HUNTING TECHNICAL SERVICES LTD

4, ALBEMARLE ST.,

LONDON W.1.

REPORT ON

RECONNAISSANCE SOIL SURVEY AND LAND CLASSIFICATION

OF THE

WADI DHULEIL INVESTIGATION

HASHEMITE KINGDOM OF JORDAN

Hunting Technical Services Ltd.,
4 Albemarle Street,
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The area studied lies about 40 kilometres to the north-east of Amman and is 29,894 hectares in extent. This excludes a military zone 1,235 hectares in extent.

1.2

The geological formations consist of dissected beds of limestone, chalks and marls partly buried by basaltic sheets of lava. The present landscape comprises the central, gently rolling plateau bounded by limestone hills. Wadi Dhuleil with its tributaries cuts across the middle of the area.

1.3

The climate is semi-arid with a very irregular rainfall averaging 150 mm. annually and mean monthly temperatures varying from 8° C in January to over 26° C in July. There are strong westerly winds and occasional winter frosts. The natural vegetation consists of sparse grass cover and scattered fire tolerant shrubs and small trees.

1.4

Four types of agricultural land-use have been recognised and these are mentioned in order of their predominance:-

Nomadic grazing by sheep, goats, camels and occasionally cattle.

Grazing combined with some shifting cultivation by the nomads.

Dry farming with winter cereals, wheat and barley entirely dependent on local rainfall.

Irrigated farming based on either winter flood irrigation in the wadis or the supply of water from local wells. Only six permanent irrigated farms have been established in the area.

Generally, the yields of rainfed crops are very low and there are frequent failures due to insufficient rainfall. Cereals, vegetables and recently fruit trees on the irrigated farms appear to give relatively high yields and the produce is marketed in the neighbouring towns.

1.5

Following a stereoscopic analysis of the aerial photographs, the area was divided into two major groups of land forms; Group A comprising 15,443 hectares and Group B, 14,451 hectares. Group B referred to as "miscellaneous land types" consisting of bare rocky hills and highly dissected surfaces, has been excluded as unsuitable for further invetigations. Group A land forms with sufficient soil cover have been surveyed in the field. The soil and land classes described in this report refer to this area only.

1.6

The field work was carried out between May 23rd and July 8th. Soil observations were made either on pre-selected traverses or individually within the photo-interpretation boundaries. In all 18 representative profile pits and 138 routine auger holes were described and sampled giving an overall observation density of one site per square kilometre.

1.7

All chemical analyses have been done in the Government laboratory in Amman under the supervision of the Government Chemist. Routine determinations have been made on 306 samples taken from 112 auger holes and more detailed analyses on 30 samples from 9 profile pits. The analytical data are shown in Appendices I and II.

1.8

Individual soil observations have been grouped into several mapping units as shown on the combined soil and land class map. In separating the mapping units considerable use was made of the photo-interpretation boundaries as in general, there was a good correlation between the land forms distinguished by photo-interpretation and the soil mapping units as recognised in the field.

The major soil mapping units have been distinguished according to the type of parent material with its associated topography and the type of soil profile. Specific morphological differences in otherwise similar profiles are expressed in soil phases. Each soil classification unit has been put in an appropriate land class indicating its potential value for irrigation farming Detailed descriptions of all the mapping units are presented in the report.

1.9

Four main types of soil parent material have been recognised in the project area. Each of these types gives rise to a distinct group of soils associated with a distinct topography.

I Recent alluvium of Wadi Dhuleil and some of its tributaries with medium textured deep and pedologically immature soils shown as group A1 on the map.

II Colluvial deposits of the limestone valleys giving rise to gravelly loams and clay-loams with calcareous horizons - group A2 on the map.

III Weathering products of basalt on the plateau forming brown silty clay loams with varying amounts of basalt fragments and calcium carbonate concretions - group A3 on the map.

IV Weathered limestone hills with shallow and stony soils - group A4 on the the map.

1.10

The detailed soil and land classification criteria used in this report are based on those outlined in the U.S. Department of Agriculture Soil Survey Manual and the U.S. Bureau of Reclamation Manual. Some of these criteria have been adapted to the local conditions.

The main distinguishing features of the soil profile are texture and the presence of slowly permeable layers affecting internal drainage and limiting the effective soil depth. Among the external

features the degree of erosion, surface stoniness, slope gradient incidence of flooding and present land-use have been taken into account. Among the chemical characteristics both salinity and alkalinity of each soil mapping unit have been considered in the land classification. Neither of these characteristics is considered to be a major limiting factor in freely drained soils of units A1 and A2. However, in the less permeable and at the same time more saline and more alkaline A3 soils the development of irrigation farming on a large scale is likely to be met with serious difficulties.

1.11

The areas of land classes are shown in a table below

		Areas in hectares	Percentage of total
Land class	2	4,778	15.3
	3	1,173	3.8
	5	3,538	11.4
	6	5,954	19.1
Miscellaneous land types -	B group	14,451	46.4
		29,894	
Military zone		1,235	4.0
	Grand total	31,129	100.0

None of the mapping units in the project area has been put into land class 1. The nearest to class 1 are the deep alluvial soils of unit A1 but they have been downgraded to class 2 on account of their relatively low nutrient status and occasional occurrence of horizons with hard consistence.

Class 2, Arable: This class comprises lands of moderate suitability for irrigation farming being measurably lower than class 1 in productive capacity but still capable of producing economic returns under good management. Deep and freely drained soils of units A1 and A2 have been put in this class.

Class 3, Arable: Lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly

restricted suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics. Despite these shortcomings Class 3 lands are expected to have adequate payment capacity under proper management. Very gravelly phases of A2 group and shallow and stony soils of A2.2 association have been put in this class.

Class 5, Non Arable: Lands in this class are non arable under existing conditions but have potential value sufficient to warrant tentative segregation for special study. In the project area A3.2 soils derived from basalt have been put in this class. These soils appear to be more saline and more alkaline than any other soils in the area and are often underlain by impermeable rock strata at relatively shallow depths. With these serious limitations, an expensive drainage system would be required, if the whole area was to be developed for irrigation farming and in such a case these soils would fall into class 6. If on the other hand water supplies were available only for restricted development in small and disconnected blocks of land, natural lateral drainage may be sufficient to prevent the formation and rise of the water table and to effect adequate leaching. Assuming that the development will be restricted in this way, the selected A3.2 soils would come into class 3 as in this case no drainage works would be required. Therefore, the final assessment of class 5 lands must await solution of the water supply problem and of the agricultural and economic investigations. For instance, the problem of the minimum size of an economic holding is important because it is felt that although A3.2 soils may support, by means of natural drainage, small areas of irrigation, they cannot be developed in larger units.

For these reasons it is also recommended that a small irrigated pilot farm be established in the area in order to test the response of the soils to irrigation and cropping.

Class 6, Non Arable: Lands in this class are completely unsuitable for irrigation farming. They contain shallow, gravelly or stony or severely eroded soils occurring on relatively steep hills or on rough, broken and highly dissected ground. All A4 soils and shallow and stony soils of A3 group have been put in this class.

1.12

Depending on the availability of water, it is recommended that the development of irrigation farming in the project area should be planned in stages beginning from the best available class 2 lands of A1 group comprising approximately 1485 hectares. In the second stage, which may begin before the completion of the first one, class 2 lands of A2 group comprising approximately 3293 hectares could be developed. The introduction of irrigation farming into class 3 lands should be deferred until sufficient technical and economic resources are available to handle these soils which have a comparatively lower payment capacity and will be more difficult and more expensive to develop. In the meantime the solution to the problems of class 5 lands would be sought by further hydrological investigations as recommended in our Preliminary Report, by agricultural and economic investigations now in progress and from soil and crop data obtained from the proposed pilot farm.

2. THE ENVIRONMENT

2.1 Location and Extent

The area studied lies about 40 kilometres to the north-east of Amman. It is defined by the co-ordinates E. 257 - E. 280 and N. 165 - N. 180 and covers most of the Qasr El Hallabat map sheet and the eastern margin of the Es - Sukhna map sheet. The total area investigated, excluding the military zone, is 29,894 hectares.

2.2 Geology and Physiography

Geology of the area has been fully described in the Preliminary Report on the Hydrogeological Investigations*. Briefly, the area consists of dissected beds of limestone, chalks and marls, partly buried by sheets of basaltic lava. The present landscape comprises the central gently rolling plateau bounded by limestone hills to the north and to the south. Wadi Dhuleil with its tributary wadis cuts across the middle of the area and its seasonal flow is from east to west. Soil type and distribution pattern described in the subsequent sections of this report, is closely associated with changes in relief and drainage.

2.3 Climate and Vegetation

The climate is semi-arid with a very irregular rainfall averaging 150 mm annually. The mean monthly temperatures vary from $8^{\circ}C$ in January to over $26^{\circ}C$ in July.

The natural vegetation consists of short and sparse grasses with scattered shrubs mainly Anabasis articulate. This vegetation cover is not continuous but alternates frequently with areas of bare soil which are probably due to erosion caused by overgrazing and to moisture deficiency particularly in shallow soils. A somewhat denser vegetation with a greater variety of species occurs in the natural drainage channels and in the valleys. The dominant species include

* Wadi Dhuleil Investigation. Preliminary Report on the Hydrogeological Investigations. Hunting Technical Services Ltd. and Sir Murdoch MacDonald and Partners August, 1964.

Anabasis articulate, Artemisia herba alba, Peganum harmala. Anabasis articulate seems to be the first species to re-establish itself on fallow farmland.

Apart from the scarcity of the rainfall two other aspects have a direct bearing on crops and soils; occasional winter frosts may damage the cereals and strong westerly winds are liable to cause erosion of the topsoil.

2.4 Present Land-Use

As a rule agricultural land use in the surveyed area is governed by the availability of water. Basically four types of agricultural land use are distinguished.

I Rough grazing
II Grazing combined with some dry farming
III Dry farming
IV Irrigated farming
   a. semi-irrigation
   b. irrigation from wells.

I Rough grazing

The relatively steep limestone hills with shallow soils, considerable run-off, and extremely scanty vegetation are used for limited grazing by sheep, goats and camels. Temporary settlements of the nomadic Bedouins are restricted to hills adjacent to the cultivated valleys. In several places cisterns have been dug in the lower hill slopes.

II Grazing combined with some dry farming

This form of land use is mainly found in the plateau areas. Dry farming is practised here on a very small scale only and is entirely dependent on rainfall. Small scattered plots, cleared from boulders and ploughed, but nearly always fallow are a common feature.

If dry farming offers little chance of success, grazing on the other hand is widely practised in the plateau areas, and large, nomad-owned herds are a familiar sight.

III Dry farming

This type of land-use prevails in the north-eastern corner of the basalt plateau. The presence of public wells, exceptionally low surface stoniness and some extra run-off water from the adjacent limestone hills are the main factors which may have encouraged farming in this area. Winter cereals chiefly wheat and barley are grown in small plots generally confined to the valleys. At the time of the survey (June - July, 1964) most of the plots were fallowed and intensively grazed.

IV Irrigated farming

a. Semi-irrigation

This type of farming based on winter flood irrigation is found in the broader middle parts of the Dhuleil valley. The wheat crop is irrigated from the river, which is checked by a stone dam. Low bunds surround the fields to be watered, and a spillway is provided to let off excess water. The system only works in years of sufficient river charge and is confined to the very lowest part of the valley-floor.

b. Irrigation from wells

At present pumped well irrigation is practised only on a few relatively small farms, where groundwater of satisfactory quality and quantity has been found. All these farms have been established recently and they do not appear on the aerial photographs. Their approximate location is shown on the map.

Two of the oldest irrigated farms, (Miss Coate's farm and Muasher's farm) are situated in valleys infilled with colluvial limestone gravel, a third one (Abu Machli's farm) occupies a similar position but is now being extended uphill towards the adjacent plateau area.

Two other small farms have been established on gently sloping terraces in the western part of the wadi Dhuleil.

The irrigated land consists of either more or less square plots (2.5 x 2.5 metres) surrounded by low bunds or elongated beds (100 x 30 cms) separated by shallow furrows. The main crops grown are summer and winter vegetables such as cabbage, cucumbers, marrows, pepper, tomatoes and there are also small orchards of citrus trees, olives and apricots.

A very common soil feature which seems to develop as a result of irrigation is a surface crust. It has a thickness of one to two centimetres, slightly hard consistence and massive or thin platy structure which cracks on drying. The crust can easily be broken by hoeing which is done periodically in order to improve the infiltration rate.

The following data supplied by a landowner show how the penetration of water is affected by the formation of the crust in the absence of surface hoeing; after the first watering water disappears from the surface in two to three hours, after the second water remains on the surface for about eight hours, after the third watering a total infiltration takes one to two days.

At Miss Coate's farm irrigation water is supplied by a pump with a reported capacity of 125-140 cubic metres per hour.

Irrigation water is normally applied to units of 75 donums at five day intervals for ten to twelve hours at a time. In the driest months pumping is continued for 24 instead of 12 hours. With these figures, it is obvious that irrigation applications are exceedingly light.

Beside channel irrigation described above, sprinklers have recently been introduced on one farm.

3. SURVEY METHODS

3.1 Aerial Photo-interpretation

The investigations began by a preliminary analysis of 88 vertical photographs at an average scale of 1:25,000 covering the whole area. At this stage two major groups of land types have been recognized, Group A with a more or less continuous soil cover and Group B - "miscellaneous land types" represented by bare rocky hills and highly dissected surfaces. In the project area of 29,894 hectares Group B lands, as delineated on the aerial photographs and shown on the map, comprise 14,451 hectares. These lands have been excluded from further investigations as unsuitable for any agricultural development. The remaining area (Group A) comprising 15,443 hectares has been surveyed in the field. The soil and land classes described in this report refer to this area only.

Within Group A more detailed sub-divisions were made between land types and these together with the appropriate map sheets were used for the planning and execution of field work.

As the aerial photographs were taken in the early fifties more recent terrain features are absent. These include the oil tap line road, the irrigated farms, certain nomadic land-use patterns and the most recent meanders of the major river courses.

3.2 Soil Survey Procedure

The field work was carried out in the period between May 23rd and July 8th. Three days were spent in locating the position of the oil tap line road and the plotting of the kilometre posts along the main Zurqa - Mafraq road. Both these roads were used as base lines for the traverses through the plateau area.

In areas of sufficient extent such as the basalt plateau, observations were made at intervals of one kilometre. Elsewhere the observations were distributed according to the photo-interpretation boundaries. With the exception of the very uniform and generally featureless basalt plateau area where traverses had to be followed, navigation was generally not difficult and the observation sites were plotted with an accuracy certainly not lower than that of the base maps.

Routine auger holes were made with a 10 cm. Jarret auger to the depth of 200 cm. and sampled from 50 cm. sections. However, owing to the presence of subsurface stones and boulders, this depth could not always be reached. Soil profile pits to the depth of 125 cm. were dug in all the major soil mapping units. The pits were sampled according to their distinguishable horizons. In all 18 profile pits and 138 routine auger holes were described and sampled giving an overall observation density of one site per square kilometre.

3.3 Chemical Analyses of Soils

All chemical analyses have been done in the Government Laboratory in Amman under the supervision of the Government Chemist and the methods employed were those of the U.S. Department of Agriculture, Handbook 60.

The following routine determinations have been made on 306 samples taken from 112 auger holes:-

- pH on paste, saturation extract and 1:5 suspension
- Electrical conductivity of the saturation extract
- Saturation percentage
- Calcium carbonate percentage on two thirds of the samples

In addition the following determinations have been made on 30 samples from 9 representative profile pits:-

- Mechanical Analysis
- Phosphorus as P_2O_5
- Nitrogen
- Organic carbon
- Total gypsum
- Soluble calcium, magnesium, sodium
- Soluble chloride, carbonate and bicarbonate
- Exchangeable sodium percentage calculated from Sodium Adsorption Ratio

Routine and detailed analyses are shown in Appendices I and II.

3.4 Map Compilation

In the final stage individual soil observations have been grouped into mapping units as shown on the combined soil and land class map. In separating the mapping units considerable use was made of the photo-interpretation boundaries as in general there was a good correlation between the physiographic units distinguished by photo-interpretation and the major soil mapping units as recognized in the field. Wherever there was any doubt about the position of a soil boundary, it is shown as a dotted line.

Attention is drawn to the fact that a number of smaller mapping units were identified by photo-deduction rather than by direct field observation. In view of the limited time available such a procedure is justified especially when the whole survey was in the nature of a reconnaissance as defined in the U.S. Bureau of Reclamation Manual, Volume V Part 2.

The final results have been presented on the combined soil and land classification map on which the boundaries of land classes coincide with soil boundaries of some kind. The main criteria used in establishing the major mapping units are the type of parent material with its associated topography and the type of soil profile. Specific morphological differences in otherwise similar profiles are expressed in soil phases. Major soil mapping units sub-divided into phases may correspond to more than one land class. This is because pedologically similar soils may vary in such limitations as depth to hard rock, stoniness, degree of erosion etc. recognised at a phase level but specifically associated with the purpose of land classification.

4. SOIL AND LAND CLASSIFICATION

4.1 Parent Material and Physiography in Relation to Soils

Four main types of soil parent material have been recognised in the project area. Each of these types gives rise to a group of soils associated with a distinct topography.

I Recent alluvium

This consists of thick (10 metres or more) and homogeneous deposits of silt loams and loams with thin gravelly layers at depths of more than 5 metres. These deposits occur mainly in the Wadi Dhuleil particularly in rather broad spreads along its eastern course and in the lower part of the Wadi Ajib. Very narrow patches of recent alluvium were also found in small natural drainage ways of the basalt plateau and in colluvial limestone valleys but they have proved far too small to be delineated separately on the map except for Association A1.2.

The soils derived from the alluvial deposits form group A1 on the Map. They are characterised by generally medium textures, great depths, high content of calcium carbonate and very weak horizon development.

In some parts of the wadis seasonal flood erosion has produced frequent deep gullies leaving very little usable land. Such areas have been classified as "miscellaneous land types" (B2 on the Map) and excluded from further investigations.

II Colluvial deposits of the limestone valleys

These deposits consisting of limestone gravel with varying proportions of fine textured materials are found in most of the valleys in the limestone areas. The valley bottoms are often dissected by shallow natural drainage channels which are filled with water during the rainy season only.

The soils derived from these deposits are represented by group A2 on the Map. They are gravelly loams to clay loams with calcareous horizons (caliche) in a varying degree of cementation. The presence of gravel, effect of erosion and dissection on the soil surface is expressed in phases as indicated on the Map.

In the valleys adjacent to the basalt area and in a strip of land roughly coinciding with the plateau gravel on the geological map the soils often contain a proportion of basalt gravel. To avoid an unduly expanded legend these soils have been classified as gravelly phases of group A2.

III The basalt plateau

Soil parent materials derived from the weathering products of basalt consist of brown silty loams to clay loams with varying amounts of basalt fragments and calcium carbonate concretions. They give rise to soils represented by group A3 on the Map. The development of a soil profile and the depth of the soil to the underlying solid rock is controlled by relief. Relatively deep soils are found in practically level central parts of the plateau. Where the plateau has been dissected by drainage channels with the resulting development of gentle undulations, the associated soils are shallow and contain abundant fragments and boulders of basalt and, in some cases, limestone. These soils are classified as lithosols represented by unit A3.1 on the Map.

In the vicinity of more deeply incised valleys erosion has removed all the soil cover exposing rock boulders or solid bedrock to the surface. Such areas have been classified as "miscellaneous land types" B1 on the Map.

Somewhat different conditions exist in the eastern part of the plateau where the topography gradually changes from level to gently undulating and finally turns into an intricate pattern of low stony, mound-like swells separated from each other by more level tracks of deeper soil. This area has been mapped as Association 3.3.

IV The limestone region

Practically all the profiles in the limestone hills with their sloping topography are very shallow and very gravelly. Together with the rougher margins of the basalt plateau they have been classed as miscellaneous land type B1. For the same reason, low, isolated outcrops of limestone and basalt have been included in this unit as well. An exception was made for two gently undulating limestone areas, nearly level with, and gradually merging into the adjoining basalt-plateau.

In both these areas represented by soil mapping unit A4.1 in the north-eastern corner of the surveyed region, soils of sufficient thickness were found to justify their inclusion in Group A. On the aerial photographs the two A4.1 areas are clearly distinguishable from both the adjacent limestone hills to the south and the basalt plateau to the north.

The parent-material of A4.1 soils is the Belqa-formation which consists of chalks, chalky limestones and marls as described in chapter 2 of the Preliminary Report on the Hydrogeological Investigations, Hunting Technical Services Ltd., August, 1964.

4.2 Soils and Land Classification Criteria

The criteria used in this report are based on those outlined in the U.S. Department of the Interior, Bureau of Reclamation Manual, Vol. V. Part 2. and the U.S.D.A. Soil Survey Manual. Some of these criteria have been modified according to the local conditions.

I Internal features

In the field the following features of the soil profile were studied.

a. Texture and gravel content of the first metre.
b. Nature and degree of profile development.
c. Parent material.
d. Effective depth which is the depth from the surface to a limiting layer, or to a layer preventing further penetration by the auger. Three kinds of limiting layers have been found in the survey-area:

Gravel-layers, with gravel content of 75 per cent or more they occur frequently in soil unit A2.1

Hard rock (basalt, limestone) occurring in A3 soils.

Strongly cemented caliches* occurring in soil units A2.1 and A3.2. Auger sites in which the caliche has been recorded are marked with letter H on the Map.

* layers of secondary calcareous material in a variable degree of cementation.

e. Internal drainage. This is a qualitative assessment based on texture, structure, consistency and depth to a limiting layer.

The depths of occurrence of hard rock and gravel layers in the soil profiles and the corresponding land classes are indicated below:-

Landclass	: 1	2S	3S	6S
Depth to gravel layers in cm:	90 or more	60-90	45-60	less than 45
Depth to hard rock in cm	: 135 " "	105-135	90-105	less than 90

II External features

a. Slope class and other topographic features. Nearly all observations are within slope class A of the Soil Survey Manual (lower limit of slope 0 per cent, upper limit of slope 1 to 3 per cent). Topographic features of any kind are either an inherent characteristic of the soil unit (e.g. A3.1, A3.3, A4.1) or expressed as phase "u" as shown on the Map.

b. Erosion As with topography, erosion is either a general feature of a specific mapping unit or it is indicated by the addition of phase signs "f" and "r".

c. Surface stoniness Again a certain degree of stoniness may be inherent to a particular soil type, but soils with abundant stones are separated as phase b. The groups of stoniness are defined as follows:-

Group 0 : No or very few stones on surface.

" 1 : Stones with diameters between 30 and 60 cm are 9 to 30 metres apart.

" 2 : Stones with diameters between 30 and 60 cm are 1.5 to 9 metres apart.

" 3 : Stones with diameters between 30 and 60 cm are 0.75 to 1.5 metres apart.

" 4 : Stones with diameters between 30 and 60 cm are less than 0.75 metre apart; group 4 stoniness is always associated with shallow soil profiles.

" 5 : Land is essentially paved with stones and often falls into a miscellaneous land type.

In the table below permissible ranges of stoniness are shown for each land class.

Stoniness groups	Land class
0 - 2	1
3	2 t
4 & 5	6 t

The relatively high degrees of stoniness adopted for land classes 2 and 3 are justified by the fact that the cultivators have accepted boulder clearance as a normal agricultural practice.

d) Flooding This phenomenon is associated with rill and lateral erosion and is therefore indicated in the appropriate erosion phases r and f.

e) Present Land-Use Present farming practices and their effect on the soil have been taken into account in the assessment of the potential land-use.

III Chemical characteristics

a) Salinity The E.C. figures show considerable variations in individual profiles and are often more than 8 mmhos/cm. However, in permeable soils under irrigation the E.C. values seem to decrease considerably. This is shown in a table below where the salinity of irrigated soils is compared with that of non irrigated soils. The irrigated group consists of both semi-irrigated and pump irrigated soils of mapping units A1.1 and A1.1f and the non irrigated group is represented by A3.2 soils. In addition to the average figures for 0-50 cm. and 50-100 cm. layers the E.C. values are split into five ranges and their relative frequencies for each layer are recorded as percentages.

	Layers in cm.	No. of samples	Average E.C. in mmhos/cm	Percentage distribution in E.C. ranges in mmhos/cm.				
				0-4	4-8	8-16	16-20	20-25
rrigated soils	0-50	20	5.61	55	15	25	5	-
	50-100	14	8.09	50	14	14	17	8
on irrigated soils	0-50	23	10.90	30.4	4.3	34.8	26.2	4.3
	50-100	20	13.72	5	-	60	30	5

These observations have led to the conclusion that soluble salts are fairly mobile under irrigation as long as free leaching is possible. Therefore due attention has been paid to conditions of natural internal drainage in the land classification and relatively high salinities have been accepted for arable land with free draining soils.

The salinity ranges and corresponding land classes are shown below:-

Average EC - value of first 100 cm in mmhos/cm.	Landclass
0 - 8	1 or 2
8 - 15	2, 3 or 5 depending on drainability
over 15	6

b) pH The pH values of soil paste range from 7.0 to 8.7. They show no definite trends and remain more or less constant throughout the profile. On the other hand an increase from pH paste to pH of 1:5 dilution is found in most profiles. Often this increase approaches one unit which under certain conditions indicates a relatively high exchangeable sodium percentage. However, in the high calcareous soils of the project area this difference between the two pH values may not necessarily be a reliable criterion in assessing soil alkalinity.

c) Free clacium carbonate The percentages of free $Ca\ Co_3$ are high and range from 20 to 65 per cent. Commonly there is a noticeable increase with depth often associated with the presence of caliches. A fall in free carbonate sometimes occurs in profiles which have a gypsum horizon below the caliche.

d) Soluble cations and anions Sodium is the dominant ion in most of the samples analysed, followed by calcium and then magnesium which normally occurs in the lowest quantity though in some horizons it is higher than calcium. Among the anions chloride usually occurs in considerably higher concentrations than bicarbonate whilst carbonate is virtually absent. It would appear therefore that sodium chloride and sodium bicarbonate are the major components of the soluble salts.

e) Exchangeable Sodium Percentages (E.S.P.) These have been calculated from sodium adsorption ratios which in turn are derived from soluble cation concentrations.

The E.S.P's show considerable variations in the individual horizons of all the profiles analysed but there is a general tendency to increase with depth.

Soils of the recent alluvium (mapping unit A1) are least alkaline with E.S.P's well below 5 in the upper horizons. Soils developed from colluvial limestone gravel (mapping unit A2) display relatively higher E.S.P's in the top horizons but the average figure is 11.7 which is well below the upper limit of 15 allowed for arable land in the U.S. Bureau of Reclamation Manual. In A3 soils the average E.S.P. of the top horizon is 10.1 but there is a very large increase down the profile with E.S.P. of the lower horizons exceeding 30.

The above figures and trends based on only 9 representative profiles (See Appendix II) are not sufficient to draw definite conclusions but they indicate that as far as land classification is concerned, E.S.P. is not likely to be a major limiting factor in A1 and A2 soils. However, very high E.S.P. in the lower horizons of some A3 soils may present a serious problem in the development of irrigated farming.

f) Organic carbon, phosphorus and nitrogen The figures obtained from 9 representative profiles indicate a relatively low content of humus and a deficiency in nitrogen and phosphorus which is likely to arise as a result of more intensive cropping.

4.3 The System of Soil and Land Classification

4.31 Soils

The approach to the classification of soils has already been discussed in Section 4.1. Four main groups of soils each developed from different parent material, have been recognised:-

A1 Soils of the recent alluvium.

A2 Soils of colluvial limestone gravel.

A3 Soils of basalt.

A4 Soils of limestone.

Each of these groups contains a number of soil series comprising soils with similar profile morphology. Some of the soil series are sub-divided into phases indicating topographical and morphological features of particular importance to agriculture.

The remaining mapping units are associations of soil series occurring in an intricate geographical pattern.

4.32 Land classes

Brief descriptions of the land classes as defined in Vol. V of the U.S. Bureau of Reclamation Manual,are given below.

Class 1 - Arable: Lands that are highly suitable for irrigation farming being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops. Both soil and topographic conditions are such that no specific farm drainage requirements are anticipated. These lands can be developed at a relatively low cost and they have potentially a relatively high payment capacity. None of the mapping units in the project area meets such high requirements. The nearest to Class 1 are deep, alluvial A1 soils but they have been downgraded to Class 2 on account of their inherently low nutrient status and occasional occurrence of horizons with hard consistence.

Class 2 - Arable: This class comprises lands of moderate suitability for irrigation farming being measurably lower than Class 1 in productive capacity, adapted to somewhat narrower range of crops. Morphological or topographical or chemical limitations render these lands more expensive to develop and generally reduce their payment capacity in comparison with Class 1 lands. Nevertheless these lands are capable of producing economic returns under good management. A total of 4,778 hectares of Class 2 land has been mapped in the project area.

Class 3 - Arable: Lands that are suitable for irrigation development but are approaching marginalty for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic or drainage characteristics. Generally greater risk and higher costs may be involved in farming Class 3 lands than the better

classes of land but under proper management they are expected to have adequate payment capacity. A total of 1,173 hectares of Class 3 land has been mapped in the project area.

Class 4 - Limited Arable or Special Use: Lands are included in this class only after special economic and engineering studies have shown them to be arable or suitable for other purpose. None of the mapping units in the project area corresponds to this class.

Class 5 - Non Arable: Lands in this class are non-arable under existing conditions but have potential value sufficient to warrant tentative segregation for special study. In the project area A3.2 soils derived from basalt have been put in this class. These soils are more saline and more alkaline than any other soils in the area and are often underlain by impermeable rock strata at relatively shallow depths. With these serious limitations an expensive drainage system would be required if the whole area was to be developed for irrigation farming and in such a case these soils would fall into land Class 6. However, it is thought that the drainage requirements may be reduced substantially if the agricultural development was restricted to relatively small and disconnected blocks of land allowing enough space for lateral leaching and to prevent the rise of the water table. This type of development will depend on the availability of water from local wells and on economic considerations.

In view of these problems it is recommended that a small irrigated pilot farm should be established in order to test the response of A3.2 soils to irrigation and cropping.

Class 5 land as mapped in the present survey is 3,538 hectares in extent. A final assessment of this land would result in the separation of Class 6 land from the arable classes suitable for irrigation in small blocks. This could only be done by means of a more detailed survey a procedure which cannot be recommended before some experimental data are obtained from the proposed pilot farm.

Class 6 - Non Arable: Lands in this class are completely unsuitable for irrigation farming. They contain shallow, gravelly or stony severely eroded soils occurring on relatively steep hills or on rough, broken and highly dissected ground. A total area of 5954 hectares has been mapped in this class.

5. DETAILED DESCRIPTIONS OF MAPPING UNITS - SOILS AND LAND CLASSES

A1 : SOILS OF THE RECENT ALLUVIUM

A1.1 : Alluvial soils on silt loam to loam

General features: Deep homogeneous soils in general without any visible profile development. Like all other mapping units in the surveyed region A1.1 soils are highly calcareous, caliche formation however, is either very weakly expressed or occurs only below a depth of at least 125 cm. The soils vary in texture from silty clay loam to silt loam or loam with a general tendency towards coarser texture with depth. As with the other soils in the investigated area the A1.1 profiles have a slightly hard platy or sometimes massive surface crust, ranging in thickness from 1 mm to 1 cm. Generally, this crust is thickest in irrigated soils and thinnest in the non-irrigated ones.

In several profiles a slight increase in hardness occurred at about 75 cm. In striking contrast to the other soil types of the area a few A1.1 profiles were slightly moist from 60 cm downwards. Like everywhere else in the area, no humus-formation was visible in the top-soil.

Description of a typical profile

Location	:	Observation No. 60 (pit)
0-0.3 cm	:	dry, yellowish red (7.5 YR 6/6), slightly hard, thin platy silt loam; abrupt, smooth boundary.
0.3-24 cm	:	dry, yellowish red (7.5 YR 6/6), slightly hard, coarse subangular blocky silt loam; plentiful in roots; gradual, smooth boundary.
24-80 cm	:	dry, strong brown (7.5 YR 5/6), slightly hard, medium angular blocky silt loam; few roots; diffuse boundary.
80-170 cm	:	dry, strong brown (7.5 YR 5/6), mainly hard and massive silt loam; very few roots.

Topography: Slope Class A.

Erosion: Slight rill-erosion and some lateral erosion in Phase f.

Stoniness: Ranging between groups 0 to 2.

Present land use: Dry farming is practised in the A1.1 and A1.1 f areas. Fields under semi-irrigation are mainly found in the direct proximity of the Dhuleil Wadi and its small affluents.

Internal drainage: The A1.1 soils seem easily drainable due to the great average soil depth, the proximity of water courses and particularly the favourable texture.

Chemical status: The average EC of the A1.1 and A1.1 f soils is 6.09 mmhos/cm for the layer 0-50 cm. (16 samples) and 11.24 mmhos/cm. for the layer 50-100 cm. (13 samples). The exchangeable sodium percentage as determined in observation No. 60(see Appendix II) is the lowest recorded in the project area i.e. well below 10 to the depth of 120 cm.

Phases: Mapping unit A1.1 occupies the flood plain of the eastern Wadi Dhuleil. Wherever the river has developed a valley floor, the soils are subject to some flooding and a limited degree of lateral erosion due to meandering, which is expressed in Phase f.

Land classification of A1.1: The EC figures, although favourable in comparison with most of the other mapping units, and the occasional occurrence of horizons with hard consistence restrict this unit to land class 2s (s = limitation of soil). Total area of this unit is 559 hectares.

Land classification of A1.1 f: Apart from the conditions mentioned under A1.1 the following features are to be taken into account:-

a) Flooding, which seems to occur periodically in the valleys of Wadi Dhuleil and Wadi Ajib. Information on this matter is scarce and contradictory.

b) Lateral erosion due to meandering. Valley parts seriously damaged by meandering are already excluded from the soil-area as a miscellaneous land type.

Both lateral erosion and flooding in A1.1 f soils are indicated by a symbol t (topography) and this limitation is added to the land class symbol. Therefore A1.1 f soils correspond to land class 2st. Total area of this unit is 670 hectares.

A1.2: Association of alluvial soils on gravelly silt loam + soils with caliche development on gravelly silt loam(colluvial basalt gravel).

General features: The association is found in a major natural drainage channel of the basalt-plateau. The first component of the association (the alluvial soil) occupies the bottom and the second one (the soil with caliche development), the gently sloping upper part of the shallow valley. Individually the two components are too small to be shown separately on the map. The two components differ in soil development, but have in common a gravelly silt loam texture and gravel layers in the deeper subsoil (deeper than 90 cm).

Description of a typical profile:

First component: alluvial soil

Location : Observation No. 128 (borehole).

0-20 cm : dry, light yellowish brown (10 YR 6/4), slightly hard, angular blocky silt loam; ploughed topsoil.

20-85 cm : very slightly moist, strong brown (7.5 YR 5/6), friable to firm silt loam; from 60 cm about 15 per cent gravel (up to 5cm flint and limestone).

85-130 cm : dry, strong brown (7.5 YR 5/6), mainly loose silt loam; gravel as in previous layer; few white calcareous mottles; gravel content increases with depth.

130 cm + : impenetrable because of gravel.

Second component: soil with caliche development

Location : Observation No. 22 (borehole)

0-0.3 cm : Surface-crust; dry, light yellowish

brown (10 YR 6/4), slightly hard, thin platy silt loam.

0.3-15 cm : dry, reddish yellow (7.5 YR 6/6) slightly hard, angular blocky silt loam to loam, about 30 per cent gravel (up to 3 cm).

15-50 cm : dry, strong brown (7.5 YR 5/6), slightly hard, fine granular silt loam to loam; gravel as in previous layer; some white, calcareous mottles and streaks.

50-90 cm : Caliche; dry, pink (7.5 YR 7/4), slightly hard, fine granular silt loam to loam; about 30 per cent gravel (up to 5 cm. all with white coatings); many white (10 YR 8/2), soft calcareous mottles.

90-140 cm : Possible zone of weathering of basalt gravel; dry, light brownish grey (2.5 YR 6/2), slightly hard, fine granular silt loam to loam; about 30 per cent basalt gravel; gravel content increases rapidly downwards.

140 + cm : gravel layer.

Topography: Slope class A; bottom part of the channel is about 2.5m, below the plateau-level.

Stoniness: Variable as the valley has been partially cleared of boulders by man; average stoniness group 3.

Present land use: Dry farming

Internal drainage: Free

Chemical status: The average EC of A1.2 soils is 6.80 mmhos/cm for the top 0-50 cm layer (4 samples) and 6.27 mmhos/cm. for the 50-100 cm. layers (4 samples). The overall average for the top metre is 6.54 mmhos and there is no limitation as far as the salinity status is concerned. Similarly E.S.P. is not likely to be a limiting factor.

Land classification of A1.2: The average stoniness group 3 restricts these soils to land class 2t (t = limitation of topography).
The total area of this unit is 256 hectares.

A2 = SOILS ON COLLUVIAL LIMESTONE GRAVEL

A2.1 = Soils with caliche-development on gravelly silt loam to gravelly silty clay loam.

General features: Mapping unit A2.1 occurs in the cultivated valleys and bottom lands in and around the limestone area. Morphologically identical soils of a few alluvial fans and terraces of the Dhuleil valley have been included in this unit. At varying depths layers of coarse limestone gravel underly the soils which have a gravelly silt loam or gravelly silty clay-loam texture. In some profiles gravel is present in smaller quantities. Two areas with general high gravel content (more than 40 per cent of volume) were separated as a very gravelly phase. The depth to the gravel layer, - variable though it is, - is practically never less than 60 cm. The profiles show a clearly expressed caliche from roughly 55 cm downwards. In profile pits, white calcareous mottling is already visible from about 30 cm and gradually changes into a real caliche between 50 and 60 cm.

The normal caliche consists of an intricate pattern of white, mainly soft, calcareous mottles (up to 2 cm diameter), regularly distributed in a matrix of yellowish brown soil material. These white mottles may occupy up to 50 or 60 per cent of the caliche horizon.

As a whole the caliche horizon is weakly cemented and contains very few living roots although a few channels of older and bigger roots are usually found. Boring through the caliche needs a slightly increased pressure but almost never seriously hampers penetration of the auger. An angular blocky structure is present in moderately developed caliche horizons but with an increasing degree of cementation the layer becomes massive.

Compared with those of the basalt soils, the caliches of mapping unit A2. 1 have a greater variation both in the degree of development and thickness. It is assumed that normally developed caliche horizons as they occur in the area do not constitute a limitation of drainage. The same does not apply to profiles with strongly cemented caliches, but these are comparatively rare. Their occurrence in the soil observation sites is indicated by letter H on the map.

Although caliches of this kind never reach a state of cementation that could be properly called "indurated", their consistence comes at least close to what is defined as "strongly cemented" in the Soil Survey Manual. In colour and general appearance they sometimes resemble soft chalks. From the soil map it can be seen that they occur chiefly in the narrow valleys of the limestone area. For the sake of complete information, the description of a profile with strongly cemented caliche is given below. It is to be emphasized however, that this kind of profile is an exception rather than a common element of mapping unit A2. 1.

As has been reported previously, patches of alluvial soil do occur in the limestone valley but are too small to be mapped separately. In some of the larger cultivated valleys which are likely to receive a relatively high amount of extra water from run-off, a relatively thick (up to 1 cm) and massive surface crust is sometimes found.

Description of a typical profile:

1 Profile with normal caliche development on pump-irrigated land.

Location : Observation No. 55 (pit)

20-0 cm : Man built, bund. dry, reddish yellow (7.5 YR 6/6) slightly hard, moderate fine angular blocky silt loam; moderate number of fine roots; gradual smooth boundary.

0-52 : Moist, strong brown (7.5 YR 5/6), friable moderate fine angular blocky, silty clay loam; few white calcareous mottles; plentiful roots; clear, wavy boundary.

52-110 : Caliche. Slightly moist, weakly cemented, strong medium angular blocky, silty clay loam with mixed brown (7.5 YR 4/4) and pinkish white (7.5 YR 8/2) colours; about 10 per cent gravel; very few roots; clear smooth boundary.

110-135 + : Gravel layer. Slightly moist, reddish yellow (7.5 YR 6/6), friable silt loam; about 90 per cent of limestone gravel.

2. Profile with strongly cemented caliche.

Location : Observation No. 142 (borehole)

0-0.4 cm : Surface crust; dry, light yellowish brown (10 YR6/4) slightly hard, thin platy silt loam.

0.4-25 : Dry, light yellowish brown (10 YR 6/4), slightly hard, subangular blocky silt loam; in the first 4 cm plentiful roots.

25-60 : Dry, strong brown (7.5 YR 5/6), slightly hard to hard, angular blocky silt loam; about 25 per cent of flint and limestone gravel.

60-85 : Caliche. Dry, light yellowish brown (10 YR 6/4) weakly cemented, fine granular silt loam; common number of white, slightly hard concretions; gravel as in the previous layer.

85-110 : Strongly cemented caliche. Dry, very pale brown (10 YR 8/3), mainly strongly cemented aggregates (up to 2.5 cm) with silt loam texture; about 15 per cent of gravel.

110 + : Impenetrable because of abundant gravel.

Topography: Slope class A, except for Phase u (See below).

Erosion: Slight rill erosion is wide-spread. Increased rill erosion in Phase r. (see below).

Stoniness: Nearly always less than group 2. Increased degree of stoniness in narrow strips along hillsides and in narrow valleys.

Limiting layers: Gravel layers and occasionally a strongly cemented caliche.

Present land use: Dry farming and farms under pump irrigation.

Internal drainage: Free or slightly impeded in profiles with silty clay loam texture.

Chemical Status: The average EC is 10.42 mmhos/cm for the 0-50 cm layer (39 samples) and 11.2 mmhos/cm for the layer 50-100 cm (32 samples). The overall average is 10.9 mmhos/cm for the top metre. The average E.S.P. of the top horizon is 11.7.

Phases: gr = Very gravelly phase with 40-75 per cent gravel.

r = Phase with increased rill erosion and occasional flooding. Although well developed erosion channels, (about 7.5 cm deep over a distance of 1 to 2 metres) do occur in this phase, it is believed that they can be obliterated by tilling.

u = Phase dissected by natural drainage ways and/or gently undulating or gently sloping topography; with maximal height differences of approximately 12.5m.

Land classification of A2.1: Because of gravel layers between 60 and 90 cm this soil type comes into class 2s.
Total area of this unit is 2.613 hectares.

Land classification of A2.1 gr: The very gravelly phase is thought to constitute a soil limitation of sufficient weight to down-grade this mapping unit into class 3s.
Total area of this unit is 701 hectares.

Land classification of A2.1 r and A2.1 u : Limitations of topography restrict these phases into class 2 st.

The total areas are 381 hectares for A2.1 r and 299 hectares for A2.1 u.

A2.2 Association of A2.1 and lithosols in very gravelly silty clay loams (chalks and limestones)

General features: In the A2.2 area very subdued and inconspicuous out-crops of chalks and limestones are surrounded by deposits of colluvial limestone gravel. The soil that has formed in this material is shallow and very gravelly. Profile development, if any, is obscured by the large quantity of gravel. Only a description of the second component, the lithosol, will be given as the first one has been treated fully under the previous mapping-unit.

Description of a typical profile

Location : Observation No. 68 (pit)

0-38 cm : Dry, reddish yellow (7.5 6/6), slightly hard, moderate medium angular blocky silty clay loam with about 15 per cent gravel (up to 2 cm); first 4 cm plentiful roots; gradual, smooth boundary.

38-63 : Dry, reddish yellow (7.5 YR 6/6) slightly hard, moderate medium angular blocky clay-loam; about 60 per cent gravel (up to 2 cm. all with white, calcareous coating); few roots; gradual, smooth boundary.

63 + : Limestone bed.

Topography: Slope class A.

Erosion: Slight rill erosion.

Stoniness: Average group 1.

Limiting layers: The lithosol has hard rock within 90 cm. and constitutes approximately 40 per cent of A2.2 association.

Present land use: Dry farming.

Internal drainage: Impeded on account of the rock strata occurring within 90 cm from the surface.

Chemical status: A few EC figures available for the lithosol (See Appendix I) indicate a relatively high salt content which is a further serious limitation of this soil in view of its impeded internal drainage.

Land classification of A2.2: The second component of the association (the lithosol) falls into class 6s. Unit A2.2 as a whole, however, comprises approximately 60 per cent of land belonging to class 2s (component A2.1) and technically would become an association of land classes 2s and 6s. Such a designation seems however undesirable for practical purposes and hence it has been decided to put association A2.2 into land class 3s, this apparently being the only workable compromise. Total area of this unit is 472 hectares.

A3 = SOILS ON BASALT

A3.1 = Lithosols on gravelly silt loam and very gravelly silt loam (mainly on basalt, occasionally on other parent materials.

General features: These soils are shallow, gravelly to very gravelly and have a high degree of surface stoniness. Presumably due to their shallowness, they show little or no profile development.

Description of a typical profile:

Location: Observation No. 122 (borehole)

0-0.3 cm : Surface crust. dry, light yellowish brown (10 YR 6/4), slightly hard, thin platy silt loam.

0.3-20 : Dry, light yellowish brown (10 YR 6/4), slightly hard, angular blocky silt loam; plentiful roots in the first 4 cm.

20-43 : Dry, strong brown (7.5 YR 5/6), loose fine granular silt loam; about 40 per cent gravel (up to 3.5 cm basalt, limestone).

43+ : Impenetrable because of basalt boulders.

Topography: Slope class A, very gently undulating; maximal height differences of 12.5 m. Usually dissected by natural drainage channels.

Erosion: Slight rill erosion.

Stoniness: Average stoniness group 4.

Limiting layer: Boulders between 45 and 60 cm.

Present land use: Mainly grazing; occasionally some dry farming. On two Dhuleil terraces belonging to mapping unit A3.1, small irrigated farms have been laid out.

Internal drainage: It would appear that the basalt boulders as such do not seriously impede drainage as there exists sufficient space in between them for free downward movement of water. It is not known however at what depth the boulders merge into a continuous and completely impervious layer of basalt.

Chemical status: The average EC of A3.1 soils is 8.9 mmhos/cm for the layer 0-50 cm (16 samples). As boulders are found between 40 and 60 cm no data exist for the second layer.

Land classification of A3.1: As a lithosol mapping unit A3.1 falls into land class 6s.
Total area of this unit is 2.865 hectares.

Å3.2 = Soils with caliche-development on silty clay loam to gravelly silty clay loam

General features: Apart from Phase b (see below) A3.2 soils have an average depth of at least 90 cm. In the A3.2 area bounded by Wadi Dhuleil and Wadi es Zatari, in 16 out of 20 observations a depth of more than 105 cm was found. Gravelly and non-gravelly profiles are found in roughly equal numbers. Caliche development shows little variation throughout the whole of the A3.2 area and is normally observed in boreholes from an average depth of 60 cm downwards.

The mechanical analysis of 19 samples shows that the texture of these soils varies from silt loam to silty clay loam or clay loam. As a rule the first 20 cm of the profile have a silt loam texture but silty clay loam prevails at depth.

A few A3.2 profiles have a strongly cemented caliche and are indicated on the soil map with the special sign H. This feature has been discussed already in connection with A2.1 soils. Occasionally weakly cemented clusters of shiny salt crystals were found in a layer below the caliche. These crystals are assumed to be gypsum. The gypsum horizon, if present, usually begins from 125 cm and may extend downwards to a depth of 2 metres.

In most cases gravel of the plateau soils is not composed of basalt, but of secondary limestone. Inclusions of weathered basalt were frequently found inside these red, (2.5 YR 5/6) limestone nodules.

Description of a typical profile

Location : Observation No. 34 (pit)

0-0.3 cm : Surface crust, dry, light yellowish brown (10 YR 6/4), slightly hard, thin platy silt loam; abrupt, smooth boundary.

0.3-15 : Dry, reddish yellow (7.5 YR 6/6), slightly hard, strong fine angular blocky silt loam; first 10 cm plentiful in roots; gradual, smooth boundary.

15-48 : Dry, strong brown (7.5 YR 5/6), slightly hard, moderate fine angular blocky silty clay loam; 25 per cent gravel; moderate number of soft and weakly cemented white calcareous concretions (up to 5 mm); very few roots; gradual, wavy boundary.

48-100 : Caliche: dry, weakly cemented, moderate fine angular blocky silty clay-loam with mixed brown (7.5 YR 4/4) and white (2.5 YR 8/2) colours; about 15 per cent gravel gradual, wavy boundary.

100-135 + : Zone of weathering rock. Disintegrated particles of bluish black basalt.

Topography: Slope class A.

Erosion: Slight sheet erosion.

Stoniness: Stoniness of this unit is variable and ranges from group 1 to 3. Wherever a higher average degree of stoniness prevailed, a bouldery phase has been introduced (phase b). This bouldery phase is associated with a decreased average depth of the soil (between 60 and 90 cm). Apart from the extreme cases, it seems difficult to establish any definite relationship between surface stoniness and the amount of boulders in the soil. Sometimes, underneath a surface with stoniness of group 3 or 4 a deep profile with relatively few boulders is found. Elsewhere, on a site nearly free of stones, the soil proves to be shallow because of the boulders it contains. Occasionally but certainly not always, this latter case is the result of human interference.

Limiting layers: Boulders or weathering rock. A strongly cemented caliche is occasionally found.

The soil depth is not uniform throughout the area. The greatest average depth was found in the A3.2 - area in the north-eastern corner of the investigated region where all observations have a depth of more than 105 cm. In the A3.2 area west of Wadi es Zatari, 80 per cent of the observations have a depth of more than 105 cm, whilst in the A3.2 area east of Wadi es Zatari, 66 per cent of the observations still have a depth between 90 and 105 cm.

Present land use: Mainly grazing. Small, scattered blocks of cultivated land (dry farming) are occasionally found. In the north-eastern corner of the area dry farming is practised on a larger scale.

Internal drainage: Somewhat impeded due to the relatively fine texture and the occurrence of rock strata at depth.

Chemical status: The average EC is 11.1 mmhos/cm for the 0-50 cm layer (38 samples) and 14.46 mmhos/cm for the layer 50-100 cm layer (34 samples). The average EC for the top metre is 12.71 mmhos/cm. The average EC of A3.2 b soils is 14.6 mmhos/cm for the 0-50 cm layer (12 samples) and 16.3 mmhos/cm for the 50-100 cm layer (8 samples). The average ECfor the top metre is 15.33 mmhos/cm just above the upper limit for land class 2. Although the average E.S.P. for the top horizon is 10.1, it increases rapidly with depth and E.S.P. of the lower horizons exceeds 30.

Phases: Phase b with stoniness in excess of group 3 and/or the average soil depth of less than 90 cm in 40 per cent or more of the area.

Land classification of A3.2: In the classification of this mapping unit the following problems have arisen. A combination of slow internal drainage with high salinities and alkalinities would render these soils very risky for a large scale development of irrigated farming.

If the plateau was to be irrigated in its entirety an expensive drainage system would have to be installed, which would downgrade these soils to land class 6. If on the other hand water supplies were available only for restricted development, natural lateral drainage may be sufficient to prevent water-logging and to effect adequate leaching. Assuming that the development will be by relatively small wells and this can be restricted to a safe extent, the selected A3.2 soils would come into class 3 s as in this case no drainage works would be required.

For these reasons A3.2 soils have been put into land class 5 pending further investigations on the water supply problems and on the agricultural and economic aspects of the suggested development. The problem of the minimum size of an economic holding is important because it is felt that although the plateau may support, by means of natural drainage, small areas of irrigation, it cannot be developed in larger units. In view of these problems it is recommended that a small irrigated pilot farm be established in the area in order to test the

response of these soils to irrigation and cropping.
The total areas of this unit is 3,538 hectares.

Land classification of A3.2b : The average salinity of more than 15 mmhos/cm., surface stoniness exceeding group 3 and the average soil depth of less than 90 cm in 40 per cent or more of the area downgrade this mapping unit to class 6s.
Total area of this unit 1.562 hectares.

A3.3 : Association of A3.1 and A3.2 soils

General features: Stony, lithosolic A3.1 soils constitute approximately 70 per cent of the area. They are surrounded by basin-like tracts of deeper A3.2 soils. Both constituents of the association have been described fully in the previous sections.

Topography: System of low, gently sloping swells separated by shallow, nearly level basins.

Erosion: Slight sheet erosion.

Stoniness: Average stoniness of component A3.1 is of group 4 to 5 and that of component A3.2 corresponds to group 3.

Limiting layers: As previously described for each component.

Present land use: Grazing on the stony swells and dry farming on the major tracts of deeper soil in between the swells.

Both the internal drainage and chemical status have been previously described for each component.

Land classification of A3.3: As roughly 70 per cent of the association consists of lithosols this mapping unit comes into class 6s.
Total area of this unit is 1,221 hectares.

A4 = SOILS ON BELQA FORMATION:

A4.1 Soils with caliche development in very gravelly silty clay loam

General features: This area in the north-eastern corner of the surveyed region, is the only part of the limestone formation with a sufficient general thickness of the solum to be included in the soil area; otherwise it is a soil with nearly as many limitations as the lithosols of mapping unit A3.1

Description of a typical profile:

Location	:	Observation No. 38 (borehole).
0-0.3 cm	:	Surface crust, dry, reddish yellow (7.5 YR 6/6). slightly hard, thin platy silt loam.
0.3-20	:	Dry, reddish yellow (7.5 YR 6/6). Slightly hard, angular blocky silty clay-loam; about 40 per cent gravel; very few roots.
20-45	:	Dry, strong brown (7.5 YR 5/8), loose, single grained silty clay-loam; gravel as in the previous layer.
45-60	:	Caliche: dry light brown (7.5 YR 6/4), weakly cemented, fine granular silty clay loam; about 50 per cent gravel.
60 +	:	Impenetrable because of underlying rock.

Topography: Slope-class A, very gently undulating; maximal height differences of 12.5 m; dissected by natural drainage ways.

Erosion: Slight sheet-erosion.

Stoniness: Average group 2.

Limiting layers: Hard rock within 60 cm.

Present land use: Mainly grazing and some dry farming.

Internal drainage: Seriously impeded by the underlying rock.

Chemical status: Only very few EC figures are available and these show a relatively high salinity particularly in the sub surface horizons.

Land classification of A4.1: A combination of high gravel content, close proximity to the underlying rock and a somewhat irregular topography downgrades this mapping unit into class 6s.
Total area of this unit is 306 hectares.

APPENDIX I

Routine Chemical Analyses

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH			EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	$CaCO_3$ %
				Paste	Extract	1:5			
S 145	P-63	25-35	Al.1	7.7	7.8	8.7	17.67	44.82	32.9
S 146		80-90		7.0	7.5	8.7	17.67	47.08	31.3
S 147		150-160		7.7	7.6	8.7	17.67	43.82	59.9
S 148	B-64	0-50	Al.1	8.0	8.0	8.7	2.05	47.10	30.9
S 149		50-100		7.6	7.4	8.3	7.77	45.81	30.3
S 150		100-150		7.7	7.5	8.4	6.17	38.30	30.9
S 151		150-200		7.7	7.8	8.5	5.13	34.64	34.3
S 152	B-65	0-50	Al.1	8.0	7.8	8.6	1.11	45.32	32.4
S 153		50-100		8.7	8.3	9.2	1.28	44.38	31.9
S 154		100-150		8.0	7.5	8.7	3.66	47.90	31.4
S 155		150-200		7.8	7.3	8.5	10.30	43.13	31.7
S 156	B-67	0-50	Al.1	7.9	7.8	8.5	1.33	46.98	23.8
S 157		50-100		8.1	8.2	8.8	0.99	49.94	29.6
S 158		100-150		8.1	7.7	9.0	1.65	53.83	25.4
S 159		150-200		7.9	7.7	8.6	5.39	58.83	27.7
S 252	B-124	0-50	Al.1	7.6	7.5	8.6	10.25	44.79	29.7
S 253		50-100		7.7	7.6	8.4	15.07	49.21	27.9
S 254		100-150		7.7	7.7	8.3	16.02	38.02	31.8
S 255		150-200		7.7	7.6	8.3	16.83	38.18	28.8
S 294	B-145	0-50	Al.1	8.1	7.5	9.3	8.43	41.32	22.7
S 295		50-100		7.9	7.4	8.6	20.24	59.82	31.1
S 296		100-150		7.8	7.2	8.4	31.63	57.48	49.2
S 297		150-200		7.7	7.3	8.3	29.80	59.49	40.7
S 298	B-145A	0-50		8.1	7.6	9.5	4.60	51.07	
S 274	B-136	0-50	Al.1f	7.7	7.7	8.2	14.88	40.77	21.5
S 275		50-100		7.9	8.0	8.7	19.46	44.55	24.5
S 276		100-150		7.9	7.8	8.6	18.07	52.08	30.0
S 277		150-200		8.0	8.1	8.5	21.08	62.81	31.8
S 129	B-56	0-50	Al.1f	7.9	8.1	8.6	1.25	36.97	22.0
S 130		50-100		8.5	8.4	9.2	1.09	48.55	21.2
S 131		100-150		8.2	8.0	9.0	2.05	75.21	44.8
S 132	B-57	0-50	Al.1f	7.6	7.2	8.5	11.17	34.13	
S 133		50-100		7.7	7.3	8.6	17.67	52.83	
S 134		100-150		7.8	7.8	8.5	21.35	50.68	
S 135		150-200		7.7	7.4	8.4	32.03	48.66	
S 136	B-59	0-50	Al.1f	8.0	7.5	8.7	2.14	46.76	39.8
S 137		50-100		8.0	7.1	8.1	2.44	58.55	36.4
S 138	P-60	0-25	Al.1f	8.0	7.6	8.7	0.88	36.39	
S 139		45-55		8.0	7.9	8.8	1.09	41.44	
S 140		105-120		7.7	7.4	8.0	7.32	46.98	
S 141	B-61	0-50	Al.1f	8.1	7.6	8.0	1.01	37.80	27.3
S 142		50-100		8.0	7.5	8.6	5.82	41.88	27.8
S 143		100-150		7.7	7.0	8.3	12.81	36.69	28.2
S 144		150-200		7.6	7.2	8.3	13.49	34.51	26.1

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH Paste	pH Extract	pH 1:5	EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	$CaCO_3$ %
S 211	B-99	0-50	A1.1f	8.0	7.3	9.0	4.26	54.32	24.2
S 212		50-100		7.8	7.2	8.0	24.70	53.07	24.8
S 213		100-150		7.8	7.2	8.2	24.44	55.80	21.0
S 214		150-200		7.7	7.6	8.2	29.06	58.94	22.4
S 226	B-110	0-50	A1.1f	8.0	7.9	8.7	12.35	43.78	
S 227		50-100		8.0	7.7	8.5	14.97	51.00	
S 228		100-150		7.9	7.4	8.3	15.97	53.17	
S 61	B-22	0-50	A1.2	7.6	7.6	8.3	20.94	43.32	
S 62		50-100		8.1	7.8	8.8	11.14	51.65	28.1
S 63		100-150		8.2	7.9	9.1	9.52	47.51	56.7
S 64	B-23	0-50	A1.2	8.1	7.9	8.6	1.87	48.00	20.4
S 65		50-100		8.2	8.1	8.7	11.01	51.75	21.6
S 66		100-150		8.1	8.2	8.8	1.59	55.57	24.50
S 67		150-200		8.0	8.0	8.8	2.01	66.42	56.9
S 258	B-128	0-50	A1.2	8.0	8.0	8.5	3.11	38.41	23.6
S 259		50-100		8.1	8.2	9.1	4.66	39.03	25.7
S 260		100-150		8.2	8.2	8.9	6.74	56.50	28.2
S 261	B-129	0-50	A1.2	8.3	8.3	9.1	1.28	42.33	21.3
S 262		50-100		8.2	8.1	9.0	8.27	61.41	49.6
S 263		100-150		8.0	8.0	8.7	11.39	64.87	53.8
S 177	B-80	0-50	A2.1	7.7	7.3	8.7	9.50	38.62	37.5
S 178	B-81	0-50	A2.1	7.9	7.3	8.8	8.82	37.86	39.6
S 179		50-100		7.8	7.6	8.5	16.46	48.36	41.6
S 180	B-82	0-50	A2.1	8.0	7.9	8.0	10.51	41.77	
S 181		50-100		7.9	7.0	8.2	16.46	50.44	
S 182	B-83	0-50	A2.1	8.0	7.0	8.7	10.97	43.33	29.1
S 183		50-100		8.1	7.2	8.8	10.29	63.19	42.3
S 184		100-150		7.8	7.1	8.2	15.93	43.64	59.1
S 185		150-200		7.8	7.1	8.1	21.47	48.38	38.5
S 186	P-84	55-65	A2.1	8.0	7.1	8.5	6.17	47.13	
S 187		115-125		7.9	7.9	8.3	26.17	46.64	
S 188	B-85	0-50	A2.1	7.7	7.7	8.3	26.00	44.59	
S 189		50-100		7.8	7.3	8.2	26.00	47.56	
S 190	B-86	0-50	A2.1	7.7	7.6	8.3	24.70	33.19	26.5
S 191		50-100		7.8	7.1	8.3	20.58	42.75	40.9
S 174	B-78	0-50	A2.1	8.0	7.8	8.6	11.76	51.97	34.6
S 175		50-100		7.9	7.6	8.5	13.42	65.16	60.9
S 299	B-150	0-50	A2.1	7.9	7.2	8.8	4.60	44.12	
S 300		50-100		7.9	7.5	8.8	11.00	56.66	
S 278	B-137	0-50	A2.1	7.8	7.7	8.6	28.11	45.26	
S 279		50-100		8.0	7.9	8.3	22.00	59.80	
S 119	B-52	0-50	A2.1	7.9	7.6	8.5	19.00	48.83	
S 120		50-100		7.7	7.6	8.3	18.30	51.42	

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH			EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	CaCO3 %
				Paste	Extract 1:5				
S 121	B-53	0-50	A2.1	7.9	8.0	8.7	1.90	39.41	39.4
S 122	B-54	0-50	A2.1	8.0	8.0	8.5	1.37	41.52	32.2
S 123		50-100		8.3	8.3	9.2	1.50	37.33	27.9
S 124		100-150		8.0	7.6	9.0	3.94	48.00	34.4
S 125	P-55	20-5	A2.1	7.5	7.3	8.2	15.53	39.83	
S 126		20-30		7.9	7.6	9.0	7.77	42.47	
S 127		70-80		8.3	7.5	9.3	3.42	57.14	
S 128		115-130		8.0	7.7	8.7	4.66	45.22	
S 239	B-118	0-50	A2.1	8.0	7.8	9.0	4.10	74.97	21.5
S 240		50-100		8.6	8.2	9.5	1.90	65.45	44.5
S 241		100-150		7.9	7.6	8.4	7.32	58.33	47.2
S 242		150-200		7.7	7.4	8.4	19.71	67.80	42.5
S 290	P-144	0-20	A2.1	7.9	7.5	8.5	2.11	39.61	
S 291		55-70		7.9	7.3	8.7	8.16	57.46	
S 292		120-130		7.9	7.3	8.9	10.77	46.28	
S 293		155-165		8.0	7.3	8.7	12.34	60.36	
S 284	B-140	0-50	A2.1	8.1	8.1	9.2	3.16	39.16	14.8
S 285		50-100		8.0	7.9	9.0	13.68	56.51	64.5
S 286		100-150		8.1	8.0	8.4	17.45	63.68	72.2
S 162	B-69	0-50	A2.1	7.9	7.5	8.3	1.46	47.23	
S 163	B-72	0-50	A2.1	8.0	7.8	8.6	1.39	40.18	
S 164		50-100		7.8	7.4	8.5	10.90	58.48	
S 165	B-73	0-50	A2.1	8.0	7.6	8.5	1.89	53.50	17.6
S 166		50-100		8.1	7.8	8.5	1.22	65.30	27.8
S 167	P-74	0-20	A2.1	8.0	7.7	8.5	2.70	39.17	
S 168		45-55		7.8	7.5	8.6	20.50	48.96	
S 169		70-80		7.9	7.6	8.5	19.71	57.45	
S 288	B-142	0-50	A2.1	7.7	7.3	8.7	7.91	45.21	
S 289		50-100		7.8	7.3	8.8	19.46	49.96	
S 264	B-131	0-50	A2.1	7.9	7.8	8.7	2.56	41.65	
S 25	B-9	0-50	A2.1	8.1	8.2	9.3	14.14	50.24	28.1
S 26		50-100		7.8	7.8	8.5	16.16	51.99	62.8
S 27		100-150		7.8	7.8	8.5	14.83	60.03	54.4
S 238	B-117	20-30	A_2.1gr	7.0	7.6	8.6	20.50	44.23	
S 194	B-89	0-50	A2.1gr	8.7	7.8	9.4	1.59	39.96	22.6
S 195		50-100		7.4	7.1	8.8	9.68	50.74	53.6
S 196		100-150		7.4	7.8	8.3	19.76	49.10	48.1
S 197	B-90	0-50	A2.1gr	7.3	7.9	8.5	41.16	40.81	
S 198		50-100		7.3	7.3	8.2	27.44	51.12	
S 199	B-91	0-50	A2.1gr	7.7	7.4	8.4	14.11	41.96	29.2
S 200		50-100		7.9	7.0	8.6	14.11	59.16	46.1
S 192	B-88	0-50	A2.1gr	8.4	7.6	9.2	3.87	39.58	
S 193	[illegible]	50-100	[illegible]	8.6	7.5	9.4	1.79	55.64	

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH Paste	pH Extract 1:5		EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	$CaCO_3$ %
S 265	B-132	0-50	A2.1gr	8.0	8.0	8.7	2.23	42.72	
S 266		50-100		8.0	8.0	7.9	7.67	61.89	
S 28	B-10	0-50	A2.1r	7.6	7.7	8.2	23.50	44.97	
S 29		50-100		7.8	7.8	8.5	15.66	52.47	
S 30		100-150		7.7	7.8	8.4	16.68	51.54	
S.31	B-11	0-50	A2.1r	7.9	8.1	8.5	2.59	42.21	
S 32		50-100		8.4	8.4	9.1	3.11	42.41	
S 33	B-12	0-50	A2.1r	7.6	7.8	8.7	18.30	44.48	31.1
S 34		50-100		7.8	7.9	8.5	16.02	56.68	26.9
S 35		100-150		7.8	7.8	8.3	14.64	57.66	66.3
S 74	B-28	0-50	A2.1r	7.8	7.9	8.7	9.35	44.27	28.9
S 75		50-100		7.8	8.0	8.5	7.93	59.90	56.2
S 76		100-150		7.8	7.9	8.3	11.38	62.24	46.9
S 23	B-8	0-50	A2.1r	7.7	7.8	8.5	9.94	46.23	
S 24		50-100		7.8	7.8	8.5	4.95	54.44	
S 250	B-123	0-50	A2.1r	8.1	8.0	8.7	1.25	39.59	
S 251		50-100		8.3	8.1	9.4	0.92	47.31	
S 170	B-75	0-50	A2.1u	7.8	7.6	8.5	0.82	38.49	24.1
S 171		50-100		7.9	8.0	8.7	1.27	52.50	34.3
S 172	B-76	0-50	A2.1u	7.7	7.9	8.5	14.53	52.82	
S 243	B-119	0-50	A2.2	7.9	7.7	8.6	22.28	45.49	48.4
S 244		50-100		7.9	7.5	8.3	22.28	57.09	44.1
S 245		100-150		7.9	7.3	8.4	28.41	56.35	43.7
S 160	P-68	15-25	A2.2	7.7	7.4	8.7	12.80	38.62	17.6
S 161		45-55		7.7	7.3	8.5	17.08	45.52	
S 246	B-120	0-50	A2.2	8.1	7.6	9.2	6.25	42.21	29.7
S 247		50-100		7.9	7.5	8.7	14.64	48.75	58.0
S 248		100-150		7.8	7.4	8.4	22.28	51.22	43.5
S 176	B-79	0-50	A3.1	7.8	7.7	8.2	3.80	43.00	
S 173	B-77	0-50	A3.1	7.9	7.9	8.7	10.74	53.10	
S 257	B-127	0-50	A3.1	7.7	7.7	8.5	21.35	49.30	
S 287	B-141	0-50	A3.1	8.1	8.1	8.8	3.89	44.35	
S 249	B-122	0-50	A3.1	7.8	7.6	8.5	11.14	44.23	
S 219	B-102	0-50	A3.1	8.0	7.2	8.7	20.58	50.67	
S 220	B-103	0-50	A3.1	7.9	7.4	8.5	16.47	56.93	
S 77	B-31	0-50	A3.1	8.1	8.0	8.4	2.09	41.52	21.7
S 84	B-35	0-50	A3.1	8.1	8.1	8.5	4.03	42.70	21.1
S 96	B-43	0-50	A3.1	8.0	8.0	8.0	6.54	71.71	12.8
S 97	P-44	0-11	A3.1	8.1	8.0	8.4	3.08	40.16	44.1
S 98	B-45	0-50	A3.1	7.5	7.6	8.0	18.70	43.75	20.3

Sample Bore	Bore No.	Depth (cms)	Soil Mapping Unit	pH			EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	CaCO3 %
				Paste	Extract 1:5				
S 72	B-26	0-50	A3.1	7.7	8.0	8.3	6.71	47.19	
S 73	B-27	0-50	A3.1	7.8	7.9	8.3	4.76	44.34	24.7
S 76A	B-29	0-50	A3.1	7.8	7.8	8.3	6.98	43.27	25.9
S 76B		50-100		7.7	7.7	8.2	11.90	63.04	36.1
S 233	B-114	0-50	A3.1	8.0	7.9	8.8	1.83	40.28	
S 301	B-151	0-50	A3.2	7.8	7.2	8.7	19.46	42.91	23.6
S 302		50-100		7.8	7.2	8.5	24.10	56.08	53.3
S 303		100-150		7.9	7.2	8.5	25.30	61.83	48.2
S 304	B-151A	0-50	A3.2	8.0	7.6	9.4	3.37	50.46	22.7
S 305		50-100		8.1	7.4	8.4	5.06	58.07	58.2
S 306		100-150		8.0	7.4	9.0	9.73	58.74	48.1
S 267	B-133	0-50	A3.2	7.8	7.9	8.5	12.65	43.70	
S 268		50-100		8.0	8.1	8.6	18.07	55.16	
S 269		100-150		8.0	8.0	8.5	16.87	60.68	
S 280	F-139	0-15	A3.2	8.1	8.0	8.8	2.98	38.37	
S 281		25-35		8.2	8.1	8.8	1.45	45.34	
S 282		70-80		7.9	7.9	8.8	17.45	49.46	
S 283		110-120		8.0	8.0	8.6	19.46	51.12	
S 270	B-135	0-50	A3.2	8.1	7.9	8.9	6.49	46.35	27.7
S 271		50-100		7.8	7.8	8.5	15.14	53.49	72.4
S 272		100-150		7.9	7.9	8.5	15.81	69.79	73.4
S 273		150-200		7.8	7.7	8.3	22.00	64.79	29.7
S 36	P.13	0-6	A3.2	8.0	8.2	8.5	1.46	38.52	
S 37		15-25		8.0	8.2	8.5	2.33	46.37	
S 38		25-45		7.7	7.8	8.4	9.49	52.79	
S 39		70-80		7.7	7.8	8.3	16.53	48.74	
S 40	B-14	0-50	A3.2	7.7	7.8	8.2	19.71	45.67	
S 41		50-100		7.8	7.8	8.3	20.50	55.17	
S 42	B-15	0-50	A3.2	8.3	8.4	8.8	1.77	43.26	17.2
S 43		50-100		8.0	8.0	8.6	8.87	56.76	34.3
S 44		100-150		7.9	7.9	8.4	8.27	61.98	56.0
S 45		150-200		7.8	7.9	8.3	18.98	66.46	38.2
S 46	B-16	0-50	A3.2	8.1	8.1	8.6	3.57	46.20	
S 47		50-100		7.9	8.0	8.6	11.75	55.40	
S 48		100-150		7.8	7.8	8.2	8.34	63.68	
S 49		150-200		7.8	7.8	8.1	9.40	63.97	
S 1	B-1	0-50	A3.2	7.7	7.8	8.5	17.10	47.92	21.5
S 2		50-100		7.9	8.0	8.6	8.40	66.09	69.1
S 3	B-2	0-50	A3.2	7.6	7.8	8.7	10.68	44.23	
S 4		50-100		7.8	7.9	8.7	10.05	59.76	
S 5	B-3	0-50	A3.2	7.8	7.9	8.8	14.24	49.73	27.1
S 6		50-100		7.8	7.9	8.5	13.14	62.76	57.9
S 7		100-150		7.7	7.8	8.3	16.02	63.19	46.3
S 8		150-200		7.8	7.9	8.3	12.81	72.19	39.4

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH			EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	CaCO3 %
				Paste	Extract 1:5				
S 9	B-4	0-50	A3.2	7.7	8.0	8.8	19.15	52.70	30.1
S 10		50-100		7.9	8.0	8.7	15.07	63.55	51.7
S 11		100-150		7.8	7.9	8.4	19.71	60.82	38.4
S 12		150-200		7.8	7.9	8.6	18.98	72.90	34.1
S 50	B-17	0-50	A3.2	7.7	7.8	8.2	17.83	48.80	21.4
S 51		50-100		7.8	7.8	8.4	18.46	57.75	59.4
S 52		100-150		7.8	7.8	8.2	14.77	61.11	60.9
S 53	B-18	0-50	A3.2	8.0	8.3	8.5	1.33	44.12	23.9
S 54		50-100		8.3	8.5	9.0	1.18	55.81	37.5
S 55		100-150		8.5	8.6	9.1	0.99	77.71	47.9
S 106	B-47A	0-50	A3.2	7.7	7.6	8.3	19.76	48.83	28.7
S 107		50-100		7.9	7.9	8.5	15.97	76.20	45.0
S 108		100-150		7.8	7.7	8.1	18.30	73.39	16.0
S 109		150-200		7.8	7.6	8.1	17.03	83.98	14.5
S 110	B-48	0-50	A3.2	7.7	7.7	8.5	17.64	44.97	
S 111		50-100		7.8	7.6	8.4	17.03	60.25	
S 112		100-150		7.9	7.7	8.7	17.03	72.75	
S 113	B-49	0-50	A3.2	7.7	7.7	8.4	15.97	44.22	21.5
S 114		50-100		7.9	7.7	8.5	14.53	51.64	58.1
S 115	B-50	0-50	A3.2	7.8	7.8	8.6	13.00	48.30	
S 116		50-100		8.0	7.7	8.7	13.35	59.48	
S 117	P-51	20-30	A3.2	7.9	7.8	8.6	4.94	42.45	19.9
S 118		70-80		8.0	7.9	8.7	12.35	51.41	48.1
S 15	B-6	0-50	A3.2	7.8	8.0	8.6	14.36	42.54	14.2
S 16		50-100		7.8	7.9	8.8	12.31	51.31	45.6
S 17		100-150		7.8	7.8	8.4	12.61	62.18	45.3
S 18		150-200		7.8	7.8	8.5	9.40	60.10	49.5
S 19	B-7	0-50	A3.2	7.7	7.8	8.5	9.75	50.92	
S 20		50-100		7.9	8.0	8.8	18.91	52.35	
S 21		100-150		7.8	7.8	8.4	14.83	65.70	
S 22		150-200		7.8	7.8	8.3	10.14	65.77	
S 57	P-21	0-16	A3.2	8.1	8.2	8.4	1.05	45.81	
S 58		25-35		7.8	7.8	8.5	11.14	52.88	
S 59		70-80		7.7	7.6	8.7	17.45	50.03	
S 68	B-24	0-50	A3.2	7.8	7.7	8.5	22.76	47.28	48.10
S 69		50-100		8.1	7.9	8.7	17.95	64.44	
S 70		100-150		8.2	8.0	8.7	16.36	81.18	
S 71		150-200		7.9	7.8	8.5	19.39	84.59	
S 207	B-97	0-50	A3.2	8.2	7.3	8.9	3.52	49.44	21.3
S 208		50-100		7.9	7.4	8.4	10.72	59.32	27.5
S 209		100-150		7.8	7.2	8.3	19.76	65.87	22.4
S 210		150-200		7.9	7.2	8.0	23.53	65.65	46.8
S 93	B-40	0-50	A3.2	7.6	7.6	8.0	37.39	42.14	
S 94	B-41	0-50	A3.2	7.7	7.6	8.4	21.81	47.16	21.6
S 95		50-100		8.0	7.9	8.4	19.39	65.50	52.0

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH Paste	pH Extract 1:5		EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	CaCO3 %
S 99	B-46	0-50	A3.2	7.8	7.7	8.4	17.45	45.29	22.1
S 100		50-100		7.9	7.9	8.4	18.05	31.43	47.7
S 101		100-150		7.8	7.8	8.3	19.39	33.16	52.7
S 102	P-47	0-8	A3.2	8.0	7.9	8.3	3.49	34.49	18.4
S 103		10-20		7.8	7.0	8.6	9.35	27.94	18.2
S 104		40-50		7.9	7.8	8.6	19.39	37.63	44.1
S 105		75-85		7.9	7.7	8.7	21.81	35.70	56.1
S 78	B-32	0-50	A3.2	7.9	7.9	8.1	2.38	43.37	18.5
S 79		50-100		8.0	8.0	8.5	3.08	48.47	36.8
S 80		100-150		8.0	8.0	8.4	3.08	64.88	49.3
S 81	P-34	0-15	A3.2	8.1	8.1	8.5	1.75	42.75	26.8
S 82		30-40		8.0	8.1	8.5	11.63	61.99	31.2
S 83		70-80		7.9	7.9	8.7	9.52	66.28	62.3
S 229	B-112	0-50	A3.2b	7.9	7.5	8.5	7.65	43.06	
S 230		50-100		7.9	7.4	8.6	11.92	64.05	
S 231	B-113	0-50	A3.2c	7.5	7.1	8.3	51.25	41.48	27.4
S 232		50-100		7.8	7.4	8.4	24.41	68.22	69.8
S 234	P-116	0-15	A3.2c	8.0	7.8	8.6	1.83	34.20	
S 235		50-60		8.1	7.6	9.0	3.66	53.38	
S 236		100-110		8.1	7.6	8.9	5.39	61.01	
S 237		140-150		7.9	7.4	8.8	8.27	50.24	
S 90	P-39	0-20	A3.2b	8.0	8.0	8.4	2.91	41.50	20.0
S 91		35-45		8.2	8.3	8.7	1.34	56.76	28.0
S 92		70-80		8.3	8.2	8.8	2.31	77.40	55.5
S 201	B-94	0-50	A3.2b	8.2	7.6	9.0	1.90	39.67	
S 202	B-95	0-50	A3.2b	7.9	7.5	8.8	8.82	49.30	28.8
S 203		50-100		7.8	7.7	8.3	22.45	73.71	47.6
S 204		100-150		7.8	7.6	8.1	26.50	40.63	26.2
S 205		150-200		7.8	7.2	8.2	29.65	46.05	24.8
S 221	B-105	0-50	A3.2b	7.6	7.3	8.5	17.30	47.32	20.0
S 222		50-100		7.8	7.3	8.2	21.48	59.93	31.1
S 215	P-100	0-20	A3.2b	7.9	7.4	8.8	14.97	41.96	
S 216		40-50		7.7	7.6	8.4	30.88	51.92	
S 217		95-110		7.9	7.4	8.5	27.44	60.29	
S 218		150-160		7.9	7.3	8.3	27.44	70.24	
S 224	B-107	0-50	A3.2b	7.9	7.6	8.6	20.58	47.06	22.1
S 225		50-100		7.9	7.6	8.4	23.52	62.41	24.2
S 13	B-5	0-50	A3.2b	7.6	7.7	8.5	16.02	44.65	
S 14		50-100		7.7	7.8	8.4	21.35	56.34	
S 223	B-106	0-50	A3.3	7.8	9.4	8.3	22.45	42.55	
S 85	B-36	0-50	A4.1	7.8	7.7	8.2	18.73	44.20	22.1

Sample No.	Bore No.	Depth (cms)	Soil Mapping Unit	pH			EC x 10^3 (Extract) mmhos/cm	Saturation Percentage	$CaCO_3$ %
				Paste	Extract	1:5			
S 86	B-37	0-50	A4.1	7.8	7.8	8.2	10.10	42.70	24.7
S 87		50-100		7.7	7.7	8.2	20.94	57.87	67.9
S 88		100-150		7.8	7.9	8.1	18.05	73.08	15.0
S 89	B-38	0-50	A4.1	7.9	8.1	8.4	10.68	46.33	
S 256	B-126	0-50	B.1	7.9	7.8	8.7	1.07	45.04	
S 56	B-20	0-50	B.2	8.0	8.3	8.4	0.65	23.95	

APPENDIX II

DETAILED CHEMICAL ANALYSES

Pit No.	Soil Mapping Unit	Sample No.	Depth cms	pH Paste	pH Extract 1:5		ECx10³ mmhos/cm	SP	CaCO3 %	P2O5 Kg/D	N %	Org.C %	Mechanical Analysis Sand %	Silt %	Clay %	Texture	Total Gypsum	Analysis of saturated extract meq./litre Ca	Mg	Na	Cl	CO3	HCO3	Total Cations	% Na	SAR	ESP
39	A3.2b	S 90	0-20	8.0	8.0	8.4	2.91	41.50	20.0	10.9	0.11	1.1	33	48	19	L	tr	14.50	4.00	7.50	12.50	0.00	6.25	26.00	28.85	2.5	2.3
		S 91	35-45	8.2	8.3	8.7	1.34	56.76	28.0	5.7	0.10	1.0	11	59	30	Sl.CL	"	5.00	2.50	8.75	8.20	0.00	5.00	15.75	52.38	4.5	5.0
		S 92	70-80	8.3	8.2	8.8	2.31	77.43	55.5	8.4	0.12	1.2	27	55	18	Sl.L	"	5.00	1.50	19.50	7.50	0.00	7.50	25.50	76.41	11.3	12.8
47	A3.2	S 102	0-8	8.0	7.9	8.3	3.49	34.49	18.4	10.0	0.11	1.1	20	57	23	Sl.L	"	6.50	8.50	12.53	8.50	0.00	4.00	27.53	45.51	4.6	5.0
		S 103	10-20	7.8	7.8	8.6	9.35	27.94	18.2	6.6	0.11	1.1	11	58	31	Sl.CL	"	19.00	23.50	130.00	80.00	0.00	2.50	172.50	84.69	28.2	28.8
		S 104	40-50	7.9	7.8	8.6	19.39	37.63	44.1	7.3	0.11	1.1	7	61	32	Sl.CL	"	8.50	2.00	155.00	20.00	0.00	5.00	165.50	93.66	67.7	50.0
		S 105	75-85	7.9	7.7	8.4	21.81	35.70	56.1	5.0	0.09	0.9	26	54	20	Sl.L	"	18.00	7.00	195.00	85.00	0.00	3.75	220.00	88.64	55.1	45.0
60	A1.1f	S 138	0-25	8.0	7.6	8.4	0.88	36.39	10.4	10.4	0.11	1.1	16	53	31	Sl.CL	"	4.00	7.40	2.40	4.00	0.00	4.00	13.80	17.39	1.0	0.3
		S 139	45-55	8.0	7.9	8.8	1.09	41.44		6.8	0.12	1.2	27	50	23	L or Sl.L	"	6.00	2.00	7.25	3.00	0.00	4.25	15.25	47.54	3.6	3.7
		S 140	105-120	7.7	7.4	8.0	7.32	46.98		13.2	0.12	1.2	29	48	23	L	"	35.00	10.60	27.50	27.00	0.00	2.50	73.10	37.62	5.8	6.6
68	A2.2	S 160	0-25	7.7	7.4	8.4	12.80	38.62		10.2	0.10	1.0	18	49	33	Sl.CL	"	25.00	22.50	82.50	100.00	0.00	3.50	130.00	63.46	16.9	19
		S 161	45-55	7.7	7.3	8.5	17.08	45.52		7.3	0.10	1.0	27	42	31	CL	"	25.00	25.00	132.50	141.00	0.00	3.00	182.50	72.60	22.5	23.6
84	A2.1	S 186	55-65	8.0	7.1	8.5	6.17	47.13		8.8	0.09	0.90	22	55	23	Sl.L	"	16.00	6.50	38.00	30.00	0.00	2.50	60.50	62.80	11.3	13
		S 187	115-125	7.9	7.9	8.3	26.17	46.64		5.2	0.06	0.60	25	52	23	Sl.L	"	25.00	11.50	42.00	16.00	0.00	2.50	78.50	53.50	9.8	11
100	A3.2b	S 215	0-20	7.9	7.4	8.8	14.97	41.96		8.8	0.10	1.0	17	64	19	Sl.L	"	30.00	21.00	115.00	131.00	0.00	3.00	166.00	69.28	22.8	25
		S 216	40-50	7.7	7.6	8.4	30.88	51.92		4.1	0.08	0.8	21	48	31	CL	"	80.00	39.00	263.86	334.00	0.00	2.50	382.86	68.92	34.2	33
		S 217	95-110	7.9	7.4	8.5	27.44	60.29		4.1	0.12	1.2	18	50	32	Sl.CL	"	40.00	50.0	240.48	267.50	0.00	2.50	330.48	72.77	35.8	34
		S 218	150-160	7.9	7.3	8.3	27.44	70.24		5.2	0.13	1.3	16	52	32	Sl.CL	"	60.00	35.00	263.86	254.00	0.00	2.00	358.86	73.53	38.3	35
116	A3.2b	S 234	0-15	8.0	7.8	8.6	1.83	34.20		6.8	0.10	1.0	26	55	19	Sl.L	"	5.00	5.00	8.00	4.00	0.00	4.00	18.00	44.44	3.6	4
		S 235	50-60	8.1	7.6	9.0	3.66	53.38		5.9	0.10	1.0	25	48	27	CL or L	"	3.00	2.00	29.50	27.00	0.00	3.00	34.50	85.51	10.7	20.8
		S 236	100-110	8.1	7.6	8.9	5.39	61.01		5.4	0.11	1.1	17	47	36	Sl.CL	"	4.00	4.00	46.00	31.00	0.00	3.50	54.00	85.19	23.0	25
		S 237	140-150	7.9	7.4	8.8	8.27	50.24		6.8	0.11	1.1	22	61	17	Sl.L	"	22.50	7.50	68.47	29.00	0.00	3.50	98.47	69.53	17.7	20
139	A3.2	S 280	0-15	8.1	8.0	8.8	2.98	38.37		13.2	0.12	1.2	25	51	18	Sl.L	"	13.00	3.00	10.60	14.50	0.00	5.00	26.60	39.85	3.7	4
		S 281	25-35	8.2	8.1	8.8	1.45	45.34		6.8	0.09	0.9	18	58	24	Sl.L	"	4.00	2.00	8.25	10.00	0.00	3.00	14.25	57.89	4.8	5.2
		S 282	70-80	7.9	7.9	8.8	17.45	49.46		8.4	0.10	1.0	20	51	29	CL or Sl.CL	"	34.00	9.50	167.00	157.00	0.00	4.50	210.50	79.34	35.8	34
		S 283	110-120	8.0	8.0	8.6	19.46	51.12		9.3	0.10	1.0	18	46	36	Sl.CL	"	37.00	35.50	173.70	183.00	0.00	4.00	246.20	70.55	28.8	29
144	A2.1	S 290	0-20	7.9	7.5	8.5	2.11	39.61		9.3	0.12	1.2	25	55	20	Sl.L	"	6.50	1.00	5.70	8.00	0.00	4.50	13.20	43.18	2.9	3
		S 291	55-70	7.9	7.3	8.7	8.16	57.46		5.0	0.12	1.2	11	47	42	Sl.L	"	17.50	11.50	59.00	74.00	0.00	3.00	88.00	67.05	15.5	18.3
		S 292	120-130	7.9	7.3	8.9	10.77	46.28		10.0	0.10	1.0	12	52	36	Sl.CL	"	25.60	11.40	86.84	96.00	3.00	3.00	123.84	70.12	20.2	22
		S 293	155-165	8.0	7.3	8.7	12.34	60.36		10.9	0.11	1.1	7	60	33	Sl.CL	"	27.50	17.50	83.50	110.00	4.00	4.00	128.50	64.98	17.6	20