FUNDS-IN-TRUST FOR KUWAIT

FAO/KU/TF 17

Report to the Government of

KUWAIT

RECONNAISSANCE SOIL SURVEY

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1969

FOR KUWAIT

FUNDS-IN-TRUST FAO/KU/TF-17

RECONNAISSANCE SOIL SURVEY

Based on the work of

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1969

ABSTRACT

RECONNAISSANCE SOIL SURVEY OF KUWAIT

An FAO Soil Survey Specialist, Mr. Halim N. Ergun, was in Kuwait from January 1965 to December 1968, to carry out a soil survey project under a Trust Fund agreement with FAO.

The main objectives of the Project were to study and map the soils of Kuwait and to provide the interpretative data needed for an assessment of the soil potentialities, particularly for irrigation and conservation.

Soil surveys were made at the reconnaissance level for all of Kuwait and a soils map was prepared. The highest category of soil classification used was the Great Soil Group; while the lowest units used were soil series, mainly grouped into soil associations.

Soil interpretation information based on data gathered during the soil studies are included in the report. This information provides a guide for soil management practices, particularly for proper land use and on soil productivity. Interpretative groupings are also given for potential irrigability and rangeland suitability.

Recommendations for future work in soils and land use are presented. These recommendations emphasize the need for detailed soil survey and irrigation suitability classifications in those areas having the most promising irrigable soil. Emphasis is also placed on the need for additional studies of the major soil properties, as well as on the need for erosion control measures to protect against overgrazing and soil blowing.

In addition to the reconnaissance soil map, other maps pertinent to the soil studies are included in the report.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

1. Government Request and Appointment of Expert

At the request of the Government of Kuwait an agreement was reached between the Kuwait Government and the Food and Agriculture Organization of the United Nations, to conduct a Soil Survey in Kuwait.

2. Terms of Reference

1. To study and map the soils in relation to local geology and vegetation.
2. To study and interpret climatic data in relation to hydrologic and biotic cycles and to assess soil potentialities for soil conservation and irrigation purposes.
3. To control and supervise all laboratory work carried out in support of soil classification and to train local personnel in these various fields.

3. Summary of Assignment

The FAO Expert, Mr. Halim N. Ergun arrived in Kuwait in 19 January 1965 and served with the Agricultural Section, Ministry of Public Works until 31 December 1968.

The first part of his assignment was to prepare a Reconnaissance Soil Map of Kuwait. In accordance with the request of the Agricultural Section, a preliminary report was prepared with a map in a scale of 1:250 000 and published 1:500 000 for the purpose of supplying urgently needed information about the soils of the State which contains 1 559 975 hectares. This survey was initiated in March 1965 and the field work was completed in March 1966. The Preliminary report was available in July 1966 for immediate use.

Beside the Reconnaissance Soil Survey, Land Irrigability Surveys and composite surveys were made on request.

According to the agreement between FAO and the Government of Kuwait, the Soil Survey Expert was requested to prepare Terms of Reference for some consultant firms engaged to perform more detailed soil surveys of areas selected by the Government. After selecting a consultant firm, the Expert was asked to assist and advise the Government in controlling and supervising the work of the consultant with regard to soil survey project. He carried out this work until the end of his assignment.

Training was one of the important parts of the work. Two non-Kuwait's counterparts were trained in various subjects related to soil survey and classification, in the field and the office.

During the assignment one field vehicle and one worker were available all the time for the field work. Core-type soil augers were used for the field work and a drilling machine of about 80 cm diameter was used for the hardpan soils.

All soil samples were analysed by the Agricultural Sections Laboratory. The laboratory was capable of undertaking all kinds of soils analyses, except soil permeability.

4. Acknowledgements

FAO is greatly indebted to the many people who collaborated with the expert; particularly Mr. Salem Al-Mannai, Head of the Agricultural Department, Mr. Tewfick Al-Nagib, Deputy Head of the Department, and their staff members.

CHAPTER II

CONCLUSIONS AND RECOMMENDATIONS

As a result of the soil studies for the development of agriculture in Kuwait, the following conclusions and recommendations are given:

1. Approximately 200 000 hectares of the Kuwait soils are relatively suitable for agriculture under irrigation, as shown by the symbol (B1) on the Reconnaissance Soil Map. It should be kept in mind that a reconnaissance soil map is not intended to show minor differences in the soils, but to record major soil delineations.

2. Considering the importance of irrigation in Kuwait, the Expert recommended in his preliminary report a detailed Soil Survey and Irrigability Survey for mapping unit (B1) which contains the most promising irrigable soils of Kuwait. Only 80 000 hectares of this area were allocated for agricultural purposes by the Government, in view of the future expansion of oil fields. The semidetailed soil survey was completed by the consultant and 10 000 hectares from the 80 000 will be surveyed in detail for Irrigation Land Classification (see Map 11).

It is recommended that after having the irrigability survey most of the agricultural activity should be in this particular part of the State, which should have the best soils for irrigation. The Pilot Farm, which will be established in this area, should make the necessary demonstrations and experiments on these soils according to the characteristics of the different soil series; and the results should be given to the farmers by the Extension Service.

3. The Pan (Gatch) layer occurs in most of the soils of Kuwait. It restricts the permeability of the soil and root penetration. The thickness and degree of cementation of this layer differ from place to place (see Map 10).

It is recommended that additional studies should be made of the physical, chemical, and biological properties of this material, giving priority to the sites most suitable for range and forestry purposes.

4. It is recommended that, before any system of irrigation is developed, soil permeability, infiltration rate and soil moisture tension relationships be determined and drainage be studied. To undertake this work, special equipment and apparatus will be needed. The salinity content of the irrigation water and soil should be periodically checked.

5. Attention should be given to the use of brackish water for irrigation which contains an average salinity of about 6260 $EC \times 10^6$. After some years of irrigation with brackish water, salt is likely to accumulate in the surface layers of the soil. It is recommended that a suitable crop rotation be developed and studied and a proper drainage system adopted before large-scale irrigation is developed.

6. It is recommended that experimental and demonstration forestry and grazing units be established in areas not suitable for general agriculture.

7. Over-grazing is general in Kuwait, especially during periods of extended drought. It is recommended that the carrying capacity of the natural range be determined for each of the defined plant associations in Kuwait. To facilitate this work some type of control must be established over those using the range.

8. The collection of gravel from the surface layers of the soils for commercial use as building material is the cause of accelerated wind erosion. This can be evidenced on both sides of Kuwait-Basrah Highway after Mutla.

It is recommended that such gravel be obtained from selected gravel pits which occur in Shigaya area, rather than from the surface layers of the soil over large areas.

9. It is recommended that the Government should employ a Kuwaiti Agricultural Engineer in the Soil Survey and Classification Branch.

10. It is recommended that the detailed survey work on 17 000 hectares for irrigation purposes to be carried out by the consultant, should be executed in exact accordance with the Terms of Reference (see Appendix 1.4) as the minimum requirement.

11. Land of Irrigation Class 5 should not be included in the consultant's maps. This land class needs to be further studied from an economic and engineering point of view.

CHAPTER III

GENERAL DESCRIPTION OF KUWAIT

1. Location and Extent

The State of Kuwait is located at the northwest corner of the Arabian Gulf between latitudes 28° 30' and 30° 50', and longitudes 46° 30' and 48° 30' east. It is bounded on the south by the Neutral Zone and Saudi Arabia, on the north and west by Iraq, and on the east by the Arabian Gulf (see Map 1). The State of Kuwait is about 1 555 975 hectares. The Neutral Zone area is about 569 000 hectares and is administrated jointly by Kuwait and Saudi Arabia. Bubiyan, Warbah and Failaka are the important islands of Kuwait and only Failaka island is inhabited.

2. Climate

The climate of Kuwait may be classified as follows:

Tropical and Subtropical Desert (BWh, Köppen)
Arid Tropical Dry (EAd, Thornthwaite)
Tropical Desert (Koeppe)
Arid Hot (Aa24, Tree Planting Practices for Arid Zones, FAO)

The climate is characterized by hot and dry summers with frequent sandstorms, and mild winters with low rainfall.

Air temperatures range from 14° C to 37° C with average maximum 44° C in August and average minimum 8° C in January. The hottest months are July and August, the coldest are December and January. The daily difference of temperature amounts to 10° or more. Temperatures are very high between May and September.

Three years' records from 1961 to 1964 show that mean ground temperature at 5 cm deep is maximum 38.8° C in July and 15.2° C minimum in January; at 120 cm it is maximum 34.3° C in August and minimum 23.1° C in January.

The rainy season is from November to March. But rainfall is very irregular and a rainfall pattern is not known inland. The average annual rainfall is about 100 mm. A maximum of 336 mm was recorded in 1954, and a minimum of 26.3 in 1964. The ratio of the annual maximum to the annual minimum is about 13:1.

The mean relative humidity is between 27 percent and 63 percent. The average maximum is 80 percent in December and minimum 13 percent in June. The maximum humidity sometimes reaches 98 percent or even 100 percent.

Evaporation is very high. The mean evaporation is 14.1 mm/day and the maximum reaches 24.3 mm in summer. In winter it is 4.9 mm.

Northwest wind blows most of the year. It is cold in winter and hot in summer. Southeasterly winds blow between July and October from the Arabian Gulf producing humid conditions.

Sand storms usually occur between March and August and may continue several days.

3. Physiography

The physiography of Kuwait is related to the Arabian desert plain. It is an undulating desert country and rises gradually from the coast to the west (see Map 4). There are some low hills and small depressions in this undulating desert plain. Elevation ranges from 0 to 300 metres above sea level. The highest part of the country is located on the western boundary.

West of Kuwait Bay, Az Zor escarpment reaches a maximum height of 110 metres above sea level. A plain, interrupted by Wadi Al Batin, extends in the north. Many small depressions, which are separated by gravel-capped ridges, are located in the northern plain.

The northeastern part of Kuwait is influenced by the deltaic and estuarine deposition of the Tigris-Eupharates river system, and includes shallow islands such as Bubiyah and Warbah. Surrounding these islands are extensive mud flats.

The topography gradually increases from the south of Kuwait Bay toward the west. After Ahmadi there is a plain, with the Burgan fields to the south and west. North of Burgan, the Wara hills rise as local conical hillrocks. South of Ahmadi and Burgan a low, flat plain joins the Neutral Zone.

Geologically, Kuwait is a part of the Arabian foreland with unfolded block fronting on the Arabian Gulf. This horizontal, gentle folding is reflected in the undulating topography.

The escarpment of Az Zor is a fault-scarp and similar faulting occurs in the Burgan and Magwa oilfields.

Most of northern Kuwait is a gravelly plain littered with pebbles and cobbles coming from the underlying sand and gravel deposits. In western Kuwait the coarse gravel caps the terraces in and along Wadi Al Batin. The coarse gravel also occurs along the southern border between Batin and Minagish.

Wind blown sands occur in patches within the gravel plain. They are extensive in the northeastern and southeastern parts of Kuwait. Inland sand dunes about 0.5 or two metres high occur only in the Umm Nigga area in the northeast of the State.

Recent marine deposits are present along the coast of Kuwait Bay and northeast coasts.

Stratigraphy 1/

(i) Recent deposits: These are shallow deposits which have developed extensively in Kuwait.

a. Beach deposits: Along the coast of Kuwait, beach deposits have developed. They differ from place to place. Generally they are sand containing shells and are cemented with calcium and magnesium carbonate.

b. Deltaic and tidal mud flats: On the northeast shores of Kuwait and Bubiyan island, there are mud flats. These have developed from the fine material of the Tigris-Eupharates river system.

c. Wind blown sand: They are a product of wind erosion and accumulated on the leeward side.

(ii) Pleistocene: Dibdiba formation is represented as outcropping north of a line between Az Zor escarpment and Al Mussanat; while the underlying

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1/ Report on the Surface Geology of Kuwait with Reference to the Natural Resources of Building Materials. (I.E. Higgenbottom, 1954)

Kuwait series occupies the low lying country around the Burgan oilfield. The Dibdiba formation has poorly consolidated sandy beds which are exposed at the top of Az Zor above the prominent crags of calcareous gritstone.

The Dibdiba formation consist of two general units:

a. Upland gravel: These are pebbles and cobbles of silicious rocks with a dark reddish to black color and are smooth and well rounded.

b. Consolidated blanket-type deposits: These are dominantly sandstones overlying the Lower Fars formation which contains more sandstone and less shale.

(iii) Pleistocene-Miocene: Kuwait group underlies the Dibdiba formation and has coarse feldspatic sands and calcareous gritstones with thin saline clays and limestones containing shells.

4. Vegetation 2/

The natural vegetation of Kuwait belongs to the Saharo-Sindian distribution. about 260 species of plant have been recorded and 60 percent of these are annuals. The annual plants grow during the cool season between November and April. Their growth and size depends on the amount of rainfall. Some 50-60 species of annuals are known to be grazed by animals and about 35-40 have wide distribution in all the areas. Stipa tortilitis is common on the north and southwest. In the northern part of the State Gymnarrhena micrantha, Savingnya parviflora, Helianthemum ledifolium, Arnebia decumbens, Polycarpaea repens and Plantago ovata are the common annuals. In the depressions of the different part of the country, with excess moisture, Medicago aschersonia and Trigonella anguina grow during the moist season. In the sandy areas of the south, the important annual grasses are: Sphenopus divaricatus, Koeleria phleoides, Cutandia memphitica, Bromus tectorum; among the legumes, Medicago aschersoniana and Lotus pusillus are very common. Plantago albicans is the most common herb of the whole State. Koelpinia linearis, Brassica tournefortii, Emex spinosa, Matthiola oxyceras, Neurada procumbens are the important herbs of the sandy region.

The perennial vegetation of Kuwait comprises the following major plant communities:

a. Coastal salt brush association: They occur in lowlands along the seashore, where the salinity is high. Dominant plant is Zygophyllum coccineum, in association with other halophytes such as Nitraria retusa, Lycium arabicum, Halocnemon strobilaceum.

2/ Natural Vegetation and Animal Production in Kuwait. (M.D. Kernick)

b. Coastal sand association: They occupy the land extending around Kuwait Bay and down to the Gulf coast. The main plant is Panicum turgidum. The other plants of the association are: Convolvunus oxyphllus, Lithospermum callosum and Aristida plumosa.

c. Cyperus steppe association: The Cyperus steppe is represented by Cyperus conglomeratus. This sedge grows on the sandy areas of the southern half of the State, chiefly between Kuwait City and the Burgan oilfield. The other members of the association are Aristida plumosa and Danthonia forskalii.

d. Rhanterium steppe association: Rhanterium epapossum occupy a very large area which extends from the south to the north half of the State.

e. Haloxylon steppe association: This is composed chiefly of Haloxylon salicornicum, which mainly occurs in the west and north. In Dibdiba region Haloxylon salicornicum is found in association with Anabasis articulata and Anabasis setifera.

5. Agriculture

5.1 General

Kuwait imports most of the agricultural produce from outside. Present agriculture mainly depends on irrigation water availability, which is not sufficient. Other restricting factors of agriculture in Kuwait are soil (coarse texture, and pan layer with salinity content), and climate (high temperature, high evaporation) and wind erosion.

Approximately 200 000 hectares, 12.82 percent, of the land is suitable for arable farming. At present less than one percent of the total area is under cultivation due to scarcity of water. Dry farming is practically impossible because of very high evapotranspiration.

Most of the agricultural activities are concerned with animal farming, but in a few areas crops such as vegetables and alfalfa are cultivated (Jahara, Fantas, Abdali areas).

With the establishment of the Experimental Farm in 1953, new agricultural techniques have been introduced for various crops, shrubs and trees to determine the varieties most suited to local conditions. Gradually the activities of the farm have been extended as more water is made available. The area covered by farms now covers about 5 700 decars with about ten million gallons of water consumed each day.

Future development of agriculture on any scale in Kuwait depends on much greater quantities of water. A project for the treatment of sewage water is now being developed and in 1971 it is expected that 20 million gallons per day will be available from this source for agricultural purposes. In the later years implementation of the Shatt-Al-Arab project could help to transform agriculture in Kuwait as the agreement with the Republic of Iraq provides for a supply of up to 120 million imperial gallons a day to be piped to Kuwait.

5.2 Crops

Crop production in Kuwait is limited to a few villages scattered throughout the country and the quantity produced is very small compared with the demand. Tomatoes, onions,radish, spinach, jews mallow and cucumbers are the main vegetables. Generally fruit production is not very promising the limiting factors being mostly lack of water and high salt content in the available water. However, date palm, grapes and pomegranate are produced relatively well in Kuwait. The demonstrations have shown that alfalfa can be produced well. The productivity is high and succeeds under local conditions. Sudan grass, fescue and stavium were also found to survive. and produce well.

5.3 Animals 1/

The desert provides grazing for flocks of sheep, goats and camels kept by the Bedouin tribes but the numbers vary according to the amount of rainfall.

(i) Sheep: The main breed of sheep is the Arab fat tail type, though there are some other breeds. The estimated number of sheep are about 70 000.

(ii) Goats: Goats are kept mainly for their milk and hair. They are about 70 000 in number.

(iii) Camels: Camels are kept mainly for their milk and only secondarily for their meat. They are now seldom used for transport. The number of camels is about 6 000.

(iv) Cattle: There are no large herds of cows in Kuwait but small herds of local type called Beladi are kept for their milk. There are about 10 000.

(v) Poultry: There are about 40 commercial poultry farms located around Kuwait City. They are intended in the first place for egg production and in the second for poultry meat.

1/ "Kuwait-Past and Present" (K.G. Fenelon)

5.4 Farms

There are about 120 farms in Kuwait, covering a total area of around 5 700 decars. The farms are planted with vegetables and alfalfa. They are irrigated with brackish water. The approximate total yields is 700 tons per year. This accounts for only one percent of the total requirements.

CHAPTER IV

SOILS OF KUWAIT

1. Reconnaissance Soil Survey

The purpose of a soil survey is to examine, classify and map the soils in the field. According to the kind of survey, soils are systematically examined in the whole survey area. The pits are dug, borings are made and exposures, such as those in road cuts and gravel pits, are studied. Each excavation exposes a succession of distinct soil layers or horizons which is called soil profile. The soil parent material and each soil horizon are studied. The colour, structure, consistence, reaction, organic matter, lime content, root distribution, gravel and stones are noted. The runoff, permeability and internal drainage and external features such as relief, slope and erosion are taken into consideration. and the soil plant relationship is studied.

Soil maps are made by observing the soils in the field. The boundaries of different soils are plotted on the maps or aerial photographs. Soils are studied to the depth of 150 cm. After being classified and their boundaries plotted, they are correlated. Correlation consists of comparing the soil units mapped with those already defined in the international system of classification.

Soils vary from place to place. They may be shallow or deep, well drained or poorly drained, sandy or clayey, rolling or level. For the best production, these various kinds of soils need different types of management. The soil information gained from the soil studies has little prediction value unless it is classified and properly interpreted.

In reconnaissance soil mapping, the classification units can be shown by soil associations. A soil association is a group of defined and named taxonomic units, occuring together in an individual and characteristics pattern over a geographic region.

In this report, names, proportions and defin tions of soil series are given. Reconnaissance maps are made by observing the area at wider intervals than in the case of detailed surveys. The intervals of traversing may vary from 0 8 km to several kilometres. Land intensity reconnaissance maps are usually planned for exploratory purposes. Other reconnaissance surveys (medium of high intensity) are used to discover and outline areas of soil suitability and more intensive development. The scale of reconnaissance survey is smaller than that of detailed maps.

A preliminary report of the reconnaissance soil survey was prepared in July 1966 with a map of 1:250 000 scale. This map was published by the Government in colour to a scale of 1:500 000.

1.1 Soil survey methods and standards

The method and standards of the reconnaissance soil survey were mainly based on the Soil Survey Manual, Agricultural Handbook No. 18, USDA. However, slight modification was made to fit local conditions (see Appendix 1.1).

The principal survey method was a general ground survey from the roads. The permanent roads and tracks were used for the location of the pits and borings as the main traverses.

The use of aerial photographs, 1:50 000 controlled mosaic, and aerial photo interpretation were not practical due to very low relief and featureless desert land and the temporary tracks. Aerial photo interpretation was only used for the Az Zor escarpment and on a small scale. Grid surveys also were not found useful because of shortage of time and lack of features such as hills, streams, trees, farms etc. The base maps were 1:100 000 and 1:250 000 topographic maps without contour lines. 1:500 000 geological and vegetation maps were used for interpretation.

Five and a half months were spent for the field study and the report was prepared during six and a half months. Very high temperatures in summer and dust storms were main restricting factors of the field work. Considering the future soil survey programme of the State, the emphasis was placed on the soil series, which were studied in detail.

The specification of the reconnaissance soil survey can be shown as follows:

Kind of soil unit: Soil association and soil series
Main purpose of map: Reconnaissance survey for very large project
General category of Map: Reconnaissance
Number of sampled pits: per 1000 ha : 004
Number of observation, auger borings per 1000 ha : 11
Depth of pits and borings: 150 cm or more
Scale of topographic maps: 1:100 000 and 1:250 000
Scale of aerial photographs: 1:50 000 controlled mosiacs

1.2 Laboratory methods

Data obtained by mechanical and chemical analysis of soils in Kuwait are given in Appendix 3.1. The procedures used in these analyses were essentially the same as those given in "Agricultural Handbook, 60, Diagnosis and Improvement of Saline and Alkaline Soils, USDA." as shown below:

Particle size distribution: by hydrometer
pH: glass electrode
Electrical conductivity: direct indicating bridge
Soluble cations and anions:
Calcium and Magnesium: by titration with ethylenediaminetetraacetate
Sodium: by flame photometer
Potassium: by flame photometer
Cation exchange capacity: by ammonium acetate
Gypsum: 1. by precipitation with acetone
2. by increase in soluble calcium plus magnesium content upon dilution
Organic matter: 1. dry combustion
2. dichromate method (Walkey)
Nitrogen: by Kjeldahl method
Phosphorus: venedate-molybdate
Potassium: by flame photometer

2. General Properties of Kuwait Soils

2.1 Genesis and morphology

Soil is the natural medium for the growth of plants and has many forms. Its

characteristics, in any place, result from the soil forming factors. These are climate, living matter, parent material, relief and time, including the effect of the cultural environment and man's use of the soil. The king of soil that develops in any area is the result of these five soil forming factors.

The climate of Kuwait is arid which greatly restricts soil formation. The weathering mostly depends on physical rather than chemical and biological factors. Rainfall is very low and evaporation very high. Parent material is formed from marine origin sedimentary rocks, mainly different kinds of sandstone. The texture of the soils is generally sandy, related to their parent material which retards development. The influence of vegetation on soil formation is very small because biological weathering is not sufficient to provide organic matter. The influence of the relief is also very small due to its monotonous undulating shape.

The soils of Kuwait are not well developed since the influence of the soil forming factors is limited. Severe wind erosion, which removes the surface soil continously, also restricts soil formation in Kuwait.

2.2 Soil classification

The object of any system of classification is to group units that have similar characteristics. The basic unit of the classification system is the soil type. Soil types are grouped into soil series which are grouped into soil families. Higher categories are great soil groups, suborders and orders. In this report soil series were used as the lowest classification unit. The classification units of Kuwait soils are shown in Appendix 4.1.

The system of soil classification and nomenclature followed in this report is based on that used in FAO. The system is outlined in "Soils and Men, 1938 Yearbook of Agriculture, USDA" and modified slightly in the "Symposium on Soil Classification" published in "Soil Science", 1949.

2.3 High level classification and correlation

The higher classification units are most useful in understanding the relationships among soils. In this report the great soil group is the highest category considered.

2.3.1 Great soil groups

The great soil group is a group of soils having common internal soil characteristics. All soils in a great soil group must have the same kinds of horizons similarly arranged in the profile. The degree and some secondary properties of these horizons may vary within a great soil group.

Four kinds of great soil groups were found in Kuwait (see Maps 6 and 9). They are:

Desert
Desert-Regosol Intergrade
Lithosol
Alluvial

The size and the percentage of each great soil group are listed in Tables 2 and 3.

Desert Soils (A 1/)

Desert soils of Kuwait (see Maps 6 and 9) cover a large area extending from north to south and east to west. They are developed on undulating relief ranging from nearly level to rolling. The climate is arid with very low rainfall and very high evaporation. Drainage of the desert soils ranges from somewhat excessive to imperfect. They are usually very weakly developed. Well developed soils were not observed. AC horizons are common; if B horizon is present it is very weakly developed.

The surface soil is generally pale brown and the suboil very pale brown. These soils are characterized by a sandy texture with cemented subsoil consisting of lime pan, silica pan, lime-silica pan or a mixture of them.

In the western part, the surface of the soils is covered with a gravel layer (desert pavement) varying in size and color. The gravel are generally rounded in shape and are considered alluvial spreads of old times. The desert pavement (a layer of pebbles and stones) is considered to be residue from a mass of material, the finer material of which having been removed by wind or water.

The structure of the desert soils has not been well developed. In most cases, weakly developed platy structure was observed on the surface soil under the desert pavement, in 4-6 cm depth. Subsoils do not have a developed structure other than very weak and moderately blocky.

Desert soils of Kuwait are normally moderately to strongly calcareous. The surface layer is more calcareous than the layers below. They show variable amounts of accumulation of soluble salts and gypsum. When there are gypsiferous layers, the thickness of the profile decreases accordingly. Exposed gypsiferous layers were observed in some cases.

In many places, concentrated materials in the soil profile form a cemented layer. This hard pan (locally called Gatch) changes in consolidation and depth from place to place (see Map 10). There are mainly two kinds of hardpan. One is rich in $CaCO_3$ which can be called lime pan; the other is a silica pan which sometimes reaches 88 percent SiO_2. The mixture of silica and lime occurs in variable

1/ Mapping symbol

amounts, percentages and shapes. Caliche formation was found, especially in the north and west part of the State.

Desert soils of Kuwait are dry most of the time but are occasionally wetted by infrequent heavy rains or surface floods. They are very little leached. The biological activity and chemical weathering are very low; and the physical process of weathering is more important than chemical weathering. The rainfall is not sufficient to maintain a good plant cover. The vegetation is desert shrubs, principally Rhanterium epapossum, Cyperus conglomeratus, Haloxylon salicornicum and Panicum turgidum. The organic matter is very low because of the kind, density and coverage of the natural vegetation.

Wind erosion is very active on the desert soils, and the removal type is more common than the accumulation type.

In the Desert soil region, there are small depressions with younger sediment which had come from surrounding areas, including fine soil material such as silt and clay with moderate to slow permeability.

Five kinds of Desertic soils were reoognized:

Sandy Desert Hardpan Soils
Gypsiferous Desert Soils
Gravelly Saline Desert Soils
Gravelly Gypsiferous Saline Desert Soils
Saline Gypsiferous Desert Soils

Desert-Regosol Intergrade Soils (B)

Regosol is the term used for the soils developed on unconsolidated material. In Kuwait, Desert-Regosol intergrade soils (see Maps 6 and 9) have been developed under the same condition of the Desert soils. They differ from the Desert soils in having a weaker profile development; lighter color; generally lack a hardpan, soluble salts, gypsum, desert pavements, and better drainage. These soils are younger than the Desert soils.

These soils are found in the southeastern part of the State, extending from south of Kuwait Bay to the southeastern boundary. They occur on undulating relief, are well drainaged and have a relatively good vegetative cover.

The profile development of these soils is very weak. The colour ranges from brown to pale brown at the surface and from yellowish brown to light grey in the subsequent layers. There is no distinct structure; and the texture is dominantly sand. The soils are calcareous throughout the profile. Organic matter content and inherent fertility are very low.

The formation of the Desert-Regosol intergrade soils may be considered as resulting from wind action since wind blown sands occur everywhere in this group of soils.

Two kinds of the Desert-Regosol intergrade soils were recognized:

Sandy Desert Soils
Desert Dune Soils

Lithosols (C)

Lithosol is the term for thin soils developed on a mass of rock fragments from consolidated rocks. They are primarily found on steeply sloping land.

In Kuwait, Lithosols (see Maps 6 and 9) were observed on Az Zor escarpment, east of Kuwait Bay. They consist of A and C horizons. The A horizon is weakly developed. Under the A horizon, in many cases, semihard $CaCO_3$ and gypsum layers occur. This layer which is mixed with small gravel and sand, has a considerable thickness.

These soils overlie consolidated rocks. They may be grouped as Sandstone-Lithosols, Gypsum-Lithosols and Conglomeratic-Lithosols.

Only one kind of soil, Escarpment, was recognized.

Alluvial Soils (D)

Alluvial soils are those formed from material recently deposited by running water. They are young soils which do not have a well developed profile. Most of the alluvial soils of Kuwait are of marine origin.

They occur along the seashores on nearly level and concave relief. The colour of the soils ranges from brown to light grey, and the textures vary from sand to clay. They are saline and gypsiferous.

Alluvial soils of Kuwait have poor drainage. They are wet most of the year due to a high water table. Reduction conditions with gley horizons and colour spots were observed in some cases.

Two kinds of Alluvial soils were recognized:

Hydromorphic Saline Alluvial Soils
Recent Alluvium Soils

3. Soil Mapping Units

Soil associations and soil series were used as mapping units in this study. The taxonomic unit is the soil series. Each mapping unit is identified by a symbol within the system of classification. The soil mapping units are shown on Maps 7, 8 and 9.

3.1 Soil association

A soil association is a group of defined and named taxonomic soil units regularly geographically associated in a defined proportional pattern. Commonly two or more series are associated in any one locality and occur in the association. They usually are named by placing together two or more names of individual important soil series. In some cases a single series name can be used.

Soil associations are important to farming in that the arrangement and kind of soil in an association govern its suitability for various systems of farming. For example, the Sandy Desert Soil Association contains soils suitable for crops or pasture or general farming under irrigation. On the other hand, Gravelly Saline Desert Soil Association can be adopted for grazing.

In the reconnaissance map of Kuwait, the soil associations are simply named for practical use. They are shown in Maps 7 and 9. The size and percentage of each soil association are listed in Appendix 4.2 and 4.3.

Ten kinds of soil associations were recognized:

Sandy Desert Hardpan Soil Association
Gypsiferous Desert Soil Association
Gravelly Saline Desert Soil Association
Gravelly Gypsiferous Saline Desert Soil Association
Saline Gypsiferous Desert Soil Association
Sandy Desert Soil Association
Desert Dune Soil Association
Escarpment Soil Association
Hydromorphic Saline Alluvial Soil Association
Recent Alluvium Soil Association

Sandy Desert Hardpan Soil (Kuwait-Ahmadi-Umm ar Rimam) Association (A1)

This association consists of the Kuwait, Ahmadi and Umm ar Riman soil series. It occurs in the south and southeastern part of the State and along Kuwait Bay. This association is composed of moderately well drained sand to sandy loam textured soils developed from sandstone which shows slight to moderate consolidation. The general relief is undulating. Generally the soils are used for grazing. A very

small part of Kuwait and Ahmadi soils are used for irrigated agriculture.

Gypsiferous Desert Soil (Dibdiba-Sabriya) Association (A2)

This association consists of Dibdiba and Sabriya series and is found in the northeastern and southern part of the country. It occurs on undulating relief; and has a gypsum-rich parent material. The drainage of this association is imperfect. The texture of the soils is generally loamy sand to sandy loam. The soils are used for grazing.

Gravelly Saline Desert Soil (Batin) Association (A3)

This association is found on the western side of the State, along the Wadi Al Batin. Only Batin series was recognized. This soil is developed on calcareous conglomeratic sandy parent material which is highly saline. The texture is loamy sand and the drainage is imperfect. The relief is undulating; and the major land use is grazing.

Gravelly Gypsiferous Saline Desert Soil (Rauthatain-Kra Al Maru) Association (A4)

These soils occur in the central and northern part of Kuwait extending from Al-Shigaya to the southern Iraq border. Two series, Rauthatain and Kra Al Maru, were recognized in this association. The relief is undulating. They are shallow soils with a gravelly, gypsiferous saline substrata which includes caliche below 20-40 cm. These sandy loam textured soils are imperfectly to moderately well drained and used for grazing.

Saline Gypsiferous Desert Soil (Sadda) Association (A5)

This association is found in the south-central part of the State where it occurs on rolling relief. The underlying material is gypsiferous sandy clay loam. Drainage is imperfect to poor and the texture ranges from sandy loam to clay. They are undeveloped shallow soils, and the vegetation cover is very sparse. Only Sadda series was recognized in this association.

Sandy Desert Soil (Sulibiya-Magwa-Juwaisri) Association (B1)

These soils occur in the southeastern part of Kuwait. There are three soil series, Sulibiya, Magwa and Juwaisri, in this association. The soils are developed from sandy parent material. Relief is undulating. They are well to somewhat excessively drained and have a sand to loamy sand texture. Pan layers are sometimes exposed at the surface. These small areas would be separated from the Sandy Desert Soil Association in a detailed survey. A small part of this association is used for irrigated agriculture.

Desert Dune Soil (Umm Nigga) Association (B2)

Only Umm Nigga soil series was recognized in this association which occupies the land in the northeastern part of Kuwait. General relief is undulating and local relief is hummocky. These inland dunes are about 0.5-2 metre high, and developed by wind action on gypsiferous soil material. The drainage of the dunes is somewhat excessive while the gypsiferous layer is imperfectly drained. Texture is sandy loam and sand. There are bare spots among the dunes consisting of gypsiferous material.

Escarpment (Az Zor) Association (C1)

This association consists of only Az Zor series. It occurs on the northern side of Kuwait Bay. The escarpment is formed from sedimentary rocks, mainly sandstone. A gypsiferous layer overlies the sandstone, mixing sand and gravel. The soil is very shallow and sandy textured on steep slopes.

Hydromorphic Saline Alluvial Soil (Doha-Hugaija-Ras Al Jilaiya) Association (D1)

This association consists of three series, Doha, Hugaija and Ras Al Jilaiya. They occupy the land along the seashore of the northeast and south side of Kuwait Bay and southeast corner of the State. Relief is concave, nearly level to depressional. The soils of this association are saline and gypsiferous with the exception of those of the Doha series which lack gypsum. The parent material of Hugaija and Ras Al Jilaiya series is clay, whereas the parent material of the Doha soils is shelly sand. The drainage of this association is poor and textures range from sand to clay.

Recent Alluvium Soil (Bubiyan) Association (D2)

The soils of this association occur on Bubiyan and other surrounding islands. These are undeveloped saline alluvial soils. The relief is level and drainage is very poor. They are very saline with silt loam to clay loam texture. Very little vegetation is present on Bubiyan soils.

3.2 Soil Series

A soil series is a group of soils that have soil horizons similar in their differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material.

In this Reconnaissance soil survey emphasis is given to the soil series and the material is arranged around the soil series. Representative profile descriptions are given in Appendix 2.

The series is named for some geographic feature near the place where a soil of the series was first described. An example is the Sulibiya series which was named for the area of Sulibiya.

Eighteen soil series were recognized for this study. Their location and extent are shown in Maps 8 and 9; and the area and percentage of each soil series are listed in Appendix 4.2 and 4.3.

Kuwait Series (A11)

This series is located on the south and north side of Kuwait Bay. It is classified in the Desert great soil group and is a member of the Sandy Desert Hardpan Association. The parent material is whitish semihard calcareous sandstone. There is no definite profile development. Vegetation is very sparse: and relief is level to undulating. The slope does not exceed 1% on the south, but ranges between 1% and 3% on the north side of Kuwait Bay. Kuwait series is moderately well drained.

The colour of the topsoil is pale brown and the subsoil is very pale brown. Soils of the Kuwait series are shallow to moderately deep. Generally the pan layer is developed below 40 cm. The texture is loamy sand and there is no recognizable structure. Organic matter content and inherent fertility are very low. The soils are moderate to strongly calcareous.

Kuwait series differs from all associated series in that the surface layers are of a loamy sand texture. It differs from the Ahmadi series in that it is more calcareous and it is formed from a whitish parent material. The topography is level and the gravel content is less than that of Umm ar Riman series.

A detailed description of a profile that typifies the Kuwait series is given in Appendix 2, page 49.

Ahmadi Series (Al2)

Ahmadi soils are located in the south and southeastern part of the State. They are considered as belonging to the Desert great soil group and are members of the Sandy Desert Hardpan Soil Association. Soils of the Ahmadi series are slightly consolidated and are formed from a pinkish to yellowish gravelly sandy parent material. Relief is undulating to rolling. They do not have a well defined profile; are moderately well drained.

Colour of the surface soil is brown and the subsoil is very pale brown. Ahmadi series is generally shallow. The parent material is exposed to the surface around Ahmadi Town and north part of Abduliya. The texture is sand with no recognizable structure. Ahmadi series has a pan layer which differs in consolidation and depth. Organic matter and inherent fertility are very low; soil biological activity is very slight. The soils are strongly to slightly calcareous.

Ahmadi series differs from the Kuwait series in that it has a yellowish colour, less consolidated parent material, and more rolling relief.

A detailed profile description of the Ahmadi series is given in Appendix 2, page 50.

Umm ar Riman Series (Al3)

These soils occur north of Kuwait Bay. They are considered as belonging to the Desert great soil group with no distinct profile development and are members of the Sandy Desert Hardpan Soil Association. The parent material is gravelly sand which is cemented by lime. Relief is undulating. The vegetation cover is Rhanterium epapossum. These soils are imperfectly drained.

The colour of the topsoil is brown and the subsoil is pale brown and yellowish brown. They are shallow soils. The pan layer occurs below 17-50 cm. Texture is generally sandy loam. There is a weak platy structure on the surface, about 4-8 cm thick. Organic matter content and inherent fertility are low. The soils are strongly calcareous in the upper horizons, moderate to weak in the lower horizons.

Umm ar Riman soils differ from the other series in the group of Sandy Desert Hardpan Soils, in having strongly consolidated limy, sandy hardpan subsoil material and a sandy loam texture.

A detailed profile description of the Umm ar Riman series is given in Appendix 2, page 51.

Dibdiba Series (A21)

Dibdiba soils are located in the southern part of the State. They are classified as members of the Gypsiferous Desert Soil Association. The parent material is gypsiferous sand, mixed with gravel. There is no distinct profile development. This series is found under desert saline vegetation (Haloxylon salicornicum). Relief is undulating and slope is less than 2%. It is moderately well to imperfectly drained.

The colour of the topsoil is pale brown and the subsoil is pale brown yellowish brown. The colour of the gypsifeous layer is white (10 YR 8/2). They are shallow soils with the gypsiferous gravelly layer generally occuring below 30 cm. The texture is sandy loam to loamy sand. Organic matter content and inherent fertility are low. The soils are strongly to moderately calcareous.

Dibdiba soils differ from Sabriya soils in that they have a lighter coloured topsoil, a darker gypsiferous layer, and less salinity.

A detailed profile description of the Dibdiba series is given in Appendix 2, page 52.

Sabriya Series (A22)

Sabriya soils are located in the Northeastern part of the State. They are members of the Gypsiferous Desert Soil Association. The parent material of this series is a gypsiferous gravelly sand. They are shallow, not well developed soils; and the drainage is imperfect.

Colour of the topsoil is pale brown, and the gypsiferous layer is white. Texture is sandy loam. A thin weakly developed platy structure occurs on the surface of the soil. Organic matter content and inherent fertility are very low. There is very little biological activity. The soils are strongly calcareous in the gypsiferous layer.

A detailed profile description of the Sabriya series is given in Appendix 2, page 53.

Batin Series (A31)

Batin soils are located along the Wadi Al Batin in the western part of the State. The series is the only member of the Gravelly Saline Desert Soil Association. The underlying material is consolidated conglomeratic calcareous sand. There is no distinct profile development. The parent material is exposed to the surface in some parts of the area. Haloxylon salicornicum is the predominant type of natural vegetation. The relief is undulating with low hills. The drainage of

Batin series is imperfect.

Colour of the topsoil is brown - yellowish brown and the colour of underlying pan layer is white to light grey. They are generally shallow soils. A desert pavement layer covers the surface with gravel varying in size from 2 mm to 10 cm in diameter. Below this pavement layer the texture is a loamy sand. Organic matter content and inherent fertility are very low. There is very little biological activity. They are saline and strongly calcareous soils.

A detailed profile description of the Batin series is given in Appendix 2, page 54.

Rauthatain Series (A41)

These soils are located in the northern part of the State, around the Rauthatain water wells, and are members of the Gravelly Gypsiferious Saline Desert Soil Association. They do not have well developed profiles. The underlying material is semihard gypsiferous gravelly sand. In some places a sandstone material is below this layer. The underlying material is exposed on the ridges and slopes of the small hills. The main natural vegetation is Haloxylon salicornicum, secondary is Rhanterium apapossum. Relief is undulating. They are saline; and are imperfectly to moderately well drained. The texture is sandy loam.

Colour of the topsoil is pale brown to brown and the underlying material is pale brown to yellowish brown. They are shallow soils. There is a gravel layer on the surface with the gravel varying in size from 2 mm - 2 cm in diameter. These soils are strongly calcareous. Organic matter content and inherent fertility are low. There is very little biological activity.

Rauthatain soils differ from the Batin soils in that they are a gypsum content and are more pinkish than Kra Al Maru soils in color.

A detailed profile description of the Rauthatain series is given in Appendix 2, page 55.

Kra Al Maru Series (A42)

Kra Al Maru series occur in the south-central part of the State, and are members of the Gravelly Gypsiferous Saline Desert Soil Association. There is no distinct profile development. The underlying material is gravelly gypsiferous sand with a high salinity content, and is whitish in colour. Relief is undulating with some low hills. The soils are moderately well to imperfectly drained, are shallow, and have a sandy loam texture.

The colour of the topsoil is pale brown to brown and the matrix of gypsiferous layer is light grey. Gravel occurs on and in the soil. The size of the gravel is

about 2 mm - 1 cm, and its colour ranges from white to brown. In the southwestern part of the area covered by this series the gravel content of the gypsiferous layer increases to approximately 35% - 40% of the horizon. The organic matter content and inherent fertility are very low. There is very little biological activity. The topsoil is strongly calcareous, decreasingly with depth. The gypsiferous layer is non-calcareous.

Kra Al Maru soils differ from neighbouring soils in having gravelly, whitish non-calcareous substrata. The colour of their topsoil distinguishes them from the soils of the Rauthatain series.

A detailed profile description of the Kra Al Maru series is given in Appendix 2, page 56.

Sadda Series (A51)

These soils are located in the south-central part of the country. The series is a member of the Saline Gypsiferous Desert Soil Association. There is no distinct profile since the soil is undeveloped. The underlying material is a saline gypsiferous calcareous sandy clay loam. These soils are imperfectly drained; and are sandy loam (surface) to sandy clay loam in texture. A thin gravel layer occurs on the surface. Salinity content is very high.

Colour of the topsoil is brown and the substrata is light to yellowish brown to light olive brown. Below 10 cm some whitish $CaCO_3$ concretions are present. There is gypsum in the substrata.

Sadda soils differ, with a substrata as shale, from the all soils of Kuwait.

A detailed profile description of the Sadda series is given in Appendix 2, page 57.

Sulibiya Series (B11)

Sulibiya soils are found in the Sulibiya area, located to the south of Kuwait Bay. They are considered as a Desert-Regosol Intergrade soil group and are a members of the Sandy Desert Soil Association. They are developed under a desert vegetation cover. The main type of vegetation is conglomeratus. These are well drained, sandy textured soils. The parent material is sand; and there is no distinct profile development. They have an undulating relief.

Colour of the topsoil is brown and the subsoil is brown/greyish brown to light grey. There is no well developed structure. Generally they do not have a pan layer (except in a small area, on the west side of the New Airport). Organic matter content and inherent fertility are low. There is very little biological activity. These soils are used mainly for grazing and a small part for irrigated agrioulture. Wind erosion is active on these soils.

Sulibiya series differ from Magwa and Juwaisri series in having a greyish subsoil colour and being well drained.

A detailed profile description of the Sulibiya series is given in Appendix 2, page 58.

Magwa Series (B12)

These soils are located to the west of Ahmadi and south of Sulibiya, and are members of the Sandy Desert Soil Association. The parent material is slightly cemented sand. They show no marked profile development. Natural vegetation is Cyperus conglomeratus and Rhanterium epapossum. They have an undulating relief, sandy - loamy sand texture, and are well drained.

The colour of the topsoil is pale brown and the subsoil is yellowish brown. They are generally deep soils. In places the pan layer is exposed at the surface. Organic matter content and inherent fertility are low; and there is very little biological activity. They are strongly to moderately calcareous. These soils are used for grazing.

Magwa soils differ from Sulibiya soils in having a lighter color and slightly consolidated sandy underlying material which contains $CaCO_3$ concretions.

A detailed profile description of the Magwa series is given in Appendix 2, page 59.

Juwaisri Series (B13)

These soils are found southwest of Jahra, and are members of the Sandy Desert Soil Association. The parent material is incoherent sand; and there is no distinct profile development. The natural vegetation is Rhanterium epapossum. They have loamy sand and sand textures, are somewhat excessively drained and the relief ranges from undulating to rolling.

The colour of the topsoil is brown, the subsoil is brown to yellowish brown, and the substrata are light grey to very pale brown. These are generally deep soils, although as an exception there is some exposed pan layer on low hills and slopes. Organic matter content and inherent fertility are low. The surface and subsoil are strongly calcareous and the substrata are weakly calcareous. Some soils of this unit have a hardened layer between 70-130 cm.

Juwaisri soils differ from Magwa soils in having a coarser texture and darker colour.

A detailed profile description of the Juwaisri series is given in Appendix 2, page 60.

Umm Nigga Series (B21)

These soils occur on a hummocky relief and are located in the northeast part of the State. This series is the only one recognized in the Desert Dune Soil Association. They consist of inland dunes. The dunes, 50-200 cm high, are composed of wind blown sandy material. Under the dunes a gypsiferous soil material occurs, mixed with sand and gravel. Among the dunes, there are some bare spots with characteristics similar to those of the underlying material. Drainage is somewhat excessive in the dunes and poor in the bare spots. Texture ranges from sand to loamy sand.

The colour of the dunes is brown and pale brown to yellowish brown in the gypsiferous layer. Organic matter content and inherent fertility are low; and there is little biological activity. They are strongly calcareous.

A detailed profile description of the Umm Nigga series is given in Appendix 2, page 61.

Az Zor Series (C11)

These soils are located to the north of Kuwait Bay and are classified as Lithsolic soils. This series is the only member of the Escarpment Soil Association. They have escarpment relief, and run-off is rapid and drainage is excessive. A semiconsolidated gypsiferous sand overlies strongly consolidated conglomeratic sandstone. These are very shallow soils, having 5-8 cm gravelly sand on the surface.

Colour of the surface soil is predominantly very pale brown and the gypsiferous layer is also very pale brown. Colour of the sandstone is light grey. There is a gravel layer on the surface which ranges in color from white to brown and in size from 2 mm to 7 cm in diameter. Surface soil is strongly calcareous and the gypsiferous layer moderately calcareous. The gypsiferous layer is exposed in many places.

A detailed profile description of the Az Zor series is given in Appendix 2, page 62.

Doha Series (D11)

Doha soils are located along Kuwait Bay. This series is a member of the Hydromorphic Saline Alluvial Soil Association. Relief of these soils is concave, nearly level. Slope is less than 1%. The natural vegetation consists mainly of Zygophyllum coccineum. These soils have shelly sand parent material with poor drainage. All of the profile is wet except for a very thin surface layer. The water table is high.

The colour of the topsoil is brown to pale brown, the subsoil is pale brown, and the substrata are very pale brown. Texture ranges from sandy loam to sand containing shells. They have a single grain structure. The salinity content is very high. They are strongly calcareous.

The soils, which are located on the northern edge of Kuwait Bay, have been mapped as Doha soils although a part of them differ from the concept of Doha series, being sand dunes with hummocky relief and having a water table around 120 cm with little salinity. It was not practical to separate these sand dune areas on the Reconnaissance Map.

A detailed profile description of the Doha series is given in Appendix 2, page 63.

Hugaija Series (D12)

Hugaija soils are located on the northeastern side of the State, along the seashore. This series is a member of the Hydromorphic Saline Alluvial Soil Association. They have no well developed profile. Natural vegetation is mainly Suaeda ssp. Relief is concave, permeability is very slow and the drainage is poor. Parent material is clay which contains gypsum crystals.

The colour of the topsoil is brown-yellowish brown, the subsoil is yellowish brown - brown, and the substrata are brown-dark brown. They are deep, very saline soils. The texture of the topsoil is sandy loam, subsoil is sandy clay loam, and substrata are sandy clay and clay. Structure of the subsoil is medium subangular blocky. Organic matter content and inherent fertility are relatively high. They are strongly calcareous. The substrata contain sharp angular gypsum crystals in plate formation.

A detailed profile description of the Hugaija series is given in Appendix 2, page 64.

Ras'Al Jilaiya Series (D13)

These soils are found in the southeastern part of the State, near the seashore, in the small depressions. This series is a member of the Hydromorphic Saline Alluvial Soil Association. Relief is depressional; permeability is very slow and drainage is very poor. Parent material is calcareous clay. Haloxylon salicornicum is the main type of natural vegetation.

The colour of the top and subsoil is brown to dark brown and that of the underlying materials is light grey. They have sandy clay-clay texture. There is a salty suface crust layer of 1-5 cm, which has been accumulated by wind blowing material of a sandy loam texture. This layer has a very weak platy structure. The subsoil is massive to weak subangular blocky, while the substrata have massive structure.

The organic matter content is relatively high. These soils are very saline and strongly calcareous. The $CaCO_3$ content of the substrata is about 60%, which makes the colour whitish. Gypsum crystals are present. The profile is wet all the time except for the thin crust on the surface. The water table is about 80-100 cm.

A detailed profile description of the Ras Al Jilaiya series is given in Appendix 2, page 65.

Bubiyan Series (D21)

These soils have not been studied as well as the others in Kuwait. This series is the only recognized member of the Recent Alluvium Soil Association. They are muddy and of recent deposition from the Tigris-Euphrates river system. Relief is nearly level and drainage is very poor. Their texture ranges from silt to clay, and contains wind-blown sand on the surface. Bubiyan soils are still under the influence of tidal action. They are very saline soils.

The colour of the soils is light brownish grey-pale brown to brown-dark brown.

A surface soil description of the Bubiyan series is given in Appendix 2, page 66.

4. Use, Management and Productivity of Kuwait Soils

4.1 Use

The land of Kuwait is a typical desert. Practically all of the land is used for grazing, and only a very small part of it, about 570 ha, is under cultivation. The cultivated areas under irrigation are mostly located at Jahra, Sulibiya and Mangaf. The water is obtained from wells which are saline.

Overgrazing is a problem. The carrying capacity of the land is very low and after the rainy season the natural pasture is heavily grazed.

4.2 Soil management practices

In Kuwait good soil management should include these practices: (1) use of proper crop rotations; (2) maintenance of a practical level of soil organic content; (3) restoration of depleted plant nutrients by use of commercial fertilizers; (4) proper tillage methods; (5) moisture conservation, (6) weed control, and wind erosion control.

Good soil management in Kuwait would also include the use of good quality of irrigation water. Possibly this condition could be met when water is available from the Shatt-Al-Arab water scheme or other sources.

4.3 Soil Productivity

The productivity of Kuwait soils is potentially low, due to serious climatic and soil limitations: low rainfall, high temperature and evaporation, sandy and saline condition including the problems of hardpan and gypsum. Controlling wind erosion is also an important factor for plant production. All of these factors seriously restrict plant growth and yields.

5. Interpretative Groupings

5.1 Potential Irrigability

The potential irrigability of Kuwait soils is shown in the following table. It must be kept in mind when using this table that the classification is based on a reconnaissance, not a detailed soil survey. Because of the nature of a reconnaissance soil survey, some delineations contain soil inclusions which are unlike the rest of the unit named.

The classification is based entirely on soil characteristics. The soils are placed in five groups - excellent, good, fair, poor and unsuitable - based on the number of limiting factors. The limiting factors used in this classification are: unfavourable texture, shallow depth, pan layer, drainage, salinity and gypsum etc.

Soils are classified in this table as to their potential irrigability. No economic analysis has been made to determine the feasibility of actual development, as determined by the potential income from the land.

5.2 Rangeland suitability

A broad interpretation is made for the rangeland suitability grouping. The natural range is grouped according to the vegetation type, which is largely determined by soil condition. According to the relationships of soil and vegetation, the rangeland suitability in Kuwait, is shown in the following tables.

Four distinct groupings are used: very poor, poor, fair and fairly good.

Table 1 : Potential Irrigability

Mapping Symbol	Soil Series	Potential Suitability for Irrigation
A11	Kuwait	Poor
A12	Ahmadi	Poor-Fair
A13	Umm ar Rimam	Unsuitable
A21	Dibdiba	Unsuitable
A22	Sabriya	Unsuitable
A31	Batin	Unsuitable
A41	Rauthatain	Unsuitable
A42	Kra Al Maru	Unsuitable
A51	Sadda	Unsuitable
B11	Sulibiya	Good
B12	Magwa	Fair
B13	Juwaisri	Fair
B21	Umm Nigga	Poor
C11	Az Zor	Unsuitable
D11	Doha	Unsuitable
D12	Hugaija	Unsuitable
D13	Ras Al Jilaiya	Unsuitable
D21	Bubiyan	Unsuitable

Table 2 : Rangeland Suitability

Mapping Symbol	Soil Series	Rangeland Suitability
A11	Kuwait	Poor
A12	Ahmadi	Fair
A13	Umm ar Rimam	Poor
A21	Dibdiba	Very poor
A22	Sabriya	Fair
A31	Batin	Poor
A41	Rauthatain	Poor
A42	Kra Al Maru	Poor
A51	Sadda	Very poor
B11	Sulibiya	Fairly good
B12	Magwa	Fairly good
B13	Juwaisri	Fair-Poor
B21	Umm Nigga	Fair
C11	Az Zor	Very poor
D11	Doha	Fairly good
D12	Hugaija	Fair
D13	Ras Al Jilaiya	Fair-Poor
D21	Bubiyan	Very poor

6. Special Problems of Management

6.1 Water

Water is one of the important restricting factors for agriculture in Kuwait. Mainly underground water, which is brackish, is used for irrigation. It contains between 4 000- 5 000 ppm of TDS. Five million gallons per day are available for agriculture at present. Brackish water contains primarily $NaCl_2$, secondarily $CaSO_4$ and $MgSO_4$ salts. Some of the water analyses are shown in Appendix 3 part 2.

6.2 Wind erosion control

Wind erosion is one of the limiting factors for plant growth in Kuwait. Control of wind erosion must be included in Kuwait farm planning.

Wind velocity can be reduced by planting shelter belts of trees, but it takes several years for the trees to grow high enough to become effective. The area affected by such a shelter belt is limited to about five times the height of the trees on the windward side and 20-30 times this height on the leeward side.

A second important management consideration concerns the moving soil. Practices used to trap moving soil include planting alternate strips of grasses or legumes with strips of other crops.

Maintaining a vegetative cover is one of the most important ways to reducing wind erosion. Crop residues should be left on the surface instead of being ploughed under.

For successful farming these factors will have to be considered in Kuwait.

6.3 Controlled grazing

Most of the land is overgrazed for at least part of the year, or during periods of extended drought. Animal numbers at present are not the serious problem. The problem is one of management.

CHAPTER V

OTHER SOIL SURVEYS

1. General

During the assignment of the Expert different kinds of soil surveys were made. He also supervised and controlled a number of surveys undertaken by consultant firms.

2. Soil Surveys Made by the Soil Survey Expert

2.1 Soil Conservation Surveys 1/

At the request of the Government, soil conservation surveys were made by the Expert of the following sites:

(i) Small depressions along the Kuwait-Basrah Highway

(ii) Failaka Island

1/ The method of Soil conservation survey was adopted from USDA, SCS, Texas State Manual Supplement 2251, Farm Planning Soil Conservation Surveys. The standard was modified according to the local conditions. The specification of this type of survey is shown in Appendix 1, 2. Most of the time schematic maps were used as base maps.

(iv) Forestry Experimental Sample Plots (Taungya, Sulibiya, Arboretum, Jahra and Lone Tree)

2.2 Land classification for irrigation

The Sewage Experimental Forest Plot was surveyed for irrigation purposes. The land classification system used was that of the "U.S. Department of Interior, Bureau of Reclamation, Manual 1, Volume V, Part 2" (see Appendix 1, 3).

3. Soil Surveys Controlled by the Soil Survey Expert

The reconnaissance soil map showed different kinds of soil, some suitable and some unsuitable for irrigation. As a next step, the Government of Kuwait wished to have more detailed surveys of selected areas made, not only for irrigation but also for various other purposes. The Expert was asked to act as assisting and advising agent to the Government in controlling and supervising the consultant firms called in to do the work. The field surveys, laboratory analyses maps and reports were studied by the Expert and recommendations given to the Government.

The following soil surveys were given to the consultant firms:

(i) Sewage Effluent Irrigation Pumping Station Project. The size of the area is about 5 000 hectares. A detailed Standard Soil Survey was made by the consultant. It started in January 1967 and was completed in May 1967.

(ii) Soil Survey and Land Classification for Development of Agriculture in Kuwait.

The Soil Survey and Classification part of the Terms of Reference was prepared by the Expert (they are shown in Appendix 1.4). The agreement was signed in July 1967 with a consultant firm for the period of 36 months. The field work was started in September 1967 and still continues. This project is divided in two parts:

(a) Semidetailed Soil Survey for 260 000 hectares, selected by the Government.

(b) Detailed Land Classification for Irrigation for 17 000 hectares, which will be selected after completion of the semidetailed soil survey.

The Expert studied and controlled progress reports, aerial photographs, maps, time schedules, identification and descriptive legends as well as the field work. Comments and recommendations were given to the Government on all the work of the Consultant related to soil survey. This was done until the end of his assignment.

CHAPTER VI

TRAINING

Two non-Kuwaiti Arab Agricultural Engineers were appointed to the Soil Survey and Classification Branch of the Agricultural Section, Ministry of Public Works, as counterparts of the Expert. One joined in March 1965 and the other in May 1965. Kuwaiti counterparts were not available.

They were trained by the Expert in the following subjects: use of drawing equipment, planimeter, pantograph, soil sampling tools, hand level, compass, stereoscope etc., plane table work, soil maps, soil genesis and morphology, soil classification, soil survey, land capability classification, land irrigability classification, soil survey interpretation, soil survey reports and laboratory analysis (with the cooperation of the soil laboratory).

A summary of the Soil Survey Manual, and soil survey, soil conservation survey, land classification survey standards were prepared, and made available for their use.

At the beginning, the Expert gave more importance to the theoretical basic knowledge of soil science, because the trainees had only knowledge of general agriculture and animal production.

The Expert feels that with the four years of experience, the two counterparts will be able to carry out the local soil surveys.

APPENDIX 1

SOIL SURVEY STANDARDS

APPENDIX 1.1

STANDARD SOIL SURVEY

Soil Survey Manual standards were used as main reference. Some of them were slightly modified, to fit local needs.

Parent material

Sand
Marine sand
Incoherent sand
Gravelly sand
Aeolian sand
Slightly consolidated sandstone
Sandstone
Gravel
Limestone
Calcareous hardpan
Gypsum
Recent alluvium
Marine deposits
Clay
Shale

Relief

Depressional
Concave nearly level
Level

Convex, nearly level
Undulating
Rolling
Strongly rolling
Escarpment

Slope

Single	%	Complex
Level	0-1	Level
Nearly level	1-3	Nearly level
Gently sloping	3-5	Gently sloping
Sloping	5-8	Undulating
Steep	8-16	Rolling
Very steep	16+	Hilly

Permeability

	cm/h
Slow	
Very slow	-0,13
Slow	0,13-0,51
Moderate	
Moderately slow	0,51-2,03
Moderate	2,03-6,35
Moderately rapid	6,35-12,7
Rapid	
Rapid	12,7-25,4
Very rapid	25,4+

Internal drainage

None	Water table at or near the surface
Very slow	Soil saturated 1-2 months
Slow	Soil saturated 1-2 weeks
Medium	Soil saturated few days
Rapid	Soil saturated few hours
Very rapid	Soil never saturated

Soil drainage

Very poor	Water removed slowly. Water table at or on the surface.
Poor	Water removed slowly, water table near the surface. Soil remains wet most of the time.
Imperfect	Water removed slowly. Soil remains wet for signifcant periods.
Moderately well	Water removed somewhat slowly. Soil wet for small but significant part of the time.
Well	Water removed readily, but not rapidly. Commonly intermediate texture.

Somewhat excessive	Water removed rapidly. Usually sandy or very porous soil.
Excessive	Water removed very rapidly; Steep, shallow soils on very porous, or both.

Salinity

	Salt %	EC	
Free	0,00-0,15	0-4	Soils free of excess salt
Slight	0,15-0,35	4-8	Soils slightly affected by salt.
Moderate	0,35-0,65	8-15	Soils moderately affected by salt.
Strong	0,65+	15+	Soils strongly affected by salt.

Cementation

Slight	Cemented mass is brittle and hard but can easily be broken in the hands.
Moderate	Cemented mass is brittle and harder; can be broken in the hand but is easily broken with a hammer.
Strong	Strongly cemented, brittle, cannot be broken in the hands but can be broken with a hammer.

Erosion

Wind:

Removed type	
Slight	A part of topsoil is removed.
Moderate	All topsoil and a part of subsoil is removed.
Severe	All subsoil is removed.
Accumulation type	
Slight	Less than 30 cm. accumulation.
Moderate	30-60 cm accumulation.
Severe	Hummocky relief

APPENDIX 1.2

SOIL CONSERVATION TYPE OF SURVEY

Soil units

A soil unit includes all soils within an area that have similar profile characteristics such as depth, texture, structure, permeability and consistence of the various horizons.

Descriptions of the soil units which were used in Kuwait are as follows:

Deep, fine textured, very slowly permeable soils
Deep, fine textured, slowly permeable soils
Deep, medium textured, slowly permeable soils
Deep, medium textured, moderately permeable soils
Deep, coarse textured, slowly permeable soils
Deep, coarse textured, moderately permeable soils
Deep, coarse textured, rapidly permeable soils
Moderately deep, medium textured, moderately permeable soils
Moderately deep, coarse textured, slowly permeable soils
Shallow, fine textured, slowly permeable soils
Shallow, medium textured, slowly permeable soils
Shallow, medium textured, moderately permeable soils
Shallow, coarse textured, slowly permeable soils
Very shallow, fine textured, very slowly permeable soils
Very shallow, medium textured, slowly permeable soils
Very shallow, coarse textured, slowly permeable soils

Depth

The depth of the soil refers to the depth of the solum or of the layers that are readily penetrated by plant roots or to the depth to some layer such as bedrock that would restrict root penetration.

Depth	
Very shallow	Soil less than 25 cm deep
Shallow	Soil 25 to 50 cm deep
Moderate	Soil 50 to 90 cm deep
Deep	Soil more than 90 cm deep

Textural class

Fine	Clay, Sandy clay, Silty clay, Clay loam, Sandy clay loam, and Silty clay loam
Medium	Silt loam, Loam, Very fine sandy loam and Sandy loam
Coarse	Loamy fine sand, Loamy sand, Fine sand and Sand

Permeability

Very slow	Less than 0,13 cm/h
Slow	0,13-0,51 cm/h
Moderate	0,51-12,7 cm/h
Rapid	12,7-25,4 cm/h
Very rapid	More than 25,4 cm/h

Inhibitory factors

Inhibitory factors are those that interfere with cultural practices, or those that inhibit plant growth.

Degree of Wetness

W1. Slight	Short period of high water table
W2. Moderate	Temporary high water table
W3. Wet	Permanently high water table

Salinity

S1. Slight	4-8 EC-Soils slightly affected by salt
S2. Moderate	8-15 Soils moderately affected by salt
S3. Strong	15+ Soils strongly affected by salt

Land characteristics

Slope

A	0-1%	Nearly level
B	1-3%	Gently sloping
C	3-5%	Sloping

Erosion

Wind:

Removal

1R. Slight	A part of topsoil is removed
2R. Moderate	All topsoil and a part of subsoil is removed
3R. Severe	All subsoil is removed

Accumulation

1A. Slight	Less than 30 cm accumulation
2A. Moderate	30-60 cm accumulation
3A. Severe	Hummocky relief

Mapping unit

The map symbols are arranged in the following orders: Soil unit designation followed by inhibitory factors on the top of the line and slope and erosion under the line.

APPENDIX 1.3

LAND CLASSIFICATION FOR IRRIGATION

Land classification for irrigation, based to a large extent on the physical, chemical and topographic characteristics of soils, also involves economic factors. This is because each class of land must be rated not only in terms of production under irrigation but also in terms of its probable use and the income to be derived so as to justify the cost of land development.

Six classes of land, four irrigable, one temporarily nonirrigable and one non-irrigable, may be recognized in a completed classification. These classes represent degrees of suitability for irrigated farming and are necessary primarily for the land use and repayment analyses.

Class 1 represents lands which potentially have a relatively high payment capacity; class 2 represents lands of intermediate payment capacity; and class 3 includes lands of the lowest suitability for general irrigated farming. Class 4 represents lands which have certain excessive deficiencies that result in restricted utility or special use but which have been shown to be of limited suitability for irrigation as a result of special economic and engineering studies. Class 5 lands are not suitable for irrigation under existing conditions, but have potential value sufficient to warrant tentative segregation. They are lands in existing projects whose irrigability is dependent upon additional, scheduled project construction and land improvements. Class 6 lands are not suitable for irrigation and not considered as project lands.

APPENDIX 1.4

SEMIDETAILED AND DETAILED SURVEY STANDARDS
(From the Terms of Reference Prepared for the Consultant Firm)

1. Mapping

A) Aerial photography to a scale of:

a) 1:20 000 in colour for an area of about 260 000 hectares shown on the attached map 1/ with the numbers I (80 000 ha), II (150 000 ha), III (30 000 ha).

1. The horizontal error should not exceed 1 mm in the final reproduced maps and this value should satisfy 90% of the checked points. 20 copies are required from each map.

2. Identified points should be located on the maps with the rate of each 50 km^2, their coordinates x, y, z should be supplied.

3. Negatives of the maps should be supplied.

4. Size of the map will be 15 x 10 km.

b) 1:5 000 for the area of 17 000 hectares which consist of 10 000 ha from area I and 5 000 ha from area II and 2 000 ha from area III which will be selected after semidetailed study of the whole area.

1/ Comparable to Maps 11 of this report.

1. Constant of the aerial camera 150 mm.

2. Lens distortion should be below 10 microns.

3. Forward lap 60% and side lap 30% (stereoscopic coverage must be guaranteed and flight strips should be parallel).

4. In the area near the sea if existing, the centre of the photos near the shore-line should lie on the ground.

5. Deviation from the verticality should not exceed 3°.

6. Crab should not exceed 4°.

B) Topographic maps to the scale of 1:2 000, for the areas of 17 000 hectares (10 000 hac. for area I, 5 000 ha for area II, 2 000 ha for area III) will be demarcated by the Consultant and used for irrigation purposes for agricultural development in the future.

These maps should be constructed from ground survey.

1. Traverse points at the distance 250 ms apart with their altitude points fixed with the level. They must be constructed in a suitable form.

2. Altitude points should be fixed on the map at a distance of 50 ms.

3. Contour interval 1/2 ms.

4. Size of the sheet 1.2 x 0.8 km.

2. Soil Survey, Soil Classification and Land Classification

A) Soil Survey

To carry out a soil study for about 260 000 ha as indicated by numbers I (80 000 ha), II (150 000 ha) and III (30 000 ha) on the attached map 1/.

This study will include the identification and definition of the individual taxonomic units, soil series, soil types and soil phases. It will be prepared at semidetailed scale.

Methods of aerial photo interpretation may be employed. However, emphasis should be given on ground observation.

The basic method of soil survey should be the same as that used by the FAO Soil Survey Expert presently in Kuwait (The Soil Survey Manual of the USDA).

1/ Comparable to Map No. 11 of this Report.

After the semidetailed survey, 17 000 ha of the most suitable land for irrigation will be selected, 10 000 ha in area I, 5 000 ha in area II, 2 000 ha in area III.

The specifications of this survey are as shown below:

Traverse: 700 metres
Field observation (1.5 metres deep): 1 pit for every 49 ha.
Sample: Minimum profile sample from each different horizon or layer for every 100 hectares.
Field map: 1:20 000 aerial photographs
Published map: 1:40 000 controlled aerial photograph mosaics.

B) Soil Classification

Soil classification will be made according to "1938 Soil and Man, Agricultural Handbook, USDA" and its latest modification.

Individual soil units, representing soil series, soil types and phases should be distinguished primarily on the basis of criteria which are significant in relation to the potential of the soils. At the same time, the genetic and topographic relationships of these units should be sufficiently established as to permit the construction of controlled soil legend for the basic soil maps and to permit correlation with units previously recognized in Kuwait by the FAO Soil Survey Expert.

C) Land Classification

To carry out Detailed Land Classification for irrigation of 17 000 hectares (10 000 ha from area I; 5 000 hectares from area II; 2 000 hectares from area III) which will be selected after the semidetailed soil survey.

The criteria chosen to differentiate these areas should emphasize differences in the physical characteristics of the soils and the environment which will influence the amount and nature of engineering work required to implement successful irrigated agriculture and the degree of success likely to be achieved. This study will be made according to "Bureau of Reclamation Manuel 1, Volume V, Part 2 of the U.S. Department of Interior", modified as necessary to meet local conditions.

The specification of this classification is shown below:

Land classes: 1, 2, 3, 4, 5, 6.
Traverse: 300 metres
Field observation: (1.5 metres deep): 1 pit for every 9 hectares.
Deep hole (3 metres or more): 1 deep hole for every 72 hectares.
Sample: Minimum 1 profile sample from each different horizon or layer for every 18 hectares.

3. Laboratory Analysis

The Consultant must make arrangements for the soil survey work to be supported by extensive laboratory analysis of soil and water. Complete analysis may be necessary on all samples but the minimum number of analyses of each property must be sufficient to characterize each soil unit recognized in relation to this property.

Soil analyses should include particle size distribution; cation exchange capacity and exchangeable cations (Ca., Mg., Na., K.); pH of saturation paste; total carbon and nitrogen; available P., $CaCO_3$., soluble cations (Ca., Mg., K.); soluble anions (Cl, SO4, HCO_3) and electrical conductivity of the saturation extract.

Physical determinations should include moisture characteristics of the soil using pressure membrane and pressure plate equipment (15 atmosphere suction; 1/3 atmosphere suction; 1/10 atmosphere suction on sandy soils. Additional determinations (e.g. gypsum content, permeability studies in the laboratory and in the field, infiltration rates, etc.) should be made as deemed necessary according to the Consultant's professional judgement.

When appropriate the methods of soil and water analysis employed should be those described in "Diagnosis and Improvement of Saline and Alkali Soils", Agricultural Handbook No. 60, U.S.D.A.

All kinds of tests and analyses will be done by the Consultant, by their own means (facilities and laboratory equipment).

APPENDIX 2

DETAILED DESCRIPTION OF SOIL SERIES

A representative profile of Kuwait series

Profile No. 2

0-18	Cm	Pale brown (10 YR 6/3) to brown (10 YR 5/3), moist); loamy sand; weak coarse blocky breaking to single grain; loose; strongly calcareous; small, whitish gravel layer on the surface.
18-50	Cm	Light yellowish brown-very pale brown (10 YR 6,5/4) to yellowish brown-light yellowish brown (10 YR 5,5/4, moist); loamy sand; single grain: loose; strongly calcareous; contains some whitish small gravel.
50-100	Cm	Very pale brown (10 YR 8/3) to very pale brown (10 YR 7/3, moist); gravelly sand-loamy sand; slightly hard pan layer; friable; firm; moderately to strongly calcareous.
100-148	Cm	White (10 YR 8/2) to light grey (10 YR 7/2, moist); sand; firm; moderately calcareous.

Range in characteristics:

Texture	-	Loamy sand to sand
Depth	-	Very shallow to moderately deep
Relief	-	Level to undulating
Drainage	-	Moderately well to imperfectly
Use	-	Grazing
Location of profile	-	East of Nursery
Date profile taken	-	18-3-1965

A representative profile of Ahmadi series:

Profile No. 11

0-41 Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sand; very weak coarse blocky breaking to single grain; loose; moderately calcareous; thin, small, whitish gravel cover on the surface.
41-94 Cm	Very pale brown (10YR 7/3) to pale brown (10YR 6/3 moist); sand mixed with whitish small gravel; single grain; friable to firm; weakly calcareous; slightly consolidated.
94-155 Cm	Very pale brown (10YR 8/3) to very pale brown (10YR 7/3, moist); gravelly sand; single grain; friable to firm; weakly calcareous; slightly consolidated.

Range in characteristics:

Colour	-	Colour of topsoil, light yellowish brown to brown (10YR 6/4-5/3, moist). Colour of subsoil, very pale brown (10YR 7/3, moist) to pale yellow (5Y 7/3, moist).
Depth	-	Shallow to moderately deep.
Pan	-	Pan layer is less consolidated than other series of same mapping unit.
Gravel	-	Subsoil is more gravelly than surface soil.
Relief	-	Undulating to rolling.
Drainage	-	Moderately well.
Location of profile	-	Southeast of Maaizilat.
Use	-	Grazing
Date profile taken	-	29-3-1965

A representative profile of Umm ar Rimam series:

Profile No. 21

0-5	Cm	Pale brown (10YR 6/3) to brown-dark brown (10YR 4/3, moist); sandy loam; weak platy; very friable; strongly calcareous; 2 mm - 4 mm gravel on the surface.
5-23	Cm	Brown-pale brown (10YR 5,5/3) to dark brown-brown (10YR 4/3, moist); sandy loam; weak granular; very friable; strongly calcareous.
23-55	Cm	Brown (10YR 5/3) to brown (10YR 4,5/3, moist); sandy loam; very friable; moderately calcareous.
55-100	Cm	Light yellowish brown (10YR 6/4) to brown (10YR 5/4, moist); Very pale brown (10YR 7/3) other than matrix; gravelly sandy loam; moderately hard when dry; slightly to moderately consolidated.
100-120	Cm	Very pale brown (10YR 7,5/4) to yellowish brown-light yellowish brown (10YR 5,5/4, moist); gravelly sandy pan layer cemented by lime.

Range in characteristics:

Colour	-	Colour of subsoil light yellowish brown (10YR 6/4, moist) to light grey (10YR 7/2, moist).
Depth	-	Shallow to moderately deep.
Pan	-	17 to 70 Cm
Relief	-	Undulating to rolling.
Location of profile	-	Al Auja.
Use	-	Grazing
Date profile taken	-	22-4-1965

A representative profile of Dibdiba series:

Profile No. 36

0-20	Cm	Very pale brown (10YR 7/3) to brown-pale brown (10YR 5,5/3, moist); sandy loam; weak platy at 0-5 cm; loose; strongly calcareous; thin whitish gravel layer on the surface.
20-80	Cm	Pale brown (10YR 6/3) to yellowish brown (10YR 5/4, moist); sandy loam-loamy sand; loose; strongly calcareous; after 50cm some gypsum crystals.
80-130	Cm	White (10YR 8/2) to very pale brown (10YR 7,5/3, moist); gravelly sandy gypsiferous layer; strongly calcareous.

Range in characteristics:

Texture	-	Sandy loam to loamy sand
Depth of gypsum layer	-	8 to 50 cm
Drainage	-	Imperfectly to moderately well
Location of profile	-	South of Hamatiyat
Use	-	Grazing
Date profile taken	-	8-11-1965

A representative profile of Sabriya series:

Profile No. 39

0-18	Cm	Pale brown - very pale brown (10YR 6,5/3) to yellowish brown (10YR 5/4, moist); sandy loam; weak platy structure on the surface; strongly calcareous.
18-45	Cm	Very pale brown (10YR 7/3) to very pale brown (10YR 7/4, moist); porous semihard gypsiferous layer; moderately to weakly calcareous.
45-90	Cm	White-very pale brown (10YR 8/2,5) to very pale brown (10YR 7/4, moist); porous hard gypsiferous layer; noncalcareous.

Range in characteristics:

Gypsiferous layer	-	From 18 to 30 Cm
Relief	-	Undulating (general) to Hummocky (local).
Looation of profile	-	Haswan
Use	-	Grazing
Date profile taken	-	10-11-1965

A representative profile of Batin series:

Profile No. 31

0-18	Cm	Pale brown (10YR 6/3) to brown-yellowish brown (10YR 5/3,5, moist); loamy sand; very weak platy structure on the surface; loose; strongly calcareous; desert pavement on the surface.
18-33	Cm	Pale brown (10YR 6,5/3) to brown-pale brown (10YR 5,5/3, moist); loamy sand; single grain; loose; strongly calcareous.
33-80	Cm	White (2, 5Y 8/2) to light grey (2, 5Y 7/2, moist); lime cemented conglomerates.

Range in characteristics:

Parent material	-	Lime cemented conglomerates to soft sandstone.
Depth	-	30 to 80 Cm
Desert pavement	-	Generally dark in colour, size up to 28 Cm in diameter.
Relief	-	Undulating with low hills.
Location of profile	-	West of Khabra Umm Ruwaisat
Use	-	Grazing
Date profile taken	-	1-11-1965

A representative profile of Rauthatain series:

Profile No. 17

0-9	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sandy loam; very weak platy; loose; strongly calcareous; a thin gravel layer on the surface in diameter of 2mm-1cm.
9-60	Cm	Very pale brown (10YR 7/3) to pale brown (10YR 6/3, moist); gypsiferous sandy loam; friable; strongly to moderately calcareous; gypsum increases after 45 Cm.
60-110	Cm	Light yellowish brown (10YR 6/4) to yellowish brown (10YR 5/4, moist); semihard gravelly gypsiferous layer; weakly calcareous; contains small gravel.

Range in characteristics:

Colour	-	Colour of topsoil, brown to yellowish brown (10YR 5/3-5/4, moist). Colour of gypsiferous layer, pale brown to yellowish brown (10YR 6/3-5/4, moist).
Underlying material	-	Gypsiferous gravelly sand to gypsiferous gravelly sand stone.
Location of profile	-	North of Rauthatain pump station.
Use	-	Grazing
Date profile taken	-	4-4-1965

A representative profile of Kra Al Maru series:

Profile No. 34

0-30	Cm	Very pale brown (10YR 7/3) to brown (10YR 5/3, moist); sandy loam; single grain; loose; strongly calcareous; a thin gravel layer on the surface.
30-70	Cm	Very pale brown (10YR 7/4) to light yellowish brown (10YR 6/4, moist); hard, gravelly, sandy loam textured gypsiferous layer; moderately calcareous.
70-90	Cm	White (10YR 8/1) to light grey (10YR 7/1, moist); hard, gravelly, gypsiferous layer; more gravel than horizon above, in diameter of 2 mm - 4 Cm.

Range in characteristics:

Colour	-	Colour of topsoil, grayish brown, very pale brown to brown (10YR 5/2-5/3, moist). Colour of gypsiferous layer, light grey to very pale brown (10YR 7/1-7/3, moist).
Gravel	-	Gravel content increases from north west to south east.
Drainage	-	Moderately well to imperfectly.
Location of profile	-	North of Ash Shigaya.
Use	-	Grazing
Date profile taken	-	3-11-1965

A representative profile of Sadda series:

Profile No. 35

0-11	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sandy loam-sandy clay loam; massive; friable; strongly calcareous.
11-34	Cm	Light yellowish brown-brownish yellow (10YR 6/5) to yellowish brown (10YR 5/5, moist); weak fine granular; sandy clay loam; $CaCO_3$ concentration; strongly calcareous.
34-70	Cm	Light brownish grey-light yellowish brown (2,5 Y 6/3) to light olive brown (2,5 Y 5/4, moist); sandy clay loam; more $CaCO_3$ accumulation than horizon above.
70-100	Cm	Light grey (2,5 Y 7/2, moist); sandy clay loam: gypsum and $CaCO_3$ particles; moderately calcareous.

Range in characteristics:

Sadda soils are considered complex soils. They differ from each other within a very short distance.

Relief	- Rolling to undulating
Drainage	- Imperfectly to poorly
Location of profile	- Northwest of Sadda
Use	- Grazing
Date profile taken	- 1-11-1965

A representative profile of Sulibiya series:

Profile No. 41

0-40	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); gravelly sand; single grain; loose; strongly calcareous; a thin, whitish gravel layer on the surface.
40-90	Cm	Pale brown - very pale brown (10YR 6,5/3) to brown-greyish brown (10YR 6/3,5, moist); sand; single grain; loose strongly calcareous.
90-150	Cm	Light grey (2, 5Y 7/2) to light grey - pale yellow (2, 5Y 7/3, moist); gravelly sand; single grain; loose; strongly calcareous.

Range in characteristics:

Colour - Colour of topsoil, brown to light yellowish brown (10YR 5/3, moist) to light yellowish brown (10YR 6/4, moist).

Texture - Sand to sandy loam.

Relief - Undulating to level.

Drainage - Somewhat excessively to well.

Location of profile- South of Sulibiya.

Use - Grazing

Date profile taken - 17-11-1965

A representative profile of Magwa series:

Profile No. 20

0-23	Cm	Very pale brown (10YR 7/4) to pale brown-light yellowish brown (10YR 6/3,5, moist); gravelly sand; very weak platy breaking to single grain; loose; moderately calcareous.
23-50	Cm	Light yellowish brown - very pale brown (10YR 6, 5/4) to brown yellowish brown (10YR 5, 5/3, moist); sand; single grain; loose; moderately calcareous; small $CaCO_3$ concentrations.
50-85	Cm	Light yellowish brown - very pale brown (10YR 6, 5/4) to brown-yellowish brown (10YR 6, 5/4) to brown-yellowish brown (10YR 5, 5/3, moist); sand; single grain; loose; moderately calcareous.
85-130	Cm	Very pale brown (10YR 7/3,5) to yellowish brown (10YR 5/4,, moist); sand-loamy sand; single grain; loose,strongly calcareous; a thin layer of $CaCO_3$ concentrations.
130-200	Cm	Very pale brown (10YR 8/3) to very pale brown (10YR 7/4, moist; loamy sand; slightly consolidated layer with $CaCO_3$ concentrations; strongly calcareous.

Range in characteristics;

Depth	-	Shallow to deep.
Relief	-	Undulating to rolling.
Drainage	-	Moderately well to well
Location of profile	-	Southeast of new Broadcasting Station.
Use	-	Grazing
Date profile taken	-	15-4-1965

A representative profile of Juwaisri series:

Profile No. 5

0-4	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); loamy sand; weak platy; loose; strongly calcareous; a thin whitish gravel layer on the surface.
4-70	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sand; single grain; loose; more calcareous than horizon above.
70-95	Cm	Pale brown - very pale brown (10YR 6, 5/3) to yellowish brown (10YR 5/4, moist); single grain; loose; strongly calcareous.
95-150		Light grey - very pale brown (10YR 7/2,5) to light grey (10YR 7/2, moist); sand; single grain; loose; moderately calcareous.

Location of profile - Northwest of Mutla.

Use - Grazing

Date profile taken - 21-3-1965

A representative profile of Umm Nigga series:

Profile No. 52

0-25	Cm	Brown (10YR 5/3, moist); sand; single grain; loose; strongly calcareous; a whitish gravel layer on the surface.
25-70	Cm	Yellowish brown (10YR 5/4, moist); sand; single grain; loose; strongly calcareous.
70-100	Cm	Pale brown (10YR 6/3, moist); semihard noncalcareous gypsum; contains white quartz.
100-170	Cm	Light yellowish brown (10YR 6/4, moist); hard gypsiferous layer mixed with sand and gravel; noncalcareous.

Range in characteristics:

This series is considered as a complex soil. Dunes do not cover all the area. Some gypsiferous layers exposed to the surface having a thin gravel layer with whitish sand.

Relief	-	Rolling (general) to hummocky (local).
Drainage	-	Somewhat excessively in Dunes, poorly in gypsiferous layer.
Location of profile	-	Southeast of Umm Nigga.
Use	-	Grazing
Date profile taken	-	28-2-1966

A representative profile of Az Zor series:

Profile No. 53

0-5	Cm	Very pale brown (10YR 7/3) to pale brown (10YR 6/3, moist); loamy sand with gravel; single grain; strongly calcareous.
5-50	Cm	Very pale brown (10YR 7, 5/3, moist); semiconsolidated gypsiferous layer; mixed with sand; moderately calcareous; contains some gravel in diameter of 2 mm - 7 Cm.
50-100	Cm	Very pale brown (10YR 8/3, moist); consolidated gypsiferous layer with sand and gravel; weakly calcareous.
100-300	Cm	Light grey (10YR 7/2); consolidated noncalcareous sandstone.

Range in characteristics:

Slope - Sloping to very steep.

Location - East of Abdullah Jabir Palace.

Use - Grazing

Date profile taken - 6-3-1966

A representative profile of Doha series:

Profile No. 3

0-6	Cm	Very pale brown - pale brown (10YR 6, 5/3) to brown (10YR 5/3, moist); sandy loam; loose; strongly calcareous; contains shells.
6-45	Cm	Pale brown - brown (10YR 5, 5/3, moist); loamy sand; strongly calcareous; contains shells; moist.
45-100	Cm	Very pale brown (10YR 7/3, moist); loamy sand; strongly calcareous; contain shells; saturated at 85 Cm.
100-120	Cm	Very pale brown (10YR 8/3, moist); gravelly sand; strongly calcareous; contains shells; wet; water table at 110 Cm.

Location - On the left of Doha road, 80 metres northwest of police station.

Use - Grazing

Date profile taken - 20-3-1965

A representative profile of Hugaija series:

Profile No. 38

0-26	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sandy loam; weak platy; loose; strongly calcareous; some white gravel on the surface; slightly moist.
26-50	Cm	Yellowish brown (10YR 5/4, moist); sandy clay loam; weak granular; firm; strongly calcareous; moderately moist.
50-90	Cm	Brown-dark brown (10YR 4/3, moist); silty clay-clay; subangular blocky; firm; strongly calcareous; contains sharp pointed gypsum crystals; moderately moist.
90-135	Cm	Dark brown-brown (10YR 4, 5/3, moist); sandy clay; massive; firm; strongly calcareous; moist.

Range in characteristics:

Relief	-	Nearly level to concave nearly level.
Drainage	-	Poor to very poor.
Location of profile	-	Between Hugaija and Subiya.
Use	-	Grazing
Date profile taken	-	10-11-1965

A representative profile of Ras Al Jilaiya series:

Profile No. 15

0-5	Cm	Pale brown (10YR 6/3) to brown (10YR 5/3, moist); sandy loam; weak platy; loose; strongly calcareous; white salt accumulation on the surface.
5-20	Cm	Dark brown-dark yellowish brown (10YR 3,5/3, moist); clay; weak subangular blocky; very firm; strongly calcareous; moist.
20-44	Cm	Dark brown (10YR 3/3, moist); clay; massive; very firm; strongly calcareous; contains gypsum crystals; moist.
44-70	Cm	Very pale brown-white (10YR 8/2, moist); clay: massive; strongly calcarous; saturated.
70-120	Cm	Light grey (10YR 7/1, moist); sandy clay loam; strongly calcareous; wet; wt-90 cm.

Range in characteristics:

Relief	-	Concave nearly level to depressional.
Location of profile	-	West of Ras Al Jilaiya.
Use	-	Grazing
Date profile taken	-	3-4-1965

A surface sample of Bubiyan series:

Profile No. 56

0-30 Cm - Light brownish grey - pale brown (10YR 6/2,5) to brown-dark brown (10YR 4/3, moist); clay loam; strongly calcareous; moist.

APPENDIX 3

ANALYTIC DATA

APPENDIX 3.1

Mechanical and Chemical Analytical Data for Soil Series

Soil Series	Profile No.	Depth (cm)	Gravel %	Texture			Textural Class	pH Sat. paste	Elec. Cond (EC x 10^3)	Cation exchange capacity	$CaCO_3$ equiva- capacity	Gypsum $\frac{1}{2}$ Soil Water ratio
				Sand %	Silt %	Clay %						
Kuwait	2	0-18	7.78	82.32	10.30	7.38	LS	8.2	0.80	3.32	3.32	-
							(For the above profile:			Mq/l NO_3 =	0.29,)	
							(" " "			Mq/l PO_4 =	0.06)	
		18-50	2.93	88.36	5.15	6.49	LS	8.3	1.40	11.73	11.73	-
		50-100	3.67	88.79	2.60	8.61	LS-S	8.1	3.20	12.45	12.45	-
		100-148	10.36	90.74	1.67	7.59	S	8.1	1.40	8.24	8.24	-
Ahmadi	11	0-14	6.20	91.15	4.80	4.05	S	8.4	0.20	4.20	8.04	-
		14-41	3.81	93.24	2.70	4.06	S	8.3	0.20	3.40	3.62	-
		41-94	18.63	91.28	2.80	5.92	S	8.0	1.00	5.40	6.61	-
		94-120	10.60	91.28	3.35	5.37	S	8.1	0.40	5.90	2.84	-
		120-155	13.45	93.88	2.31	3.81	S	8.2	0.40	6.60	2.29	-
Umm ar Rimam	21	0-5	-	75.00	13.00	12.00	SL	8.1	1.05	-	16.6	1.54
		5-23	-	73.00	10.00	17.00	SL	7.8	0.94	-	16.7	0.80
		23-55	-	74.00	13.00	13.00	SL	7.6	2.25	-	17.7	1.09
		55-100	-	74.00	14.00	12.00	SL	7.8	2.90	-	11.6	1.90
		100-120+	-	64.00	23.00	13.00	SL	8.0	3.50	-	18.5	0.70
Dibdiba	36	0-20	-	76.00	15.00	9.00	SL	8.0	1.00	-	13.9	0.85
		20-50	-	78.00	11.00	11.00	SL	7.9	1.60	-	15.0	1.09
		50-80	-	80.00	11.00	9.00	LS	7.8	4.20	-	8.0	5.36
		80-130	-	84.00	14.00	2.00	LS	7.9	3.80	-	6.3	5.23
Sabriya	39	0-18	-	79.00	10.00	11.00	SL	7.8	3.50	-	11.8	2.45
		18-45	-	79.00	10.00	11.00	SL	7.8	3.05	-	4.5	5.03
		45-90	-	61.00	26.00	13.00	SL	7.9	6.00	-	Nil	5.87

(Page 2)

Soil Series	Profile No.	Depth (cm)	Gravel %	Texture			Textural Class	pH Sat. paste	Elec. Cond. (EC x 10^3)	Cation exchange capacity	$CaCO_3$ equivalent %	Gypsum $\frac{1}{2}$ Soil Water ratio
				Sand %	Silt %	Clay %						
Batin	31	0-18	-	82.00	12.00	6.00	LS	8.1	0.85	-	9.8	0.69
		18-33	-	79.00	13.00	8.00	LS	7.8	7.00	-	11.8	-
		33-80+	-	-	-	-	-	7.8	16.00	-	21.0	-
Rauthatain	17	0-9	-	70.00	13.00	17.00	SL	7.5	2.50	-	16.6	0.81
		9-60	-	71.00	17.00	12.00	SL	7.5	10.00	-	8.2	6.29
		60-110	-	71.00	11.00	18.00	SL	7.6	10.00	-	1.9	5.97
Kra al Maru	34	0-30	-	68.00	19.00	13.00	SL	8.0	2.40	-	16.3	0.85
		30-70	-	78.00	10.00	12.00	SL	7.8	9.50	-	5.6	3.45
		70-90+	-	71.00	19.00	10.00	SL	7.6	18.8	-	0.4	7.61
Sadda	35	0-11	-	68.00	12.00	20.00	SL-SCL	7.8	144.0	-	10.9	0.91
		11-34	-	69.00	12.00	19.00	SL-SCL	7.8	80.0	-	13.1	5.55
		34-70	-	56.00	20.00	24.00	SCL	8.0	52.8	-	19.4	2.53
		70-100	-	57.00	9.00	34.00	SCL	8.0	38.5	-	6.2	4.35
Sulibiya	41	0-40	-	90.00	5.00	5.00	S	7.9	1.28	-	11.1	0.55
		40-90	-	91.00	4.00	5.00	S	8.1	1.18	-	10.6	0.52
		90-120	-	92.00	5.00	3.00	S	8.3	0.65	-	11.0	0.91
		120-150	-	95.00	3.00	2.00	S	8.3	0.59	-	13.2	0.91
Magwa	20	0-23	-	89.00	5.00	6.00	S	8.2	0.68	-	5.2	0.82
		23-50	-	90.00	6.00	4.00	S	8.2	0.49	-	6.0	0.73
		50-85	-	90.00	2.00	8.00	S	8.0	0.63	-	4.6	0.76
		85-130	-	86.00	6.00	8.00	LS	7.5	2.50	-	4.7	1.02
		130-200	-	81.00	9.00	10.00	LS	7.8	1.38	-	10.3	1.01

Soil Series	Profile No.	Depth (cm)	Gravel %	Texture			Textural class	pH Sat. paste	Elec. Cond. (EC x 10^3)	Cation exchange capacity	$CaCO_3$ equivalent %	Gypsum $\frac{1}{2}$ Soil Water ratio
				Sand %	Silt %	Clay%						
Juwaisri	5	0-4	16.42	83.97	9.58	6.45	LS	8.2	0.45	6.30	10.31	-
		4-30	16.81	85.70	7.93	6.37	LS	8.4	0.38	4.90	12.65	-
		30-70	6.92	88.40	5.91	5.69	LS	8.1	1.20	5.40	11.07	-
		70-95	9.45	89.73	4.42	5.85	S	8.3	0.20	6.80	11.28	-
		95-130	11.51	92.66	2.37	4.97	S	8.3	0.28	8.10	0.95	-
		130-150	8.09	95.97	0.22	3.81	S	8.4	0.35	8.70	0.92	-
												% 1/20
Umm Nigga	52	0-25	-	-	-	-	-	8.2	1.48	-	-	0.04
		25-45	-	-	-	-	-	8.3	1.16	-	-	0.01
		45-70	-	-	-	-	-	8.1	2.48	-	-	0.32
		70-100	-	-	-	-	-	8.1	2.88	-	-	5.05
		100-170	-	-	-	-	-	7.9	3.72	-	-	4.99
												mq/100 g 1/20
Az Zor	53	0-5	-	-	-	-	-	7.9	3.28	-	-	61.81
		5-50	-	-	-	-	-	8.0	4.48	-	-	62.69
		50-100	-	-	-	-	-	7.9	5.00	-	-	62.74
		100-300	-	-	-	-	-	-	-	-	-	
Doha	3	0-6	5.53	74.17	17.25	8.58	SL	7.7	392.0	6.40	59.37	-
		6-45	11.44	86.11	7.56	6.33	LS	8.0	100.8	6.60	60.55	-
		45-60	4.86	83.92	7.04	9.04	LS	8.1	100.8	5.70	72.90	-
		60-100	2.51	89.74	5.43	4.83	S	8.0	61.6	4.40	81.51	-
		100-120	22.72	93.79	1.55	4.66	S	-	-	3.90	73.55	-

(Page 4)

Soil Series	Profile No.	Depth (cm)	Gravel %	Texture			Textural class	pH Sat. paste	Elec. Cond. (EC x 10^3)	Cation exchange capacity	$CaCO_3$ equivalent %	Gypsum ½ Soil Water ratio
				Sand %	Silt %	Clay %						
Hugaija	38	0-26	-	73.00	18.00	9.00	SL	7.9	66.0	-	12.6	5.13
		26-50	-	58.00	14.00	28.00	SCL	7.9	49.5	-	18.0	6.54
		50-90	-	-	-	-	-	7.8	81.6	-	32.6	7.59
		90-135	-	47.00	4.00	49.00	SC	8.0	81.6	-	33.4	3.89
Ras al Jilaiya	15	0-5	3.87	75.87	13.31	10.82	SL	7.1	176.0	5.80	9.22	-
		5-20	1.31	40.22	18.54	41.24	C	7.3	44.0	10.70	9.79	-
		20-44	2.11	44.73	13.59	41.68	C	-	-	13.50	12.28	-
		44-70	0.12	39.32	12.71	47.97	C	7.3	105.6	4.50	59.33	-
		70-100	-	41.20	13.20	45.60	C	-	-	4.10	58.30	-
		100-120	0.49	53.27	11.35	35.38	SC	7.4	114.4	3.20	48.05	-
Bubiyan	56	0-30		41.60	22.00	36.40	SC	7.7	48.00	-	-	-

GENERAL REMARK: If a datum column or line is marked with a dash (-) it signifies that the determination was not made.

APPENDIX 3.2

Water Analytic Data

Location	Date	EC x 10^6	SSP	SAR	pH	TDS	Ca	Mg	Na	HCO_3	Cl	SO_4
Fahaheel	10-10-1961	15 120	59.5	18.1	7.2	10 584	30.20	19.25	90.00	1.80	19.00	57.30
Fahaheel	27-3-1963	1 500			7.9	1 050	4.64	3.00	6.40	1.22	7.00	4.98
Fantas W.1	26-10-1957	11 466	63.6	16.5	7.6	8 026	32.90	11.68	77.90	2.36	86.75	33.24
Failaka (H. Jaber H)	1-5-1963	500			7.9	350	2.02	0.58	2.00	2.32	1.85	0.40
Failaka S.P.1.	8-5-1963	10 000			7.7	7 000	8.40	22.64	69.00	4.00	90.20	6.66
Jahra	26-4-1960	5 299	42.8	5.8	7.1	3 640	17.81	11.13	22.00	2.30	26.10	23.32
Magwa W.c.	27-2-1963	2 800			8.4	1 960	11.48	4.12	11.40	4.40	14.60	8.33
Sabriya	7-4-1963	9 700			7.5	6 790	28.30	8.68	58.80	2.20	36.30	58.33
Sulibiya (Average of 19 wells)	2-4-1963	6 260			7.3	4 380	21.98	14.85	24.85	2.52	27.55	31.74

APPENDIX 4

SOIL CLASSIFICATION UNITS AND AREAS

APPENDIX 4.1

CLASSIFICATION UNITS

Great soil groups	Soil Associations	Soil Series
A. Desert	A1. Sandy Desert Hardpan Soils	A11. Kuwait
		A12. Ahmadi
		A13. Umm ar Riman
	A2. Gypsiferous Desert Soils	A21. Dibdiba
		A22. Sabriya
	A3. Gravelly Saline Desert Soils	A31. Batin
	A4. Gravelly Gypsiferous Saline Desert Soils	A41. Rauthatain
		A42. Kra Al Maru
	A5. Saline Gypsiferous Desert Soils	A51. Sadda
B. Desert-Regosol Intergrade Soils	B1. Sandy Desert Soils	B11. Sulibiya
		B12. Magwa
		B13. Juwaisri

	B2. Desert Dune Soils	B21. Umm Nigga
C. Lithosols	C1. Escarpment	C11. Az Zor
D. Alluvial	D1. Hydromorphic Saline Alluvial Soils	D11. Doha
		D12. Hugaija
		D13. Ras Al Jilaiya
	D2. Recent Alluvium Soils	D21. Bubiyan

APPENDIX 4.2

AREA COVERED BY DIFFERENT SOILS

Soil Symbol	Great Soil Groups	Soil Associations	Soil Series	ha	ha	ha
A	Desert			1224250.0		
A_1		Sandy desert hardpan			304750.0	
A_{11}			Kuwait			45750.0
A_{12}			Ahmadi			182375.0
A_{13}			Umm ar Rimam			76625.0
A_2		Gypsiferous desert			215250.0	
A_{21}			Dibdiba			175875.0
A_{22}			Sabriya			39375.0
A_3		Gravelly saline desert			206375.0	
A_{31}			Batin			206375.0

A_4		Gravelly gypsiferous saline desert		456625.0	
A_{41}			Rauthatain		252000.0
A_{42}			Kra Al Maru		204625.0
A_5		Saline gypsiferous desert		41250.0	
A_{51}			Sadda		41250.0
B	Desert-Regosol intergrade			213562.5	
B_1		Sandy desert		200062.5	
B_{11}			Sulibiya		25687.5
B_{12}			Magwa		153312.5
B_{13}			Juwaisri		21062.5
B_2		Desert dune		13500.0	
B_{21}			Umm Nigga		13500.0
C	Lithosols			13000.0	
C_1		Escarpment		13000.0	
C_{11}			Az Zor		13000.0
D	Alluvial			109125.0	
D_1		Hydromorphic saline Allu.		20312.5	
D_{11}			Doha		13312.5
D_{12}			Hugaija		5937.5
D_{13}			Ras Al Jilaiya		1062.5
D_2		Recent Alluvium		88812.5	
D_{21}			Bubiyan		88812.5
			Total	1559937.5 1559937.5	1559937.5

APPENDIX 4.3

PERCENTAGE OF THE DIFFERENT SOILS

Soil Symbol	Great Soil Group	Soil Associations	Soil Series	%	%	%
A	Desert			78.48		
A_1		Sandy desert hardpan			19.53	
A_{11}			Kuwait			2.93
A_{12}			Ahmadi			11.69
A_{13}			Umm ar Rimam			4.91
A_2		Gypsiferous desert			13.80	
A_{21}			Dibdiba			11.28
A_{22}			Sabriya			2.52
A_3		Gravelly saline desert			13.23	
A_{31}			Batin			13.23

A_4		Gravelly gypsiferous saline desert		29.27	
A_{41}			Rauthatain		16.16
A_{42}			Kra Al Maru		13.11
A_5		Saline gypsiferous desert		2.65	
A_{51}			Sadda		2.65
B	Desert Regosol intergrade			13.69	
B_1			Sandy desert	12.82	
B_{11}			Sulibiya		1.65
B_{12}			Magwa		9.82
B_{13}			Juwaisri		1.35
B_2		Desert dune		0.87	
B_{21}			Umm Nigga		0.87
C	Lithosols			0.83	
C_1		Escarpment		0.83	
C_{11}			Az Zor		0.83
D	Alluvial			7.00	
D_1		Hydromorphic Saline Allu.		1.30	
D_{11}			Doha		0.86
D_{12}			Hugaija		0.38
D_{13}			Ras Al Jilaiya		0.06
D_2		Recent Alluvium		5.70	
D_{21}			Bubiyan		5.70
			Total	100.00	100.00	100.00

APPENDIX 5

CLIMATOLOGICAL DATA

	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (1)												
Absolute Max	26	33	39	42	48	48	49	49	46	42	37	31
Average Max.	18	21	26	31	37	43	44	44	41	35	26	20
Mean	13	16	20	25	31	35	37	36	33	27	20	15
Average Min.	8	10	14	19	24	28	29	28	24	19	14	9
Absolute Min.	-3	0	5	9	14	22	23	21	17	11	6	-1
Relative humidity % (2)												
Average Max.	75	74	69	63	54	40	43	44	48	59	71	80
Mean	63	53	47	43	36	27	28	29	31	38	51	61
Average Min.	43	33	26	24	18	13	13	13	14	18	32	43
Evaporation rate. mm/day (3)												
Piche	4.9	6.9	10.4	13.9	17.9	24.3	23.7	22.3	18.6	12.8	7.9	5.6
Mean ground temperature (4)												
5 Cm depth	15.2	18.4	22.4	27.7	33.0	37.2	38.8	38.8	35.4	29.7	21.9	16.5
120 Cm depth	23.1	22.2	23.4	25.4	28.1	30.9	32.4	34.3	33.6	31.9	29.2	25.2

Rainfall mm													Total
1955	8.6	-	6.4	6.0	7.0	-	-	-	-	-	0.5	44.8	73.3
1956	10.8	4.7	6.0	14.2	-	-	-	-	-	-	-	119.3	155.0
1957	9.8	14.3	15.4	26.3	8.9	-	-	-	-	0.1	89.1	1.3	165.2
1958	12.1	0.7	7.6	2.2	1.9	-	-	-	-	-	15.7	61.7	101.9
1959	32.2	13.5	10.0	9.4	1.8	-	-	-	-	-	9.3	23.8	100.0
1960	7.7	2.6	2.7	4.2	-	-	-	-	-	-	11.3	0.1	28.6
1961	22.7	16.3	45.9	29.1	1.1	-	-	-	-	-	66.3	14.4	195.8
1962	27.1	3.2	4.5	18.9	0.1	-	-	-	-	-	0.1	12.7	66.6
1963	0.4	23.9	1.4	19.9	21.4	-	-	-	-	-	7.1	13.1	87.2
1964	12.2	2.2	2.2	-	-	-	-	-	-	-	1.1	8.6	26.3

(1) - During the period of 1955-1964
(2) - During the period of 1955-1964
(3) - During the period of 1961-1964
(4) - During the period of 1961-1964

GLOSSARY

Alluvium	Deposit of mineral or organic matter from flowing or still water
Alluvial soils	Soils with very weak or no genetic horizon and consisting of recently deposited alluvium.
Caloareous soil	Soil containing sufficient calcium carbonated (often with magnesium carbonate) to effervesce visibly to the naked eye when treated with Hydrochloric Acid.
Clay	Particles of diameter less than 0.002 mm. As a soil textural class, soil material that contains 40% or more clay, less than 45% of sand, and less than 40% of silt.
Clay loam	Soil material that contains 27% to 40% of clay and 20% to 45% of sand.
Consolidate (Soils)	To place into a compact mass and thus increase density and reduce pore space.
Desert soil	A zonal group of soils that have light-coloured surface soils and usually are underlain by calcareous material and frequently by hard layers. They are developed under extremely scanty scrub vegetation in warm to cool, arid climates.
Desert pavement	Surface of stones and rocks remaining after finer material has been blown away.
Hardpan	A hardened or cemented soil horizon or layer. The soil material may be sandy or clayey and may be cemented by iron oxide, silica, calcium carbonate or other substances.
Horizon	A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil forming processes.
Hydromorphic soils	Soil developed in the presence of excess water all or part of the time.
Intergrade soils	Soils intermediate in character between two different soils and genetically related to both.
Lithosol	A soil having little or no evidence of soil development and consisting mainly of a partly weathered mass of rock fragements or of nearly barren rocks.
Loam	Soil material containing 7% to 27% clay, 28% to 50% silt and less than 52% sand.

Massive (structure)	A soil structure with no observable aggregation, or no definite orderly arrangement of natural lines of weakness if coherent.
Pan	A layer or soil horizon within a soil that is firmly compacted or is very rich in clay. Examples include hardpan, fragipans and claypans.
Parent material	The unconsolidated material beneath the solum, presumably like that from which the soil is formed.
Permeability	The quality of a soil horizon that enables water or air to move through it. It can be measured quantitatively in terms of rate of flow of water through a unit cross section in unit time under specified temperature and hydraulic conditions.
Platy (structure)	Soil particles arranged around a plane, generally horizontal.
Regosol	Soils without definite genetic horizons developing from deep unconsolidated rock or soft mineral deposits.
Relief	Elevations or inequalities of the land surface considered collectively.
Saline soils	Soils containing enough salt to hinder crop growth.
Sand	Individual rock or mineral fragments in soils having diameters ranging from 0.5 mm to 2.0 mm. The textural class name of any soil that contains 85% or more sand and not more than 10% clay.
Sandy clay	Soil of this textural class contains 35% or more clay and 45% or more sand.
Sandy clay loam	Generally soil of this textural class contains 20% to 35% clay, less than 28% silt and 45% or more sand.
Sandy loam	Generally has 50% sand and less than 20% clay.
Sandy soils	A broad term for soils of the sand and loamy sand classes; soil material with more than 70% sand and less than 15% clay.
Series (soil)	A group of soils that have horizons similar in their differentiating characteristics and arrangement in their soil profile, except for the texture of the surface soil, and are formed from a particular type of parent material.
Silt	Individual mineral particles of soil that range in diameter of 0.02 to 0.002 mm.
Single grain (soil)	A structureless soil in which each particle exists separately as in dune sands.

Soil profile	The soil as exposed in a cut or vertical section with special recognition of the sequence of horizons from surface to parent material.
Soil structure	Arrangement of soil particles into aggregates of characteristic shape and size.
Soil survey	A general term for the systematic examination of soils in the field and in the laboratories, their description and classification, the mapping of kinds of soil and interpretations of soils according to their adaptability for various crops, grasses and trees, their behaviour under use or treatment for plant production or for other purposes, and their productivity under different management systems.
Soil texture	The classification of soil based on the relative amounts of the various size groups of individual soil grains.
Soil type	A subgroup or category under the soil series based on the texture of the surface soil.
Subsoil	Roughly, that part of a solum below plough depth.
Substratum	Any layer lying beneath the solum or true soil.
Surface soil	The soil ordinarily moved in tillage, or its equivalent in unoultivated soil, about 12 to 20 cm in thickness.
Topsoil	A general term applied to the surface portion of the soil, including the average plough depth (surface soil) or a horizon, where it is deeper than plough depth.

BIBLIOGRAPHY

1. Buringh, P. 1960 — Soils and Soil Conditions of Iraq, Baghdad

2. Food and Agriculture Organization of the U.N. 1960 — Multilingial Vocabulary of Soil Science Rome

3. Higgenbottom, I.E. 1954 — Report on the Surface Geology of Kuwait with Reference to the Natural Resources of Building Materials, Kuwait

4. Holzer, H.F. 1965 — Surface Geology of Kuwait, Kuwait

5. Kernick, M.D. 1963 — A Modern Approach to the Development of Range Management and Animal Production in Kuwait, Kuwait

6. Kernick, M.D. 1963 — Natural Vegetation and Animal Production in Kuwait, Kuwait

7. Millar, C.E., Turk, L.M., Fotch, H.D. 1958 — Fundamentals of Soil Science, New York

8. Ministry of Guidance and Information 1963 — Agriculture in Kuwait, Kuwait

9. Moorman, F. 1959 — Report to the Government of Jordan on the Soils of Eastern Jordan, FAO, Rome

10. Oaks, H. 1954 — Soils of Turkey, FAO, Ankara

11. Parsons Cooperation 1963 — Ground Water Resources of Kuwait, Los Angeles

12. Quality Publication Ltd 1964 — Kuwait today. A Welfare State. Nairobi

13. Research Station MPW, Government of Kuwait — Climatological Report, 1955-1964

14. South Dakota State College 1959 — Soils of South Dakota Brookings

15. Trewartha, G.T. 1954 — An Introduction to Climate New York

16. Ueda, H., Ueda, T. 1968 — Preliminary Study on Agriculture in Kuwait. Kuwait

17. United States Department of Agriculture 1938 — Soil and Man, Yearbook of Agriculture

18. United States Department of Agriculture 1951 — Soil Survey Manual, Agriculture Handbook 18

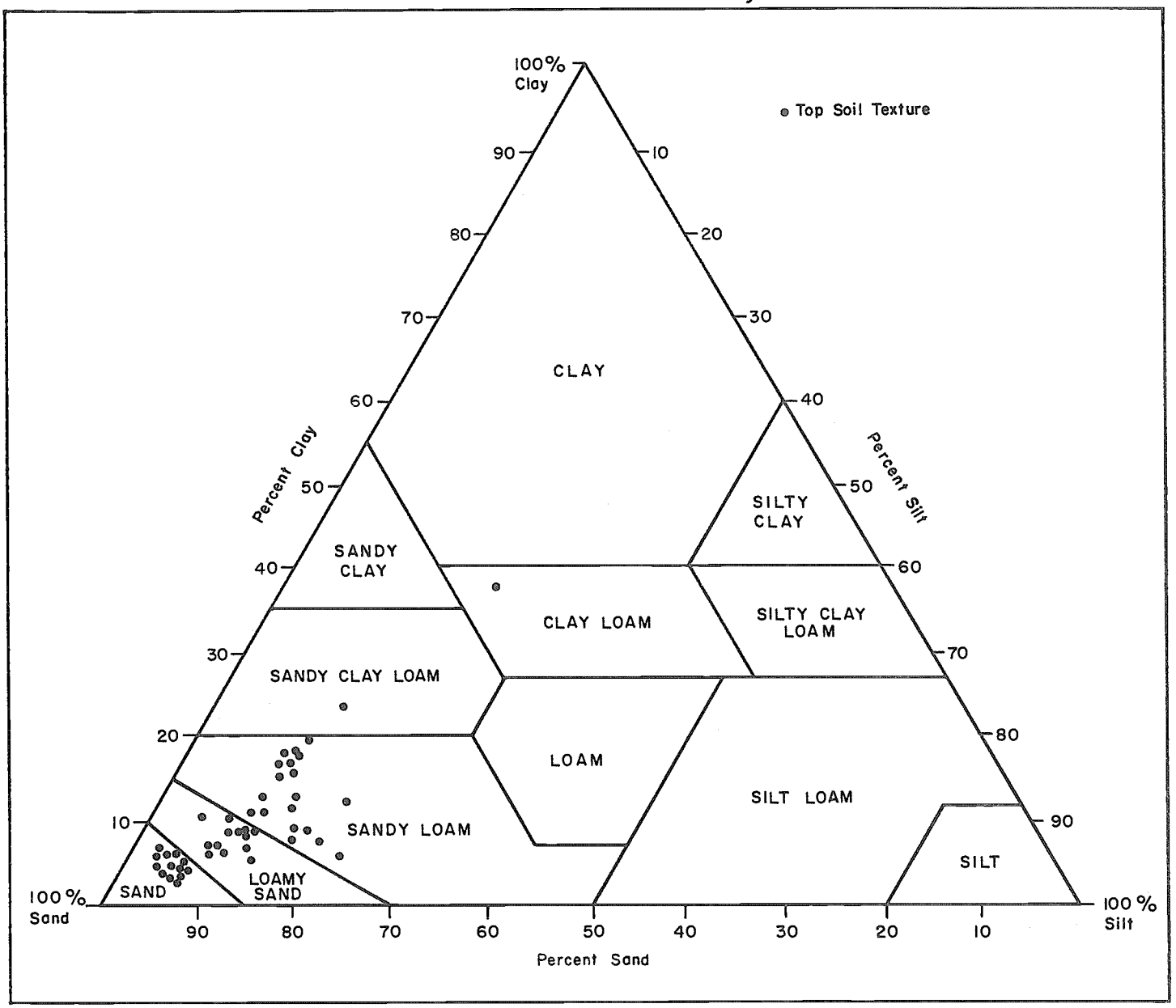
19. United States Department of Agriculture 1957 — Soil, 1957 Yearbook of Agriculture

20. United States Department of the Interior — Bureau of Reclamation Manual, Volume V, Irrigated Land Use, Part 2, Land Classification.

TEXTURAL CLASSIFICATION OF TOP SOILS

Fig. 1

for the Reconnaissance Soil Survey of Kuwait



LOCATION MAP OF KUWAIT

Map No. 1

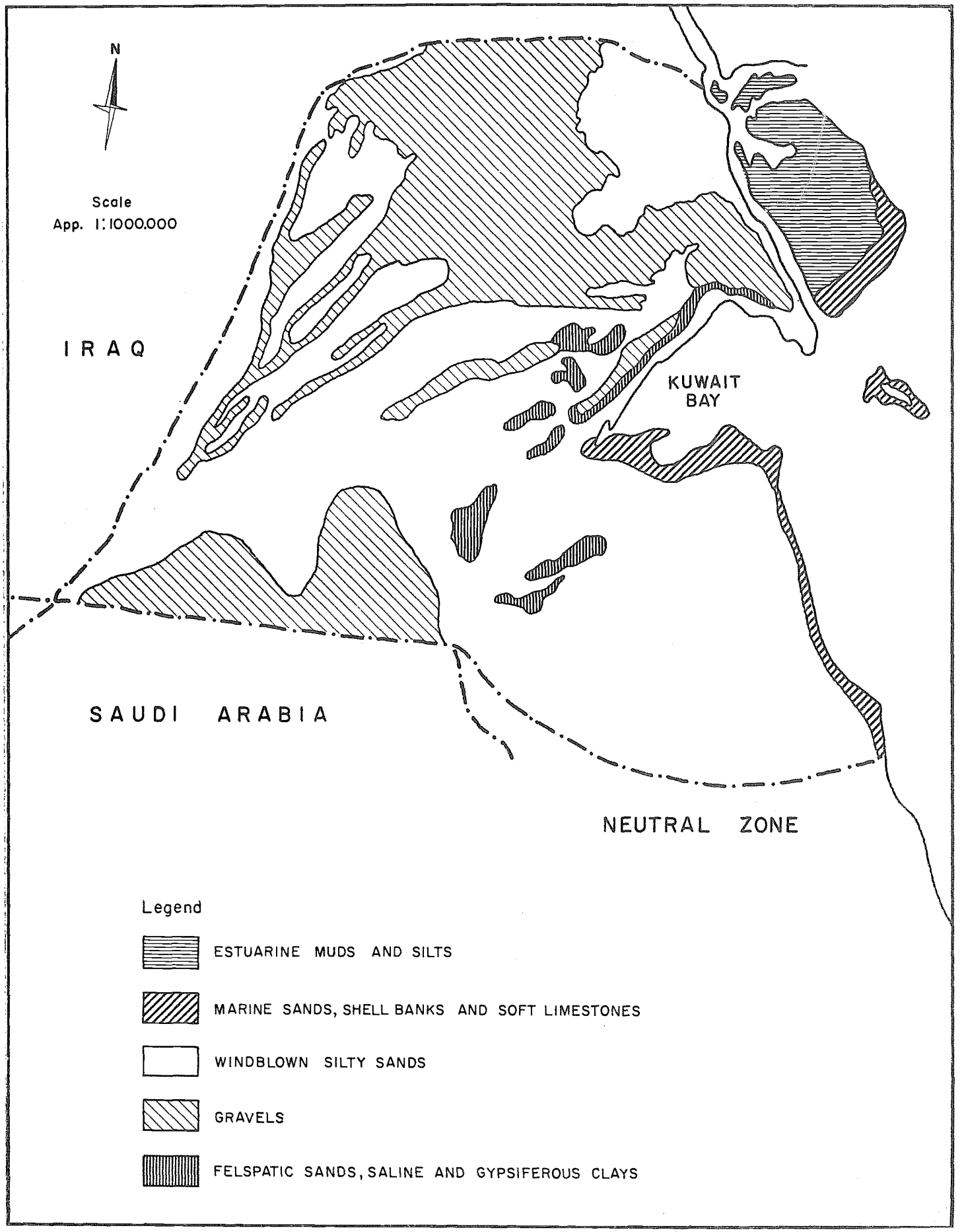
N.B. This map is not an authority for international boundaries.

GEOGRAPHICAL MAP OF KUWAIT

Map No. 2

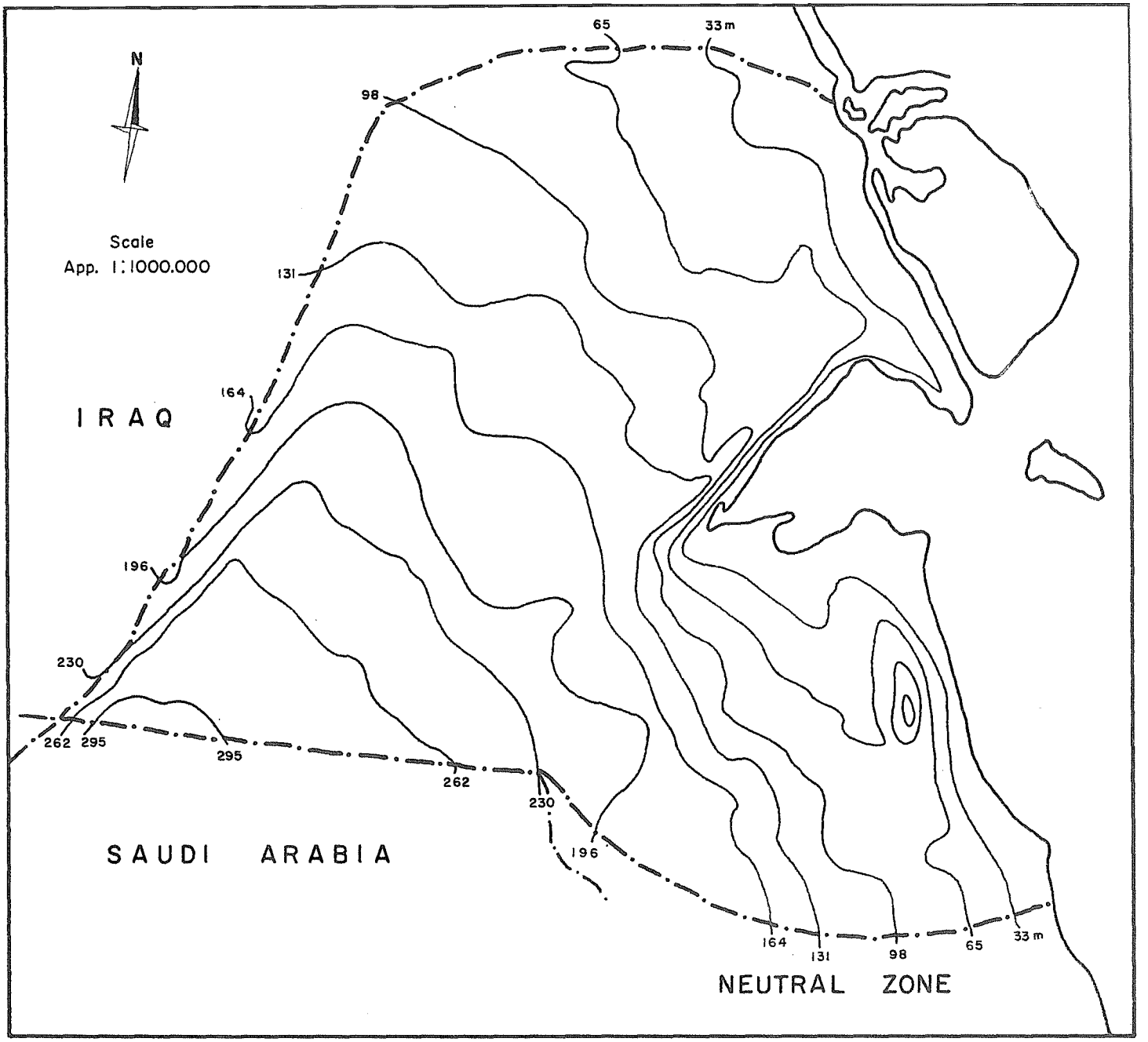
GEOLOGICAL MAP OF KUWAIT

Map No. 3



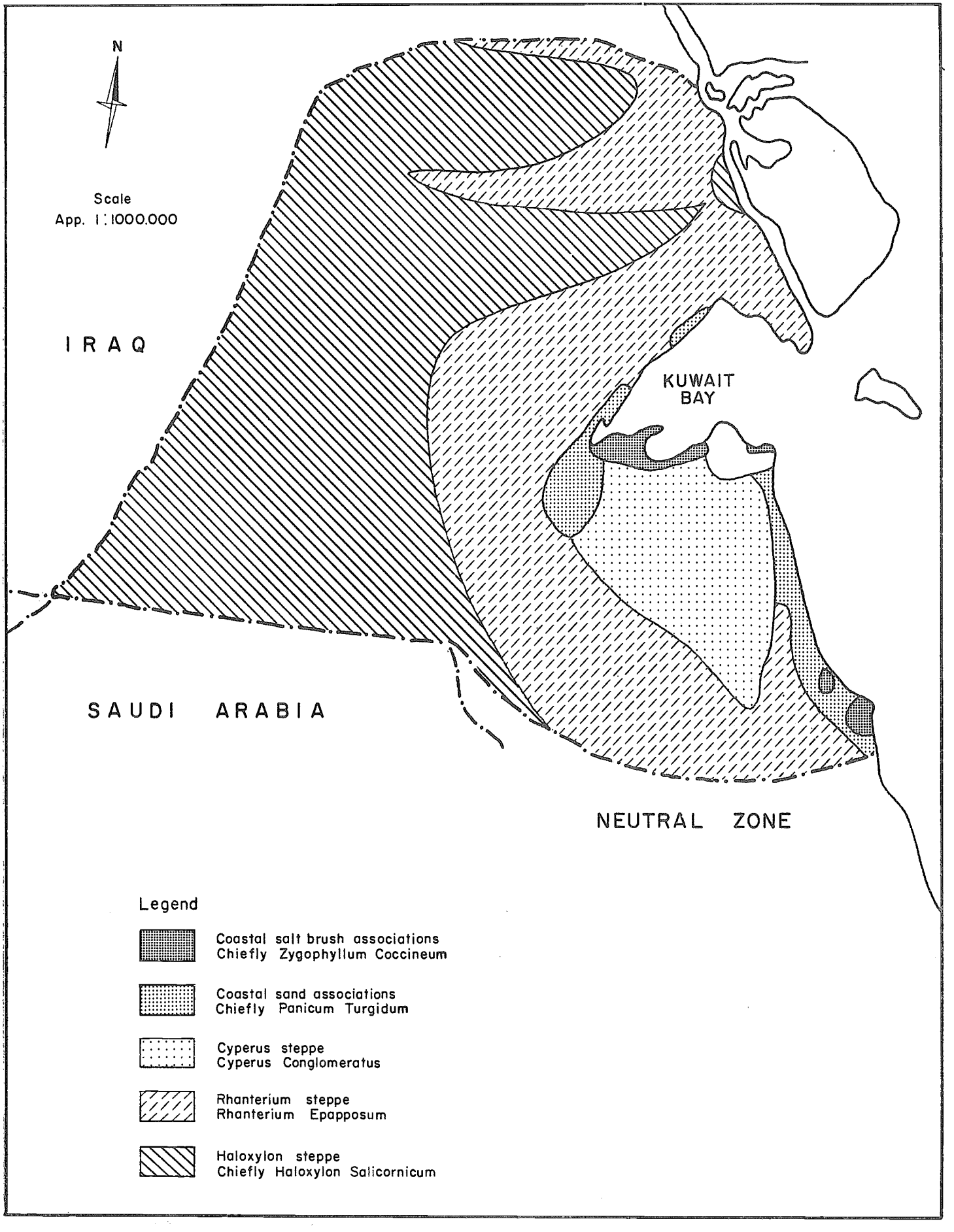
CONTOUR MAP OF KUWAIT

Map No. 4



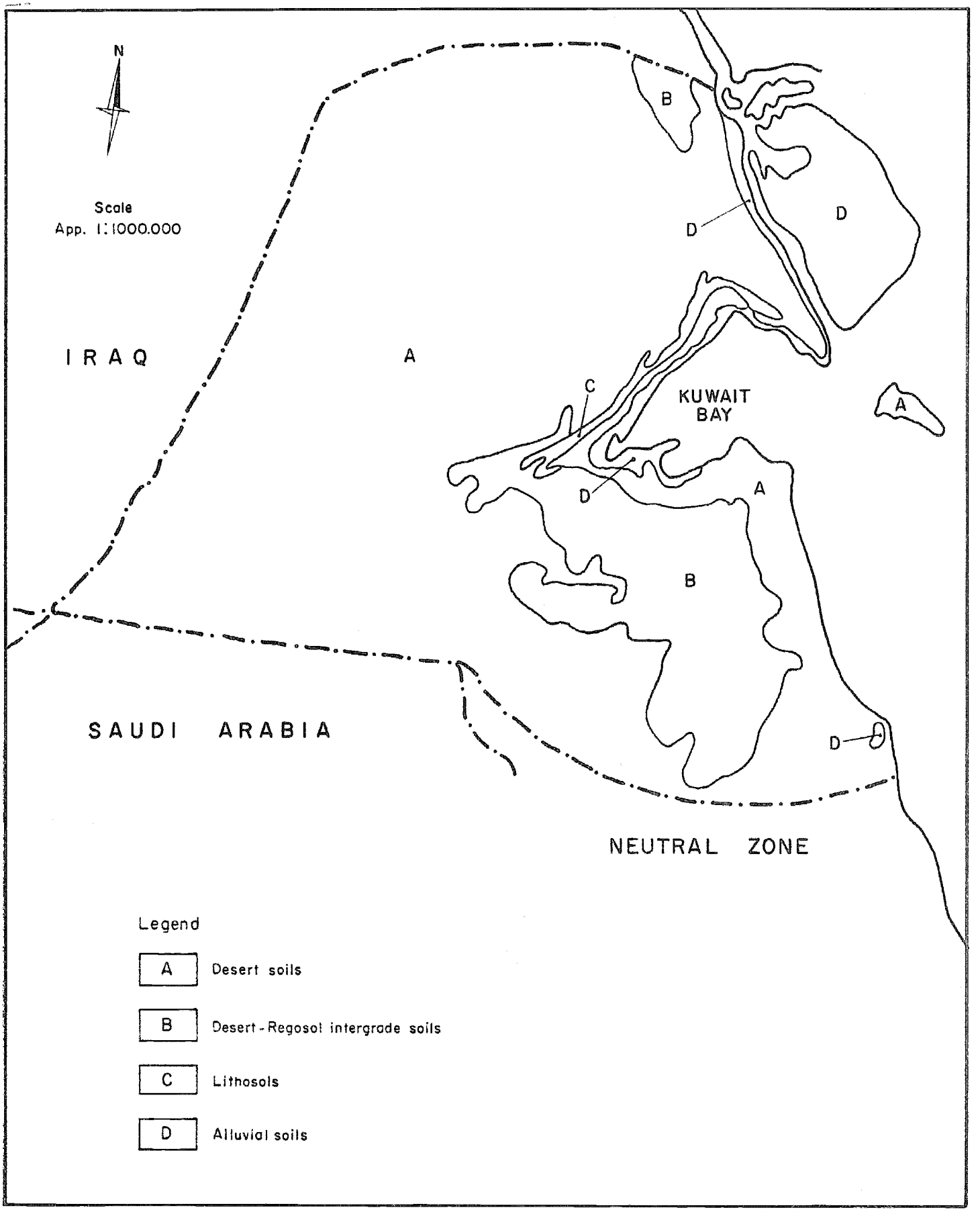
VEGETATION MAP OF KUWAIT

Map No. 5



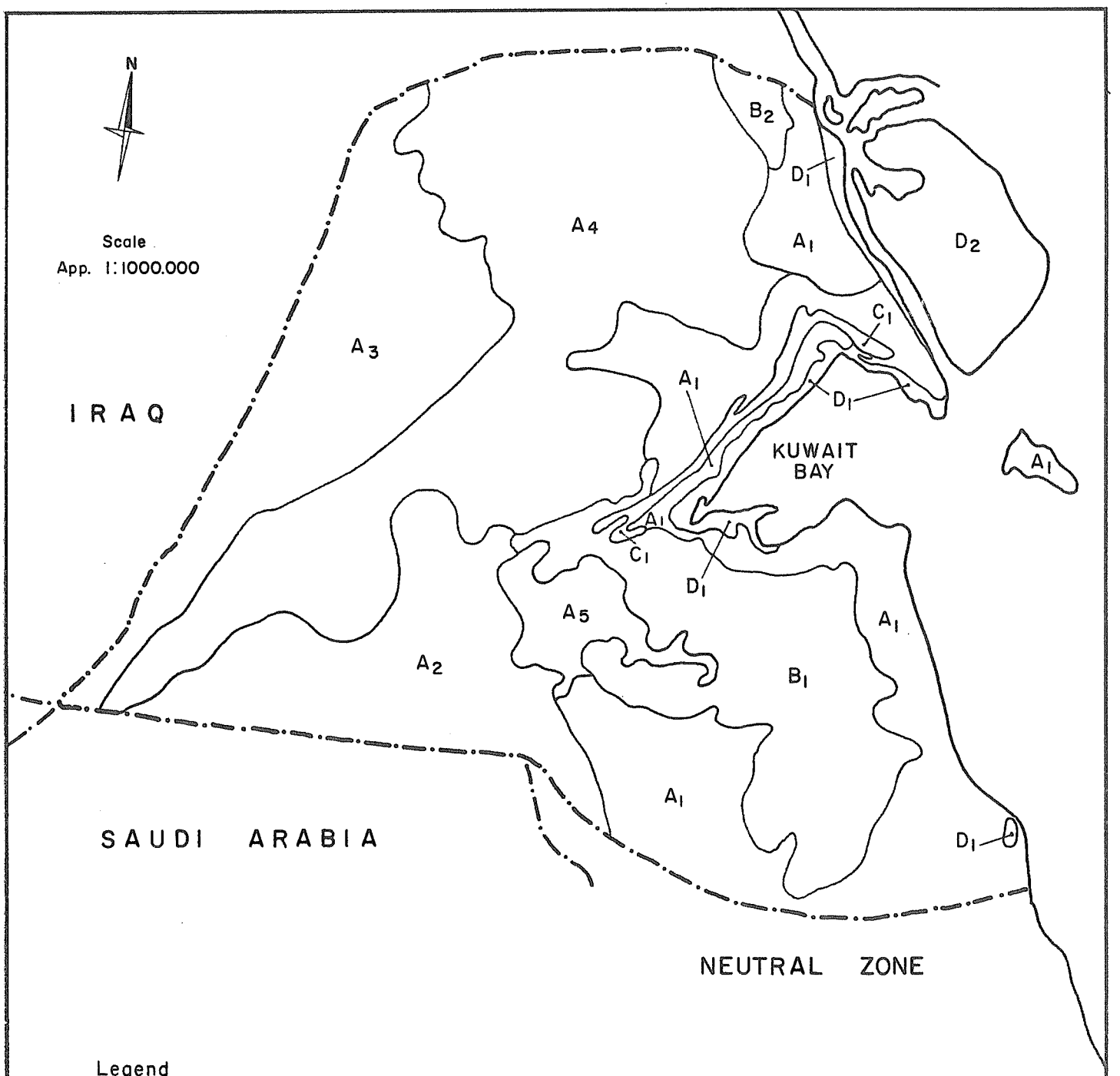
GREAT SOIL GROUPS OF KUWAIT

Map No. 6



SOIL ASSOCIATIONS OF KUWAIT

Map No. 7

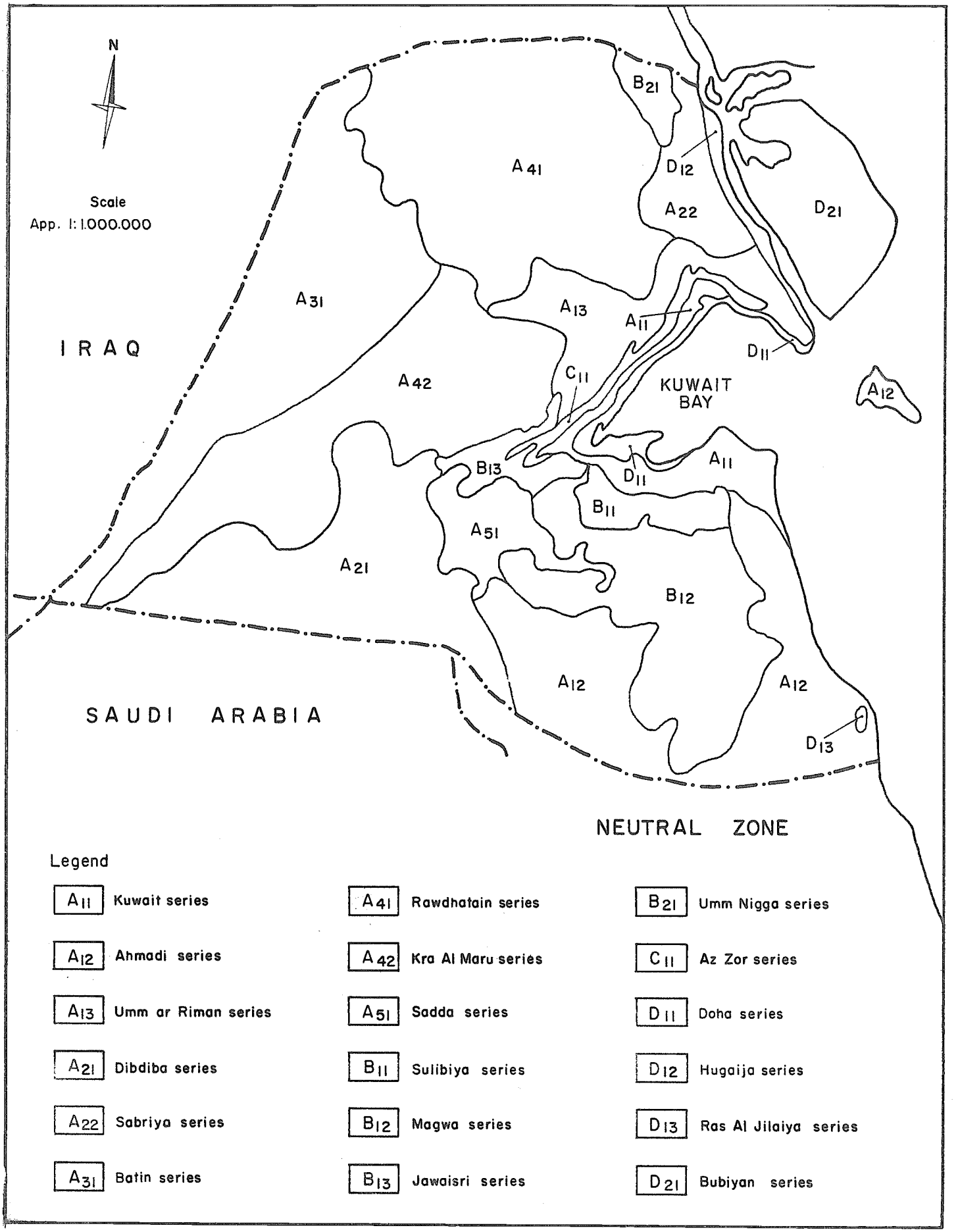


Legend

A_1	Sandy desert hardpan soils	B_1	Sandy desert soils
A_2	Gypsiferous desert soils	B_2	Desert dune soils
A_3	Gravelly saline desert soils	C_1	Escarpment
A_4	Gravelly gypsiferous saline desert soils	D_1	Hydromorphic saline alluvial soils
A_5	Saline gypsiferous desert soils	D_2	Recent alluvium soils

SOIL SERIES OF KUWAIT

Map No 8

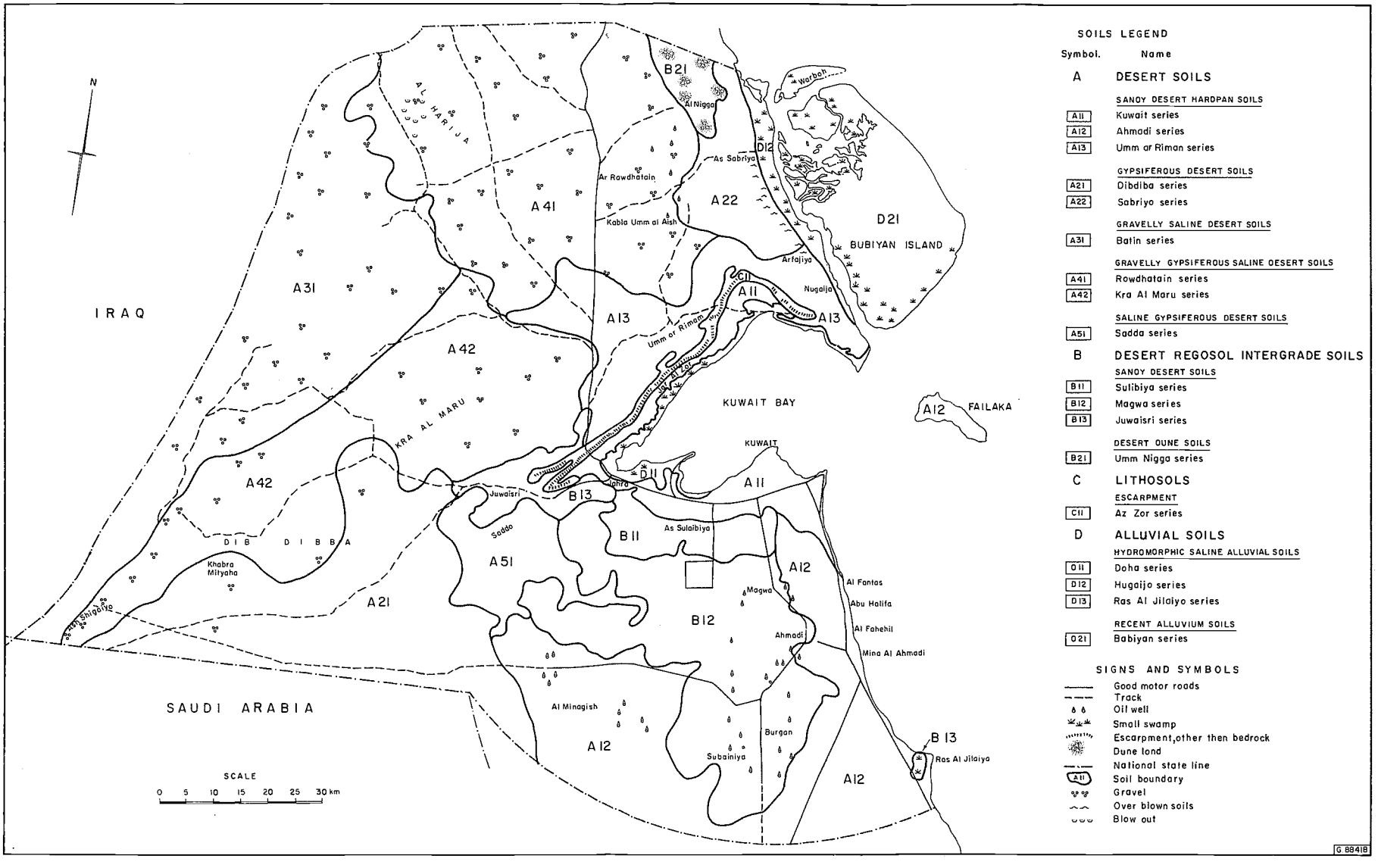


Legend

A11 Kuwait series	A41 Rawdhatain series	B21 Umm Nigga series
A12 Ahmadi series	A42 Kra Al Maru series	C11 Az Zor series
A13 Umm ar Riman series	A51 Sadda series	D11 Doha series
A21 Dibdiba series	B11 Sulibiya series	D12 Hugaija series
A22 Sabriya series	B12 Magwa series	D13 Ras Al Jilaiya series
A31 Batin series	B13 Jawaisri series	D21 Bubiyan series

RECONNAISSANCE SOIL MAP OF KUWAIT

Map No. 9



SOILS LEGEND

Symbol.	Name
A	**DESERT SOILS**
	SANDY DESERT HARDPAN SOILS
A11	Kuwait series
A12	Ahmadi series
A13	Umm ar Riman series
	GYPSIFEROUS DESERT SOILS
A21	Dibdiba series
A22	Sabriyo series
	GRAVELLY SALINE DESERT SOILS
A31	Batin series
	GRAVELLY GYPSIFEROUS SALINE DESERT SOILS
A41	Rowdhatain series
A42	Kra Al Maru series
	SALINE GYPSIFEROUS DESERT SOILS
A51	Sadda series
B	**DESERT REGOSOL INTERGRADE SOILS**
	SANDY DESERT SOILS
B11	Sulibiya series
B12	Magwa series
B13	Juwaisri series
	DESERT DUNE SOILS
B21	Umm Nigga series
C	**LITHOSOLS**
	ESCARPMENT
C11	Az Zor series
D	**ALLUVIAL SOILS**
	HYDROMORPHIC SALINE ALLUVIAL SOILS
D11	Doha series
D12	Hugaijo series
D13	Ras Al Jilaiyo series
	RECENT ALLUVIUM SOILS
D21	Babiyan series

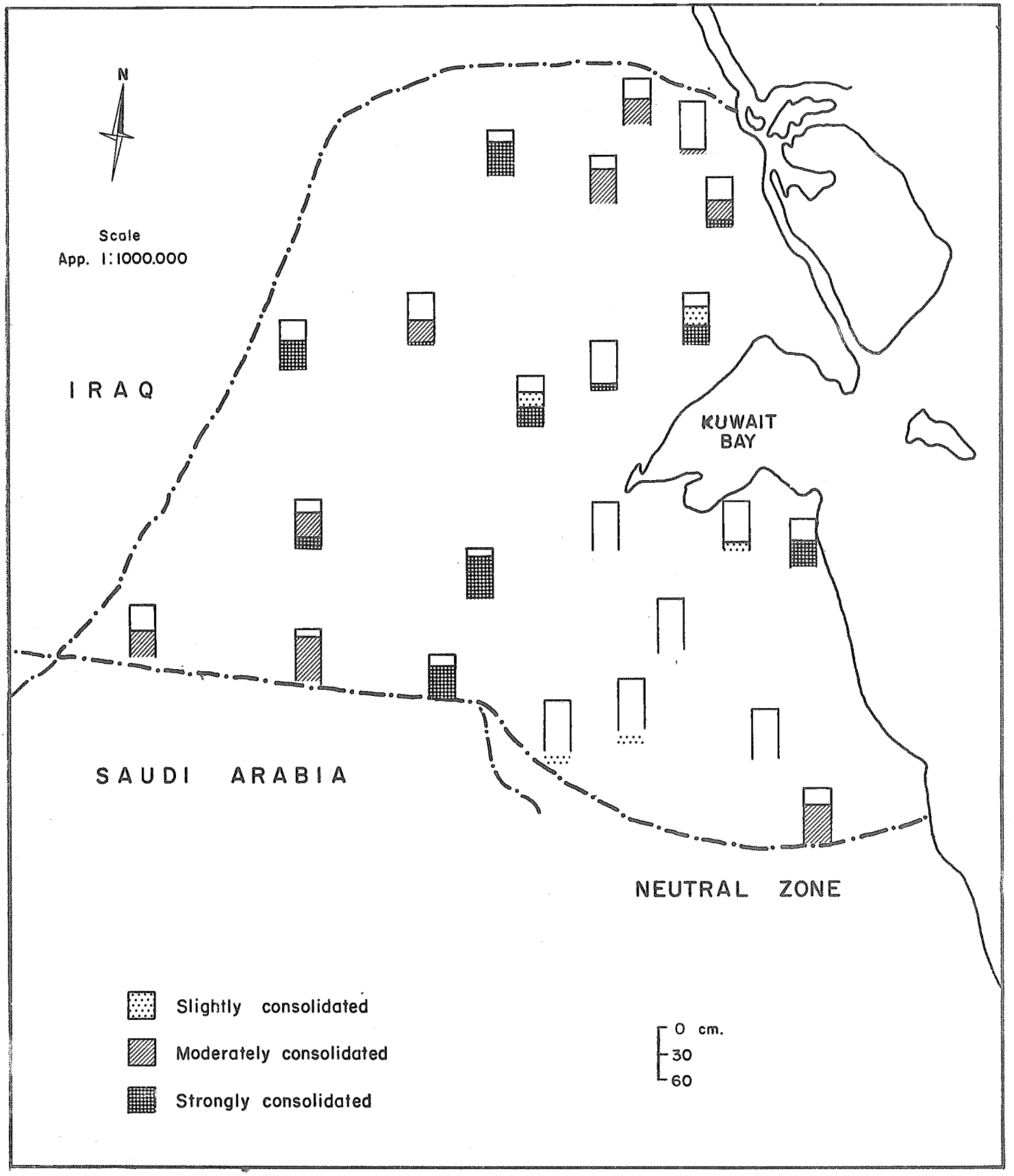
SIGNS AND SYMBOLS

- Good motor roads
- Track
- Oil well
- Small swamp
- Escarpment, other then bedrock
- Dune land
- National state line
- A11 Soil boundary
- Gravel
- Over blown soils
- Blow out

G 88418

HARDPAN SKETCH MAP OF HARDPAN (GATCH)

Map No. 10



LOCATION MAP OF SEMIDETAILED SOIL SURVEY AREAS

Map No. 11