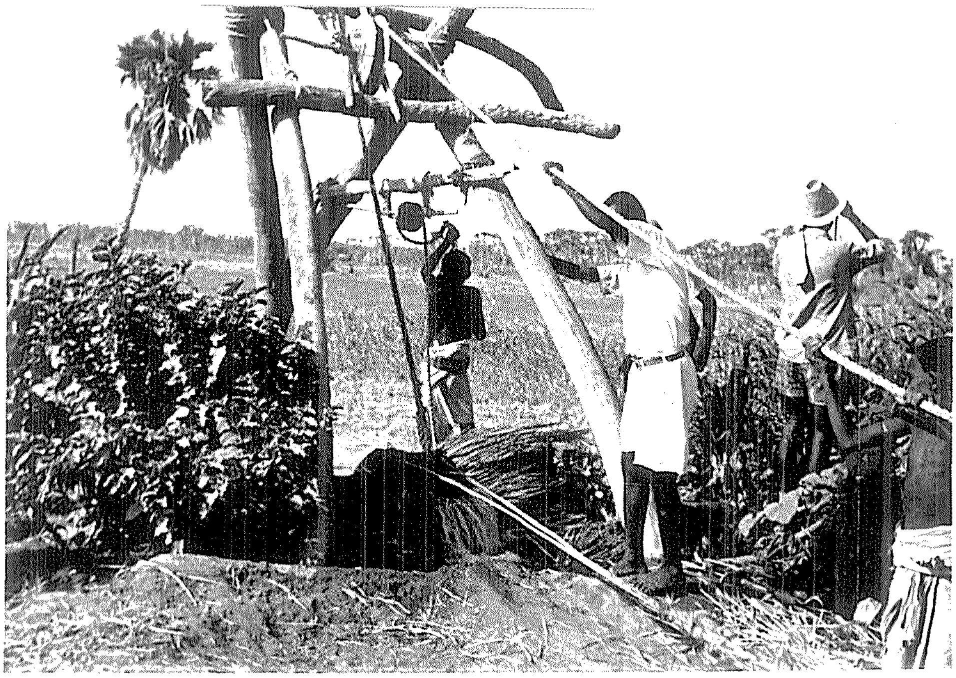


6. Alluvial soil /1.1.1/

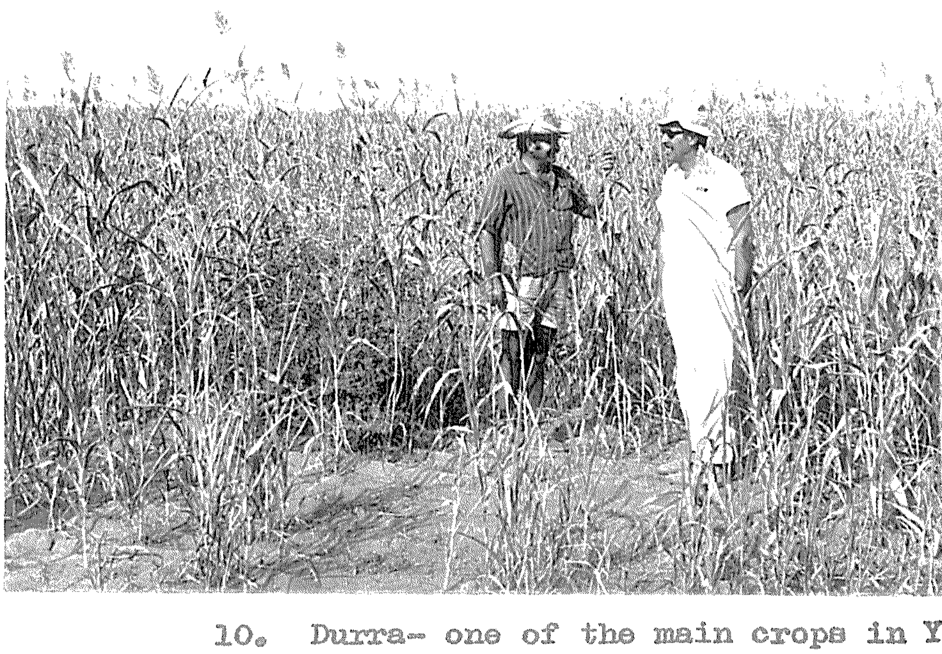
7. Ploughing and sowing in one operation



8. Steel-headed Yemeni plough with sowing tube



9. Bullocks irrigation



10. Durra- one of the main crops in Yemen

11. Corn on the field with
permanent water supply