JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE MINISTRY OF AGRICULTURE AND FISHERIES,
THE GOVERNMENT OF THE SULTANATE OF OMAN

THE STUDY
ON
AGRICULTURAL DEVELOPMENT PROJECT
IN
THE NEJD REGION
(Phase II Study, Work III)

FINAL REPORT

VOLUME II
APPENDICES

MAY, 1997

PACIFIC CONSULTANTS INTERNATIONAL

JICA
THE STUDY ON AGRICULTURAL DEVELOPMENT PROJECT
IN THE NEJD REGION (Phase II Study, Work III)
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Appendix 1 General

A - 1.1 List of Persons Contacted

Ministry of Ariculture and Fiheries (MAF)
MAF Head Quaters in Muscat

H.E. Mohamed bin Abdullah bin Zaher Al Hinai	Minister of Agriculture and Fisheries
H.E. Sayyed Sultan Ahmed Al Busaid	Undersecretary of Agriculture and Fisheries
Mr. Abdulla Al-Mawli	Director of Minster's Office
Mr. Tariq bin Suhail bin Mohamed Al-Zidzali	Agricultural Expert, Minister's Office
Mr. Ahnaf bin Omar Al Zubaidi	Advisor to the Minister
Mr. Habeeb Abdullah Al-Hasani	Acting Director of Technical Cooperation
Mr. Faisal Ali Salman	Translater Technical Cooperation
Mr. Hassan Shehatta	Economic Expert
Mr. V. Shah	Economic Expert
Mr. Wazir Hassan	Agronomy Expert

Rumais Agricultural Research Station

Mr. Saud bin Salim Al-Harthy	DG of Rumais Agricultural Research Station (Ex.)
Mr. Assad Alla bin Ahmed Taqi	Soil Scientist
Mr. Saud Al Farsi	Engineer of Soil
Dr. Andre G. Lepiece	Soil Specialist
Mr. Emad Abdull Majeed	Director General of Irrigation

Directorate General of Planning and Projects

Mr. Ibrahim Saleh Al Gahilalani	MAF, DG Planning & Project
Mr. Khalifa Al-Shaqsi	MAF, DG Planning & Project
Mr. Mohammed Moor	MAF, DG Planning & Project

Department of Agricultural Statistics

Mr. Salem Mohamed Al-Ghamari	Director of Agricultural Statistics
Mr. Mohamed Salah	Expert of Agricultural Statistics

Ministry of Development

Mr. Sabir Al-Haibi	National Accountant
Mr. Ali Alghufaili	Officer
Mr. Mohamed Al-Riyyami	Officer

Ministry of Water Resources (MWR)

H.E. Hamid bin Said al Aufi	Minister of Water Resources
Mr. Aley bin Ahmed Al Marjeby	Director General of Water Resources Assessment
Mr. Seif Al-Shaqsy	Director General of Water Resources Management
Mr. Mohamed Khalifa Al Kalbani	Acting DG of Water Resiurces Management
Mr. Bob Rowt	Expert of DG of Water Resources Management
Mr. Ali Gharbi	Department of Water Resources Management
Mr. Graham Smith	Deputy Director General of Water Resources Assessment
Mr. Ahmed bin Mohammed Al-Ghafri	Controller General of Information and Awareness Centre
Mr. Ismail Al-Sarhani	Director General,Regional Affairs, MWR
Mr. Hamad Salim Al-Mahrouqi	Director of Statistics and Field Data,MWR
Mr. Ahmed Said Al Baruwani	Director of Surface Water, MWR
Ms. Izabela Dyras	Head, Remote Sensing Section
Mr. Abdul Aziz	Staff, Remote Sensing Section
Mr. Nasser Al-Magbali	Acting Director of Dams
Mr. Majid Bilarab Al-Batashi	Deputy Director, Dept. of Dams
Mr. Salem bin Salam Al-Mawali	Technician, Department of Dams

MWR, Salalah Office

Mr. Salem Bin Ahmed Al Hash	Director, MWR Salalah Regional Office
Mr. Abdullah Mohd. Ali Bawain	Engineer, MWR Salalah office
Mr. Mohd. Abdullah Mohd. Al Amri	Engineer, MWR Salalah office
Mr. Chris O'Boy	Expert, MWR Salalah office

Other Departments

Mr. Elhag Bakhit Ahmed	Range Ecologist, Range & Forest Dept.
Mr. Mohd. bin Dhofar bin Ahmed Al-Rawas	Deputy Director
Mr. Musallem Saeed Al-Mashani	Chief of Meteorology section
Mr. Mohd. Ali Al-Tager	Staff of Meteorology section
Mr. Bhanu Pratap Singh	Meteorologist

Salalah Airport

Mr. Salim Awadh	Director of Salalah Airport
Mr. Mohd. bin Dhofar bin Ahmed Al-Rawas	Deputy Director
Mr. Musallem Saeed Al-Mashani	Chief of Meteorology section
Mr. Mohd. Ali Al-Tager	Staff of Meteorology section
Mr. Bhanu Pratap Singh	Meteorologist

Other Organizations

Mr. Ahmed Al-Fareed	Ministry of Commerce & Industry
Mr. George Heading	Farm Management, Desert Agriculture Project

A-1.2 List of Equipment and Other Items Provided by JICA Study Team

Sl.No.	Descriptions	Specifications	Qty.
1	Electronic Balance	FX-300	1 set
2	Permeameter	DIK-405	1 set
3	EC meter	CM-20S	1 set
4	Water quality checker	WQC20A	1 set
5	Soil auger	AF-108, screw type	1 set
6	Soil sampler	AF-111	2 sets
7	Cylinder kit for soil sampler	6cilinders/set	9 sets
8	Soil sampling kit	AF-112	1 set
9	Standard color for horticultural plant	CF-300	1 set
10	Soil humus test kit	BF-232	1 set
11	Sub-surface irrigation kit	PRO-AGR.FM-05	1 set
12	Thermo-hygrograph set	N0.3C	1 set
13	Oven, constant temp.	Model 082-408	1 set
14	Weighing scale	Model NBS-150K	1 set
15	Small soil sieve set	Metal # 2, 1, 1/2, 1/4mm	1 set
16	Soil three phases meter	DIK-1121	1 set
17	Soil tensiometer / 20cm	DIK-833	14 Nos.
18	Soil tensiometer / 40cm		1 No.
19	pH meter	HORIBA B-212	1 set
20	Charts for existing meteo-station		
21	Ink for existing meteo-station		
22	Charts for Thermo-hygrograph set		
23	Chart for rain gauge	IKEDA-KEIKI	
24	Pen for rain gauge	IKEDA-KEIKI 510	
25	Chart for existing thermo-hygrograph		
26	Pen for existing thermo-hygrograph		

APPENDIX - 2
CROP PRODUCTION

Appendix 2

A-2.1 Monitoring items for the cultivation of Rhodes grass

(1)Detailed observation of plant growth

1) Plant growth

Purpose	To identify the growth characteristics of the Rhodes grass in Nejd
Frequency	Every seven days during cultivation in two seasons (during harvet, 7days in Summer and 14 days in Winter)
Items	Leaf color / Number of plants Plant height / Roots extension (20cm depth) Number of leaves / Fresh weight of top and roots Number of headings / Dry weight of top and roots Number of stems
Methods	Collection of all plants in 50 cm2 quadrat 3 plots in healthy, normal and poor condition for each treatment
Necessary Equip.	Measure, scale, shovel, scissors, balance, drying oven, paper bag, pen, camera, rope with 4 poles, bucket, observation sheet

2) Analysis of moisture contents curve in the plant

Purpose	To identify the water stress in Rhodes grass These data will be utilized for the effective water frequency
Frequency	Once in every 3 months (Winter, Spring, Summer, Fall)
Items	Moisture in leaves and stems
Methods	Every 3 hours after cutting of plants, for each irrigation treatment
Necessary Equip.	Scissors, paper bag, drying oven, balance, pen, observation sheet

3) Analysis of the effect of subsoiling on the plant growth

Purpose	To study the effect of subsoiling on the growth of Rhodes grass
Frequency	After treatment of subsoiling, 2 plots from the field
Items	Leaf color / Number of plants Plant height / Roots extension (20cm depth) Number of leaves / Fresh weight of top and roots Number of headings / Dry weight of top and roots Number of stems
Methods	After subsoiling, observed items are collected once in every 2 weeks
Necessary Equip.	Measure, scale, shovel, scissors, balance, drying oven, paper bag, pen, camera, rope with 4 poles, bucket, observation sheet

(2)Daily observation of plant growth

Purpose	To observe the growth condition of Rhodes and for disease control
Frequency	Daily or Occasionally
Items	Growth stage　　Plant activities (any significant symptoms) Leaf color　　Deficiency and excess of nutrient elements Pests and diseases　　Extension of Rhodes salons Soil moisture condition Heading
Methods	Randomized area for each treatments
Necessarily equip.	Observation sheet, measure, leaf color sheet

(3) Hay analysis

1) Analysis of moisture contents curve in the hay

Purpose	To identify the drying condition of hay These data will be utilized for determining the suitable drying condition for hay baler
Frequency	4 times in a year (February, May, August and November)
Items	Moisture in leaves and stems
Methods	Every 3 hours after cutting of plants for each irrigating treatment
Necessary equip.	Scissors, balance, paper bag, drying oven

2) Quantity and quality of produced hay

Purpose	To identify the productivity of Rhodes for hay baler
Frequency	Every harvesting time
Items	Total Weight and number of hay bales Moisture content in the hay Weight of selected 20 hays Color, flavor Gloss, rate of heading stems
Methods	Measurement of weight, for each treatment
Necessary Equip.	Balance, leaf color sheet, scissors, paper bag drying oven, observation sheet

3) Estimation of harvesting loss of fodder

Purpose	To identify the loss of fodder for making hay baler and to estimate the total production of Rhodes grass
Frequency	Each harvest
Items	1 plot from each treatment
Methods	5 m square, 1 plot from each treatment
Necessary equip.	Rope (30m), pole (4), big bag, balance, observation sheet

4) Analysis of nutrients and mineral contents in hay

Purpose	To identify the hay quality and toxic content
Frequency	2 times in a year (At summer and winter harvest)
Items	NO3-N, P, K, Ca, Mg and NO2-N as Toxicity Micro elements, digestibility value, metabolizable energy Crude protein
Methods	Sampling from each treatment and oven dry Chemical analysis will be carried out at MAF laboratory
Necessary equip.	Scissors, paper bag, nylon bag, drying oven, balance

Monitoring of Tree Cultivation

Purpose	To study the growth rate for each variety
Frequency	4 times in a year (February, May, August and November)
Items	Tree height Canopy (X, Y) Diameter of the stem at bottom
Methods	Selected 10 trees for each variety
Necessary equip.	Measure (5m), pole, caliper Plate should be fixed to selected trees.

A-2.2 Cultivation method of Rhodes grass before April, 1995

The cultivation of Rhodes grass was started in September, 1994 at the newly constructed NARS. After the land preparation activities such as land leveling and plowing, the Rhodes grass was sown on virgin soil, and the harvest was carried out twice until April, 1995.
These cultivation activities had been carried out by the DGAF, SLL. However, during this period, the permanent staffs were not appointed and therefore cultivation and other activities had been managed by some contractors who had also managed the irrigation system and construction of buildings.

The cultivation practices are summarized as follows.

Soil preparation:

Center Pivot field and Linear Movement field were plowed by disk harrow in the end of August, 1994, leveled by harrow from 7th to 14th September, 1994, irrigated from 15th September, 1994 and followed by the application of chemical complex fertilizer (N20-P10-K10) of 500 kg per ha and organic manure of 15 tones per ha by broadcaster before seeding.

Seeding:

Cultivar Pioneer was sown in Center Pivot field on 15th September, 1994 and cultivar Callide was sown in Linear Movement field on 18th September, 1994 by seed drill, respectively. Seeding rate of both fields was 19 kg per ha.

Harvesting:

First harvesting and second harvesting were carried out by mowers, rakes of four wheels with fingers, square balers and trailers in January and April, 1995. The hay production in first and second harvesting was 0.49 and 1.21 tones per ha in Center Pivot field and 0.46 and 0.98 tones per ha in Linear Movement field, respectively.

Fertilization after harvesting:

Urea of 1,200 kg per ha was applied only once after the first harvest for Center pivot field in January, 1995.

A-2.3 Guidance for Rhodes grass cultivation

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials: Kinds	Materials: Quantity kg / ha	Remarks
1. Land leveling	at any time	Ripping shallowly the area to create loose soil.	Motorized grader	2			The method is decided from the existing conditions of the field.
			Several passes with a Leveling harrow	3			
		Leveling the land.	or				
			Rear blade	2			
			Several passes with a Leveling harrow	3			
2. Cultivation in the virgin soil	directly before sowing	A surface crust develops rapidly after irrigation, especially on virgin soil, which sets quickly to a cement-like hardness in as little as four hours. The thickness of the crust is proportional to the interval between irrigations.	Ripping with the Chisel cultivator to a depth of 20 cm to ensure that there is no shallow pan.	1.5			Examining the pre-irrigation to soften the soil hardness.
		The severity of crust formation is reduced by minimal and shallow cultivations to maintain the organic content in the surface soil, and by frequent irrigation scheduling to keep the crust thin and weak. The crust problem disappeared almost completely after 4-6 months of cropping. Cultivation results in a fine powdery talcum-like tilth in which it is difficult to maintain a constant sowing depth and which tends to form a crust when wetted.	Several passes with a Leveling harrow	3			
	* Technical attention	Plowing is generally not recommended unless it is essential to bury all trash and obtain a clean seedbed. No precise sequence of cultivations is recommended. This must be a field specific management decision. If cultivated soil is rolled after seeding and before irrigation surface cropping can be serious; use of rollers is not advocated. Pre-irrigation cultivation; Micro settlement of the soil surface occurs once irrigation starts but the level harrowings between irrigations smoothes the soil before the next irrigation (PDO).					
3. Sowing	between mid February and mid September, except the height of summer (from May to July)	Shallow sowing depth is essential to ensure rapid seedling emergence and to avoid the stunting.	* to be applied through a pneumatic spreader or drill mixed with Triple Supr Phosphate or sand.	3.5	Triple super phosphate (TSP)	270 kg at seeding	
		Non free-flowing seeds such as Rhodes grass can be applied through a fertilizer spreader mixed with triple super phosphate (ideally a pneumatic spreader) or through a drill mixed with sand. At normal recommended seed rates of 15 kg/ha it has taken about four months to establish a complete ground cover as a reclamation crop.	* to cover with soil by Chain harrow	2.2	Rhodes grass seeds (cv;Katambora)	20 kg	Seeding rate depends on the germination rate.

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials: Kinds	Materials: Quantity kg / ha	Remarks
(3. Sowing)		Rhodes grass grows more slowly in winter than in summer and sowing during Nov. - Jun. should be avoided. Cultivar"Katambora" has been the most successful in terms of production, ease of haymaking, persistence and resistance to pests. Yield as a mean of eight established fields was 45 t/ha of DM(DPO).					
	• Technical attention:	Virtually all the reclamation crops exhibited a bizarre(grotesque) range and sequence of leaf colorations, with poor and locally extremely variable growth. This poor initial crop growth lasted for 4-6 months after which rapid and dramatic improvement in crop growth occurred(this initial dramatic response is regarded as the reclamation phase, PDO). Rhodes grass , after a short reclamation phase, moved to high levels of production within 6 months from sowing thus proving to be the best reclamation crop (PDO). Whilst the crop can be sown in the height of summer, high water use will be incurred due to high temperature and wind, because of the need to keep the soil surface moist, prevent seedling desiccation and the need for post sowing leaching of locally saline areas.					
4. Fertilization of Triple Super Phosphate (top-dressing)	directly after harvesting Rhodes grass	Triple super phosphate is applied in the seedbed pre-planting, and for Rhodes grass 4 times a year subsequently with 2 x 15m booms of pneumatic spreader. Rate of applications; 400 kg P2O5/ha/year in 3-4 applications of 100 kg P2O5 /ha each.	Broadcasting with pneumatic fertilizer spreader, 2 passes.	1.7	Triple super phosphate	270 every appli-cation	400 kg P2O5/ha/year in 3~4 application of 100 kg P2O5/ha (270 kg /ha of TSP every application)
	• Technical attention	Potassium is apparently not necessary and in any case applied in appreciable amount in the irrigation water(PDO).					
5. Fertilization of Nitrogen : Top-dressing	every two weeks	Nitrogen, being highly mobile and easily leached, should be applied fairly frequently depending on rate of crop growth and utilization through a fertilizer injection system. Rate of application: Usually, 1,000kg N/ha/year as 38 kg N/ha (about 80 kg of urea/ ha) every two weeks. 2,000kg N/ha/year as 77 kg N/ha every two weeks (in case of 45 t of DM/ha/year of yield, PDO)	Fertilizer injection system (linear Movement and Center Pivot) In case of applying 80 kg of urea/ha every two weeks, 30 ha of Center Pivot field : 80kg*30ha/50kg=48 bags 48 bags/9 bags=5 days 18 ha of Linear Move field : 80*18/50=29 bags 29 bags/9 bags=3 days. when the weight of a urea bag is 50 kg and the capacity of injection tank per day is 9 bags of urea.		Urea	See remarks.	During 4 months after sowing: 21 kg of urea / ha every 2 weeks During next 2 months: 40 kg of urea / ha every 2 weeks After 6 months after sowing: 80 kg of urea / ha every 2 weeks In case of heavy manuring culture, take care of the toxication for ruminants which are rised with the fodder crops of excess (over 0.2% of dry matter) of nitrite.
	• Technical attention:	The rate of nitrogen recovery by the crops from urea fertilizer has been quite acceptable, as has the recovery of phosphate in Rhodes grass. Urea has been applied as a prilled fertilizer on to the surface. Urea is used because it is the cheapest and most concentrated form of nitrogen. Sulphate of ammonia has also been used to a limited extent as a seedbed pre-plant application because it is immediately available and is less readily lost by volatilization.					

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials Kinds	Materials Quantity kg / ha	Remarks
(5. Fertilization of Nitrogen Top-dressing)	• Technical attention	There are problems in the surface application of urea of Middle East origin due to prill coating and the prills coagulate into hard lumps under humid conditions. This causes an irregular spreading pattern, reduced spreading width, and causes inaccurate application. Urea of European origin is more satisfactory but more expensive. The use of a fertilizer injection system on the new center pivot and the linear movement has eliminated this problem.					
6. Soil management							
1)Filling local subsidence of the soil surface	after pre-irrigation before directly sowing, and at any time after sowing during the first two or three years	Soil levels appear locally to become lower after being cultivated and irrigated for some time. The reasons for this are not yet fully understood. It may be that soluble salts are leached downwards and where these form a substantial proportion of the soil mass the level of the soil is lowered locally. The result of this phenomenon is poor crop growth in the low areas, possibly due to a local run off effect (PDO).	Filling hollows in field with coarse soil and filling the irrigator tracks with coarse soil or gravel.		Coarse soil or gravel		
	• Technical attention:	Pre-irrigation cultivations: Micro settlement of the soil surface occurs once irrigation starts but the level harrowings between irrigations smoothes the soil before the next irrigation. Whenever any serious settlement occur, it should be filled or the area land leveled between irrigations. After reclamation crop the site should be assessed again for micro settlement and re-leveled as necessary. Micro-settlement may occur during the first two to three years of irrigation (MM). PDO experienced local subsidence of the soil surface during the yearly years of cropping. Such areas should be leveled between crops or filled where they occur in perennial crops to avoid run off of water into hollows. Unless this is done, growth will be affected by waterlogging. Tracks made by linear and center pivot irrigators will need to be filled locally, particularly where soil was initially saline. Coarse soil or gravel should be used. 100AZ(approx.) spray nozzles should be used next to irrigator tracks to reduce the amount of water falling in the tracks(MM).					
2) Subsoiling	at any time (once or two times a year)	Cultivations should be minimal and aim to build up organic matter in the top soil. Occasional subsoiling should be carried out to loosen the subsoil and reduce possible compaction which may result from farm machinery traffic and from irrigation.	Ripping with the chisel cultivator to a depth of 20 cm to ensure that there is no shallow pan.	1.5			It is necesary to examine on the effect of cutting roots of Rhodes grass.
3) Fertilization of micro-element	When the results of monitoring show deficiency or excess of micro-elements	Mo/Cu ratio is a serious problem affecting ruminants grazing PDO's forage, but apparently does not adversely affect forage production. The trials thus far show zinc and copper deficiencies also constrain both forage yield and its quality (PDO).	Fertilizing if deficient. or leaching if surplus.		$ZnSO_4$ in aqueous solutio $CuSO_4$ in aqueous solutio	30 kg of Zn 50 kg of Cu	

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials Kinds	Materials Quantity kg / ha	Remarks
(3) Fertilization of micro-element)	* Technical attention (soil)	In PDO, total copper and zinc were low; total iron and manganese were moderate to low by chemical analysis. The amounts of soluble boron were variable, ranging from near toxic to near deficiency levels, the toxic amounts are related to high EC soils. Subsequent plant tissue analyses showed molybdenum to be highly concentrated (7ppm), copper low (5ppm), zinc low (15ppm) and phosphorus low (0.16ppm). There are abnormal ratios among nutrient elements including Fe/Mn, Mo/Fe, Cu/Fe, Cu/Zn and Mo/Cu. Micro-element fertilizer trials started after problems of animal health had been traced to the unfavorable ratio in herbage of copper to molybdenum. Soil analyses conducted in March 1985 indicated that manganese, zinc, copper and iron might be limiting(PDO). The analyses from soil, water and plant tissue will enable continuous re-appraisal of plant nutrient requirements, and hence fertilizer rates, and the anticipation of problems e.g. drainage, inadequate supply or toxicity of trace elements. It is also particularly important to monitor any build up of Boron and fluoride in soil(MM).					
	* Technical attention (water quality)	The analyses in two wells of PDO show high level s of Boron, Fluoride and Potassium. The level of Boron is high and is likely to be restrictive to some crops particularly over a long period of time. The high soil temperatures will tend to aggravate(make worse) any potential Boron toxicity problems. Fluoride levels are high but are unlikely to cause problems in such a high PH soil. Some leaf damage may be caused in high dry wind conditions. Chemical analyses of the soil shows zinc to be low. The addition of this amount of zinc via irrigation water may help to alleviate any deficiency except in more sensitive crops. At these levels Iron can be beneficial to the crops particularly as it can be absorbed through the leaves. However with the high sulphate levels, deposits on pumps and irrigation equipment might be a problem over a long period of time. In conclusion the work carried out at PDO has shown that acceptable yields of various crops, particularly Rhodes grass, can be produced using the existing water supply. The salt content and level of Boron justify the high leaching fractions used. Work is now required to assess the level of salt build up at various levels in the soil and thereby check on the leaching efficiency.					
7. Irrigation 1) Irrigation in reclamation phase	every day throughout the year	Seeds will not germinate on residual soil moisture as this is too low; newly sown crops have to be irrigated daily to maintain a moist surface and maintain the movement of salt down the profile. Because the irrigation water is saline, a leaching factor will be allowed for at each irrigation. A surface crust was seen to develop rapidly after irrigation, especially on virgin soil, which sets quickly to a cement-like hardness in as little as four hours. The thickness of the crust is proportional to the interval between irrigations.	continual and frequent irrigation with Center pivot and Linear Move irrigation system				
	* Technical attention	The crust can be evident even when the surface is kept continually moist, but it is then relatively weak. The crust adversely affected germination to a varying extent according to species. Tropical species, especially Graminae(sorghums and grasses) are less affected and spear through the crust. The severity of crust formation is reduced by minimal and shallow cultivations to maintain the organic content in the surface soil, and by frequent irrigation scheduling to keep the crust thin and weak. The crust problem disappeared almost completely after 4-6 months of cropping on the farm. Emergent seedlings which were weakened by the surface crust remain permanently stunted, but the same phenomenon was not observed on the center pivot development.					

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials		Remarks
					Kinds	Quantity kg / ha	
2) Irrigation after reclamation phase	every day throughout the year	' It will be necessary to irrigate 24 hours per day in mid summer to meet peak water demands for the whole area. ' Daytime temperatures and winds are usually higher, and humidities lower; this leads to higher requirements due to evaporation in the daytime. ' However in the winter when irrigation demands are low, night time only irrigation is a possibility using large automatic systems such as linear move or center pivots.	Rhodes grass production with respect to water can be maximized with a peak summer application of 17 mm/day and minimum winter application of 6.2 mm/day (PDO). irrigating with Center pivot and Linear move irrigation system.				

* Technical attention: ' PDO soils make it imperative(necessary) to avoid large droplet size and high droplet impact. The low available water capacity requires a capability for frequent light irrigations during germination and crop establishment, and to prevent crust formation. Irrigation losses from high winds require water to be applied as close to the crop as possible.
' These requirements are met by a center pivot system, with low pressure drop sprays, for large scale operation. At PDO moving linear boom irrigators were originally chosen to simulate as far as possible the center pivot mode of action on a smaller scale.

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Kinds	Quantity kg / ha	Remarks
8. Haymaking	* 1st cut of hay; 3 to 6 months after sowing * Cutting interval; 20-25 days in June-August, 60-70 days in December-January	' During 6 months of the year (April-September) hay can be made in 24~36 hours and raking is hardly necessary. During the rest of the year some raking is necessary, usually one or two passes. ' Taking care of irrigation practice during hay making. ' It is recommended that Rhodes grass is harvested at the time when grass height becomes 60 cm or more and before the heading stems are less than 10 % of the whole stems at the most.	* Mowing with mower or mower conditioner * Tedding with hay tedder * Hay collecting with side rake * Baling with square baler or round baler * Picking up and transporting hay bale by trailer or by auto-pick up round bale trailer * Loading hay bales to purchaser's truck and weighing	1.2 or 2.5 2.2 3.2 1. 1 or 1.8 1.1 or 4	' Twine for baling	or 165 m/ton of hay	

* Technical attention: ' A Vicon Olympus KM 240(2.4 m) disc mower with crimper /conditioner has been used to cut all forage crops. There is reason to believe that wheel pressure and / or skid pressure causes soil compaction and / or mechanical damage to the grass. Commercial scale operations should therefore use a type of mower which is likely to cause minimum compaction.
' When heavy dew occurs in November-January it can take 5 days to make hay without raking, and this has an adverse effect on the grass under the swath if not lifted. It may be necessary at this time to spread the swath to accelerate drying and then rake it. Katambora Rhodes grass is less susceptible to damage from long lying swaths.
' It has been found that a loaded trailer with high pressure tyers can also cause soil compaction in the field, and it is preferable to avoid this by using flotation tiers.

Farm work	Suitable period for practice	Principles of practice	Means and methods	Working efficiency ha / hr	Materials		Remarks
					Kinds	Quantity kg / ha	

(8. Haymaking) * Technical attention:

Growth The annual yield potential as hay is over 40 t / ha at the 2,000 kg N / ha fertilizer regime used at PDO. Growth is seasonal and it is highly responsive to temperature and insolation. Production is low in January-February, and then rises to mid May. It may fall in June or July when insolation is reduced by cloud cover associated with the onset of the monsoon season, but rises rapidly as skies clear. There is a temporary yield recovery in November which is associated with a change of growth habit.

When growth is rapid in summer the habit is very upright, flower heads are produced early and hay is very easy to make. During winter, a dense leafy "bottom" is produced, flower heads appear later and in less profusion(abundance), and hay takes longer to dry because the swath is denser and temperatures are lower (PDO).

Varieties of Rhodes grass (Chiloris gayana Kunth)

1) Callide : It is a tetraploid and large in plant height, thickness of stems, leaves and head. It has a high ability of yield and a tolerance for dry, but late growing in the early stage of growth as a weak point.

2) Pioneer : It is early flowering and hence of lower nutritive value. It is a diploid, a standing type with less stolons. The level of yield and response for fertilization are low.

3) Katambora : Originating from Zimbabwe, it is a diploid , leafy, dense-growing and good seed producer. It suppresses nematodes in soil.
It is latest flowering among varieties of diploid Rhodes grass, a prostrate type with much stolons. It has a high ability of growth in early stage, yield and a tolerance for dry.

Source : 1) The desert Agricultural Project-- A Report on Project Development to March 1988, PDO. , Apr. 1988. 2) Detailed Investigations for Development of up to 1000 ha of Irrigated land : Nejd Region-Hydrogeology, Interim Report(Final), Mott MacDonald International Ltd.,Feb. 1991, 3) The Study on the Agricultural Development Project in the Nejd Region(Phase II)-Detailed Design Report, JICA, Dec.1991

A-2.4 Plan and result of fertilization for Rhodes grass

Table A-2.4.1 The Fertilization Plan and Application Results from May to December, 1995

(Unit : tonnes / 30 ha)

	May				June				July				August			
	Plan		Result		Plan		Result		Plan		Result		Plan		Result	
Date	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP
1									0.45				0.45		0.45	
2									0.45				0.45		0.45	
3					0.45				0.45						0.45	
4					0.45				0.45		0.45				0.45	
5					0.45				0.45		0.45				0.45	
6	0.45		0.45		0.45						0.45				0.45	
7	0.45		0.45		0.45						0.45				0.45	
8	0.45		0.45								0.45				0.45	
9	0.45		0.45								0.45				0.45	
10	0.45		0.45		0.45					2.7	0.45					
11					0.45					2.7						
12					0.45					2.7			0.45		0.45	
13					0.45		0.45						0.45			
14					0.45		0.45						0.45			
15							0.45		0.45				0.45		0.45	
16							0.45		0.45				0.45		0.45	
17					0.45		0.45		0.45							
18					0.45				0.45							
19					0.45				0.45							
20	0.45	2.7	0.45	4.05	0.45											
21	0.45	2.7	0.45	4.05	0.45											
22	0.45	2.7	0.45													
23	0.45		0.45													
24	0.45		0.45													
25																
26													0.45			
27							0.45						0.45			
28							0.45						0.45			
29							0.45		0.45				0.45			
30									0.45				0.45			
31									0.45							
Sum	4.5	8.1	4.5	8.1	6.75	0	3.6	0	5.85	8.1	3.15	0	5.4	0	5.4	0

	September				October				November				December			
	Plan		Result		Plan		Result		Plan		Result		Plan		Result	
Date	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP
1																
2													0.45		0.45	
3		2.7					0.45						0.45		0.45	
4		2.7					0.45		0.45				0.45		0.45	
5		2.7					0.45		0.45				0.45		0.45	
6							0.45		0.45				0.45		0.45	
7					0.45		0.45		0.45							
8					0.45				0.45							
9	0.45				0.45											
10	0.45				0.45											
11	0.45				0.45											
12	0.45															
13	0.45															
14																
15																
16													0.45		0.45	
17													0.45		0.45	
18				4.05					0.45		0.45		0.45		0.45	
19				4.05					0.45		0.45		0.45		0.45	
20			0.45						0.45		0.45		0.45		0.45	
21			0.45		0.45				0.45		0.45					
22			0.45		0.45				0.45		0.45					
23	0.45		0.45		0.45											
24	0.45		0.45		0.45											
25	0.45				0.45											
26	0.45															
27	0.45															
28																
29																
30													0.45			
31													0.45			
Sum	4.5	8.1	2.25	8.1	4.5	0	2.25	0	4.5	0	2.25	0	5.4	0	4.5	0

Note; Sum: ton/30 ha/month

Table A-2.4.2 The Fertilization Plan and Application Results from January to July, 1996

(Unit: tonnes / 30 ha)

Date	January				February				March				April				May				June				July			
	Plan		Result		Plan		Result		Plan		Result		Plan		Result		Plan		Result		Plan		Result		Plan		Result	
	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP	Urea	TSP
1	0.45						0.45						0.45												0.45			
2	0.45						0.45						0.35				0.45								0.45			
3	0.45																0.45								0.45			
4																	0.45								0.2			
5																	0.35				0.45							
6																					0.45							
7			0.45																		0.45							
8			0.45						0.45												0.45							
9			0.45						0.45												0.2							
10			0.45		0.45		0.45		0.45				0.45															
11			0.45		0.45		0.45		0.35				0.45															
12					0.45		0.45						0.45												0.45			
13	0.45				0.45		0.45						0.35				0.45								0.45			
14	0.45				0.45		0.45										0.45								0.45			
15	0.45										0.85						0.45						0.45		0.45			
16	0.45										0.85						0.35								0.2			
17	0.45																				0.45							
18																					0.45		0.45					
19									0.45												0.45							
20									0.45												0.45							
21									0.45				0.45								0.2		0.45					
22									0.35				0.45															
23													0.45															
24					0.45								0.35				0.45						0.45		0.45			
25					0.45												0.45								0.45			
26					0.45												0.45		0.85						0.45			
27	0.45				0.45												0.35		0.85				0.5		0.45			
28	0.45				0.45																				0.2			
29	0.45	8.1	0.45	8.1										8.1							0.45					8.1		
30	0.45		0.45						0.45		0.85																	8.1
31	0.45		0.45						0.45		0.85																	
Sum	5.85	8.1	3.6	8.1	4.5	0	3.15	0	4.3		3.4		4.2	8.1	0		5.1		1.7		4.45		2.3		5.55	8.1	0	8.1

Note; Sum: ton/30 ha/month, K*: Amount of K2SO4 per 15 ha.

Table A-2.4.3 The Fertilization Plan and Application Results from August to November, 1996

(Unit: tonnes / 30 ha)

	August						September						October						November					
	Plan			Result			Plan			Result			Plan			Result			Plan			Result		
Date	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*	Urea	TSP	K*
1							0.45									0.45								
2							0.2						0.45			0.45								
3			0.45										0.45		0.45	0.45								
4													0.45			0.35			0.45					
5	0.45			0.45									0.35						0.45					
6	0.45			0.45															0.45					
7	0.45			0.45															0.35					
8	0.45			0.45																				
9	0.2			0.2																				
10							0.45																	
11							0.45																	
12							0.45																	
13						0.45	0.35						0.45											
14													0.45											
15													0.45						0.45					
16													0.35						0.45					
17	0.45																		0.45					
18	0.45																		0.35					
19	0.45					0.45																		
20	0.45																							
21	0.2						0.45																	
22							0.45																	
23							0.45																	
24				0.45			0.35						0.45											
25				0.45									0.45											
26				0.45									0.45						0.45					
27				0.45									0.35						0.45					
28				0.2															0.45					
29	0.45													8.1					0.35					
30	0.45																							
31	0.45																							
Sum	5.35		0.45	4		0.9	4.05			0			5.1	8.1	0.45				5.1					

Table A-2.4.4 Actual application of urea in 1996

NO.of harvest	Date of harvest	Cutting interval	Treatment of urea in Trial 1	Planned amount of urea from last cutting	Actual amount of urea applied from last cutting	Planned amount of N from last cutting	Actual amount of N from last cutting
		days		ton/15ha	ton/15ha	kg/ha	kg/ha
9	4-may~ 14-May	67	High level	4.1	2.0	131	64
			low level	2.7	1.4	86	45
10	20-Jul.~ 28-Jul.	77	High level	7.9	2.9	253	93
			low level	5.2	1.9	166	61
11	20-Sep.~ 1-Oct.	62	High level	5.9	2.4	189	77
			low level	3.8	1.6	122	51

A-2.5 Actual irrigation use

NO. of Harvest	Date of Harvest	Cutting Interval	Planned water use days from last cutting	Actual water use days from last cutting	Treatments of irrigation in Trial 1	Planned amount of water	Actual amount of water in the irrigated day	Average of actual amount of water in the period
		days				mm/day	mm/day	mm/day
9	4-May ~ 14-May	67	52	52	High level	12	10.8	10.8
					Low level	8	6.4	6.4
10	20-Jul. ~ 28-Jul.	77	66	31	High level	15	11.6	5.5
					Low level	10	7.7	3.6
11	20-Sep.~ 1-Oct.	62	53	48	High level	12	14.7	13.3
					Low level	8	9.8	8.9
12					High level			
					Low level			

Note: During from late of May to 5 August, irrigation water of the planned daily amount in Trial 1 was applied once in every three days due to impossible pumping up water.

A-2.6 Growth characteristics of Rhodes grass

Table A-2.6.1 Growth Characteristics of Rhodes Grass by Season

Items	May, 1995			July			August			October			January, 1996		
	21-May	30-May	Increse during 10 days	4-Jul	14-Jul	Increse during 10 days	14-Aug	29-Aug	Increse during 16 days	16-Oct	31-Oct	Increse during 15 days	20-Jan.	10-Feb.	Increse during 21 days
Plant height (cm)	-	75~90	-	58~87	85~110	23~27	62~149	98	-	35~55	70~113	35~58	20~30	35~55	15~25
Number of Stems (/m2)	-	-	-	1,472	1,540	68.0	1,340.0	1,184	-156.0	1,620.0	1,592	-28.0	2,188	2,256	68.0
Number of Heading (/m2)	-	-	-	24	416	392.0	40.0	344	304.0	136	468	332.0	0	60	60
Rate of Heading (%)	-	-	-	1.6	27.0	25.4	3.0	29.1	26.1	8.4	29.4	21.0	0.0	2.7	2.7
Fresh Weight (g/m2)															
Top above 10 cm	2,290.4	4,144.0	1,853.6	2,328.8	4,660.4	2,331.6	1,974.8	162.8	188.0	1,827.2	2,838.4	1,011.2	906.4	1,424.0	517.6
Bottom top (0~10 cm)	1,578.0	1,396.4	-181.6	2,401.6	2,122.0	-279.6	1,874.4	940.8	66.4	822.8	1,540.0	717.2	3,604.4	3,678.0	73.6
Roots (depth : 20 cm)	1,568.4	3,463.2	1,894.8	3,136.0	724.0	-2,412.0	922.0	379.6	-542.4	318.8	947.2	628.4	520.8	914.8	394.0
Dry Weight (g/m2, 60C)															
Top above 10 cm	606.4	1,417.6	811.2	554.0	920.8	366.8	502.4	580.0	77.6	444.8	805.2	360.4	226.8	377.2	150.4
Bottom top (0~10 cm)	655.6	392.0	-263.6	903.6	402.0	-501.6	862.4	768.0	-94.4	314.8	660.8	346.0	1,565.6	1,559.6	-6.0
Roots (depth : 20 cm)	482.8	455.2	-27.6	1,471.2	176.8	-1,294.4	421.2	266.4	-154.8	173.6	357.6	184.0	245.2	432.4	187.2
Dry Matter Weight (g/m2, 130C)															
Top above 10 cm	-	-	-	533.3	857.5	324.2	454.2	548.6	94.4	398.3	763.5	365.2	213.9	583.8	369.9
Bottom top (0~10 cm)	-	-	-	867.0	382.0	-485.0	749.8	739.4	-10.3	300.3	611.4	311.1	1,456.2	1,699.2	243.1
Roots (depth : 20 cm)	-	-	-	1,426.9	167.2	-1,259.6	408.4	256.2	-152.3	164.2	339.1	174.9	238.5	422.6	184.1
Ratio of Dry Matter Weight (%)															
Top above 10 cm	-	-	-	18.9	61.0	-	28.2	35.5	-	46.2	44.5	-	11.2	21.6	-
Bottom top (0~10 cm)	-	-	-	30.7	27.2	-	46.5	47.9	-	34.8	35.7	-	76.3	62.8	-
Roots (depth : 20 cm)	-	-	-	50.5	11.9	-	25.3	16.6	-	19.0	19.8	-	12.5	15.6	-
Dry Matter % for Fresh Weight(60C)															
Top above 10 cm	26.5	34.2	7.7	23.8	19.8	-4.0	25.4	26.8	1.4	24.3	28.4	4.1	25.0	26.4	1.4
Bottom top (0~10 cm)	41.5	28.1	-13.4	37.6	18.9	-18.7	46.0	39.6	-6.4	38.3	42.9	4.6	43.4	42.4	-1.0
Roots (depth : 20 cm)	30.8	13.1	-17.7	46.9	24.4	-22.5	45.7	70.2	24.5	54.5	37.8	-16.7	47.1	47.3	0.2
Dry Matter % for Fresh Weight(130C)															
Top above 10 cm	-	-	-	22.9	18.4	-4.5	23.0	25.4	2.4	21.8	26.9	5.1	23.6	25.3	1.7
Bottom top (0~10 cm)	-	-	-	36.1	18.0	-18.1	40.0	38.1	-1.9	36.5	39.7	3.2	40.4	41.0	0.6
Roots (depth : 20 cm)	-	-	-	45.5	23.1	-22.4	44.3	67.5	23.2	51.5	35.8	-15.7	45.8	46.2	0.4
Time of Harvest	6-Jun			17-Jul			4-Sep			3-Nov.			27-Feb.		

Note: Observation was carried out on the samples of 50 cm square in healthy growth condition.

Table A-2.6.2 Effects of various factors on growth characteristics of Rhodes grass (31 August, 1996)

Treatments			Items	Number of	Rate of	Dry matter Weight g/m2			Increase	Ratio of dry matter weight %		
Irrigation & urea	Potassium	Compost	Location	stems-/m2	heading %	Top	Bottom	Root	during 14days	Top	Bottom	Root
High level	Applied	-	B-1	1,900	6.9	502.6	970.1	115.2	294.9	31.7	61.1	7.3
High level	Applied	Applied	B-2	1,808	8.4	548.1	781.5	103.5	273.4	38.2	54.5	7.2
			Average	**1,854**	**7.7**	**525.4**	**875.8**	**109.4**	**284.2**	**35.0**	**57.8**	**7.2**
High level	-	-	C-1	1,500	1.3	329.2	799.8	132.1	166.8	26.1	63.4	10.5
High level	-	Applied	C-2	1,800	5.8	730.5	953.8	167.5	413.7	39.4	51.5	9.0
			Average	**1,650**	**3.6**	**529.8**	**876.8**	**149.8**	**290.2**	**32.8**	**57.5**	**9.8**
		Average		*1,752*	*5.6*	*527.6*	*876.3*	*129.6*	*287.2*	*33.9*	*57.6*	*8.5*
Low level	Applied	-	A-1	1,580	3.5	264.7	963.7	111.7	-24.1	19.7	71.9	8.3
Low level	Applied	Applied	A-2	1,720	6.0	435.8	1,296.0	200.7	273.7	22.5	67.1	10.4
			Average	**1,650**	**4.8**	**350.2**	**1,129.8**	**156.2**	**124.8**	**21.1**	**69.5**	**9.4**
Low level	-	-	D-1	1,640	6.8	335.6	1,597.4	205.6	135.2	15.7	74.7	9.6
Low level	-	Applied	D-2	2,080	5.2	285.2	1,133.4	176.4	44.9	17.9	71.1	11.1
			Average	**1,860**	**6.0**	**310.4**	**1,365.4**	**191.0**	**90.1**	**16.8**	**72.9**	**10.3**
		Average		*1,755.0*	*5.4*	*330.3*	*1,247.6*	*173.6*	*107.4*	*19.0*	*71.2*	*9.8*

A-2.7 Growth of windbreak trees

Table A-2.7.1 Growth of windbreak trees in 1995

Kind of Tree	Location	Items	22-May	21 Aug.		23 Oct.		13-Nov.	
			Average	Average	Increase during 3 months	Average	Increase during 2 months	Average	Increase during 3 months
		Height	cm	cm	cm	cm	cm	cm	cm
J : Prosopis juliflora	Fence		-	-	-	-	-		
	Main Road		192.5	263.0	70.5	252.5	-10.5	-	-
S : Ziziphus spina-christi	Fence		177.5	217.4	39.9	-	-	336.0	118.6
	Main Road		200.5	275.5	75.0	310.0	34.5	-	-
T : Prosopis cineraria	Fence		117.0	91.0	-26.0	-	-	172.0	81.0
	Main Road		108.5	118.0	9.5	169.5	51.5	-	-
C : Acasia tortilis	Fence		-	-	-	-	-	-	
	Main Road		167.5	231.0	63.5	285.0	54.0		
L : Conocarpus lancifolia	Fence		254.0	307.0	53.0	-	-	390.0	83.0
	Main Road		223.0	279.3	56.3	319.5	40.2	-	-
P : Pithecolobium dulace	Fence		157.0	194.1	37.1	-	-	290.0	95.9
	Main Road		161.5	212.9	51.4	243.3	30.4	-	-
		Canopy							
J : Prosopis juliflora	Fence	X	-	-	-	-	-	-	-
		Y	-	-	-	-	-	-	-
	Main Road	X	383.5	450.8	67.3	325.9	-124.9	-	-
		Y	355.7	441.4	85.7	323.4	-118.0	-	-
S : Ziziphus spina-christi	Fence	X	156.5	198.8	42.3	-	-	326.0	127.2
		Y	152.0	166.2	14.2	-	-	285.0	118.8
	Main Road	X	177.5	232.2	54.7	209.3	-22.9	-	-
		Y	157.5	174.4	16.9	198.1	23.7	-	-
T : Prosopis cineraria	Fence	X	142.5	180.4	37.9	-	-	286.0	105.6
		Y	144.5	160.4	15.9	-	-	264.0	103.6
	Main Road	X	156.5	201.9	45.4	190.9	-11.0	-	-
		Y	143.0	193.0	50.0	177.5	-15.5	-	-
C : Acasia tortilis	Fence	X	-	-	-	-	-		
		Y	-	-	-	-	-		
	Main Road	X	142.5	291.6	149.1	213.3	-78.3	-	-
		Y	159.0	288.0	129.0	223.6	-64.4	-	-
L : Conocarpus lancifolia	Fence	X	155.0	217.5	62.5	-	-	280.0	62.5
		Y	172.0	203.6	31.6	-	-	270.0	66.4
	Main Road	X	158.0	193.8	35.8	200.6	6.8	-	-
		Y	158.5	188.7	30.2	201.9	13.2	-	-
P : Pithecolobium dulace	Fence	X	168.0	237.6	69.6	-	-	420.0	182.4
		Y	168.5	201.6	33.1	-	-	400.0	198.4
	Main Road	X	194.5	261.4	66.9	208.5	-52.9	-	-
		Y	195.5	227.3	31.8	232.5	5.2	-	-

Table A-2.7.2 Growth of windbreak trees in 1996

Kind of Trees	Location	22-May	21 Aug., 1995		23 Oct.		13-Nov.		23-Mar., 1996		13-May		6-Aug.	
		Average	Average	Increase during 3 months	Average	Increase during 2 months	Average	Increase during 3 months	Average	Increase during 5 months	Average	Increase during 6 months	Average	Increase during 5 months
Height		m	m	m	m	m	m	m	m	m	m	m	m	m
J : Prosopis juliflora	Fence	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Road	1.9	2.6	0.7	2.5	-0.1	-	-	2.7	0.2	-	-	2.5	-0.2
S : Ziziphus spina-christi	Fence	1.8	2.2	0.4	-	-	3.4	1.2	-	-	3.5	0.1	-	-
	Main Road	2.0	2.8	0.8	3.1	0.3	-	-	3.9	0.8	-	-	3.9	0.0
T : Prosopis cineraria	Fence	1.2	0.9	-0.3	-	-	1.7	0.8	-	-	2.2	0.5	-	-
	Main Road	1.1	1.2	0.1	1.7	0.5	-	-	1.9	0.2	-	-	2.2	0.3
C : Acasia tortilis	Fence	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Road	1.7	2.3	0.6	2.9	0.5	-	-	3.4	0.6	-	-	3.7	0.3
L : Conocarpus lancifolia	Fence	2.5	3.1	0.5	-	-	3.9	0.8	-	-	3.9	0.0	-	-
	Main Road	2.2	2.8	0.6	3.2	0.4	-	-	3.8	0.6	-	-	3.9	0.1
P : Pithecolobium dulace	Fence	1.6	1.9	0.4	-	-	2.9	1.0	-	-	3.8	0.9	-	-
	Main Road	1.6	2.1	0.5	2.4	0.3	-	-	3.5	1.1	-	-	3.6	0.1
Canopy		m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2	m2
J : Prosopis juliflora	Fence	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Road	10.7	15.6	4.9	8.3	-7.3	-	-	12.2	4.0	-	-	11.0	-1.2
S : Ziziphus spina-christi	Fence	1.9	2.6	0.7	-	-	7.3	4.7	-	-	4.7	0.0	-	-
	Main Road	2.2	3.2	1.0	3.3	0.0	-	-	7.1	3.8	-	-	6.6	-0.5
T : Prosopis cineraria	Fence	1.6	2.3	0.7	-	-	5.9	3.7	-	-	5.5	1.9	-	-
	Main Road	1.8	3.1	1.3	2.7	-0.4	-	-	3.6	1.0	-	-	5.1	1.5
C : Acasia tortilis	Fence	-	-	-	-	-	-	-	-	-	-	-	-	-
	Main Road	1.8	6.6	4.8	3.7	-2.8	-	-	5.1	1.4	-	-	8.0	2.9
L : Conocarpus lancifolia	Fence	2.1	3.5	1.4	-	-	5.9	2.5	-	-	3.8	1.3	-	-
	Main Road	2.0	2.9	0.9	3.2	0.3	-	-	4.0	0.8	-	-	4.7	0.7
P : Pithecolobium dulace	Fence	2.2	3.8	1.6	-	-	13.2	9.4	-	-	10.2	0.8	-	-
	Main Road	3.0	4.7	1.7	3.8	-0.9	-	-	12.2	8.4	-	-	9.6	-2.6

Note: Area (m2) of canopy was calculated with regarding the projection of tree as circle.

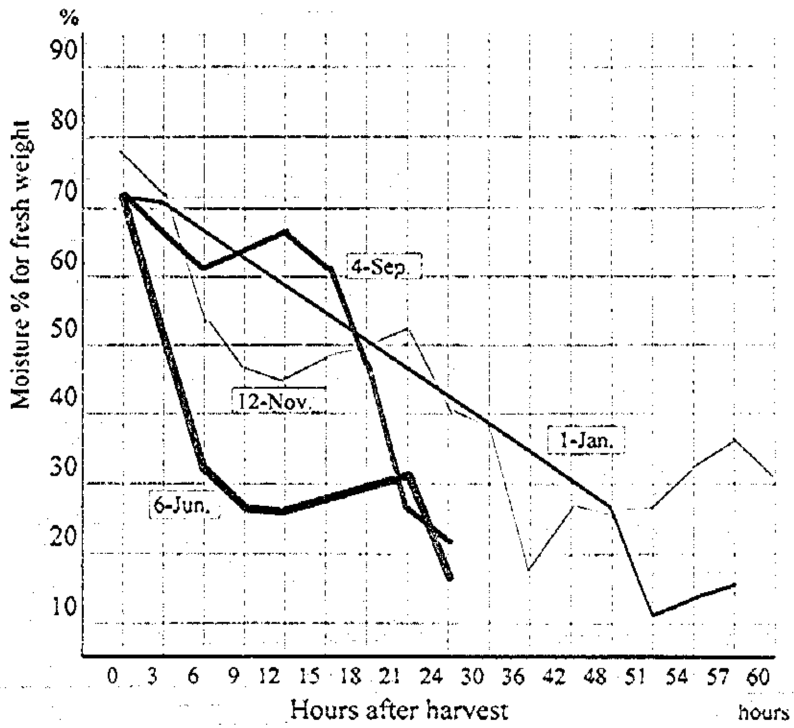
A-2.8 Change of moisture content of cut grass in the field

Table A-2.8.1 The change of moisture contents in top of Rhodes grass after cutting

Date	6-Jun		4-Sept.		12-Nov.,1995		1-Jan.,1996	
Items	Time	Moisture	Time	Moisture	Time	Moisture	Time	Moisture
		%		%		%		%
After harvest	10:00	71.7	17:00	70.1	10:00	78.7	13:00	71.4
After 3 hours	13:00	51.7	20:20	66.7	13:00	72.3	15:00	71.2
After 6 hours	16:00	31.9	23:20	61.7	16:00	52.9	-	-
After 9 hours	19:00	25.6	-	-	19:00	46.5	-	-
After 12 hours	22:00	26.1	5:30	66.4	22:00	44.8	-	-
After 15 hours	-	-	8:30	60.8	1:00	48.5	-	-
After 18 hours	-	-	11:30	48.2	4:00	50.1	-	-
After 21 hours	7:00	30.8	14:30	27.3	7:00	51.7	-	-
After 24 hours	10:00	17.6	17:30	22.0	11:30	39.9	-	-
After 30 hours	-	-	-	-	13:00	39.4	-	-
After 36 hours	-	-	-	-	16:00	18.4	-	-
After 42 hours	-	-	-	-	19:00	26.6	-	-
After 48 hours	-	-	-	-	22:00	25.4	14:00	27.5
After 51 hours	-	-	-	-	1:00	27.1	16:00	11.2
After 54 hours	-	-	-	-	4:00	31.9	19:00	14.8
After 57 hours	-	-	-	-	7:00	36.7	22:00	15.5
After 60 hours	-	-	-	-	10:30	31.8	-	-

Note: Moisture contents show average percentage of moisture for fresh weight of two or three samples.

Fig. A-2.8.1 Change of moisture contents of cut grass by season



A-2.9 Contents of nutrients of hay

Sample		Location	Farm-1*	Farm-2*	NARS*		
		Date	12-Jun.,'95	12-Jun.,'95	12-Jun.,'95	11-Mar.,'96	30-Sep.,'96
		Unit					
Minerals	Moisture	%	6.60	6.80	7.00	8.63	8.84
	NO3-N	mg/g					2.68
	P	mg/g	3.10	2.40	0.80	2.50	1.90
	K	mg/g					0.50
	Ca	mg/g	4.30	6.30	3.90	5.90	2.53
	Mg	mg/g					1.24
	Fe	mg/g					0.03
	Mg	mg/g					0.08
	Mo	mg/g					0.004
	Cu	mg/g					0.0003
	Zn	mg/g					0.002
	Acid in Soluble Ash	%	2.31	3.46	3.48	3.29	3.46
Nutrients	Crude Protein	%	8.30	8.00	4.70	6.37	4.80
	Crude Fat	%	1.70	2.20	1.33	2.22	1.65
	Crude Fibre	%	32.35	29.80	35.00	29.56	33.55
	Nitrogen-free Extract	%	42.23	42.53	44.31	44.43	44.30
	Ash	%	8.82	10.67	7.66	8.81	8.90
	Organic Substance	%	84.58	82.53	85.34	82.56	84.30

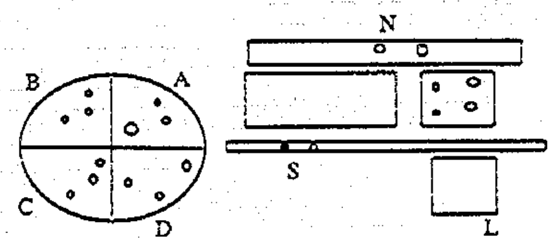
Note: 1) Analyst: Dhofar Cattle Feeding Factory
2) ** NARS: Nejd Agricutural Research Center,
Farm-1, and Farm-2: Farms near NARS

APPENDIX - 3
SOIL

Table A - 3.1 Measurement of pH, EC and Organic Matter

Sample	pH(1:2.5)					EC (1:5), mS/cm					Organic Matter (%)				
No.	May. 95	Aug. 95	Apr. 96	July. 96	Oct. 96	May. 95	Aug. 95	Apr. 96	July. 96	Oct. 96	May. 95	Aug. 95	Mar. 96	June. 96	Oct. 96
A-1	8.1	8.2	8.1	8.2	8.0	0.276	0.640	0.445	0.833	0.240	0.20	0.00	0.25	0.50	1.00
A-2	8.2	8.4	8.0	8.2	7.7	0.226	0.730	0.346	0.751	0.260	0.10	0.00	0.25	0.50	0.50
B-1	8.0	8.2	8.1	7.6	7.8	0.237	0.558	0.302	0.339	0.243	0.10	0.00	0.25	0.50	0.75
B-2	7.9	8.1	7.9	8.1	7.8	0.332	0.510	0.499	0.605	0.200	0.10	0.00	0.75	0.50	1.00
C-1	8.0	8.4	8.2	8.2	7.8	0.258	0.380	0.489	0.570	0.245	1.00	0.00	0.50	0.50	1.50
C-2	7.9	8.2	8.2	8.1	7.9	0.361	0.662	0.371	0.560	0.224	1.75	0.00	0.25	0.50	1.00
D-1	8.1	8.3	8.1	8.0	8.0	0.264	0.643	0.553	0.720	0.305	0.10	0.00	0.25	0.50	0.75
D-2	7.8	8.2	8.1	8.0	7.8	0.339	0.742	0.438	0.446	0.605	0.20	0.00	0.25	0.50	0.50
N-1	8.0	8.3	8.1	8.3	8.1	0.311	0.671	0.242	0.218	0.155	0.00	0.00	1.00	0.50	1.75
N-2	8.3	7.9	8.1	8.1	8.0	0.187	0.880	0.280	0.220	0.230	0.10	0.00	1.00	0.50	2.00
S-1	7.8	8.5	8.1	8.0	8.0	0.275	0.573	0.459	0.251	0.209	0.10	0.00	0.75	1.00	2.00
S-2	8.0	8.4	7.8	8.0	7.9	0.507	0.489	0.485	0.232	0.255	0.10	0.00	0.75	1.00	1.00

A=North East Quarter in C.P.
B=North West Quarter in C.P.
C=South West Quarter in C.P.
D=South East Quarter in C.P.
S=South Windbreak trees
N=North Windbreak trees



Appendix A - 3.2 (1) Summary of Pit Excavation Survey (Pit - 1)

Date of Survey : May 1, 1995
Location : Nejd Agricultural Research Station, Center pivot northern direction

1) Site Information

USDA Classification : Typic Calciorthids (Calcids)
FAO Classification : Calcic Yemosols
Elevation : 282 m
Slope : < 1%
Micro relief : Even
Landuse : Rhodes grass

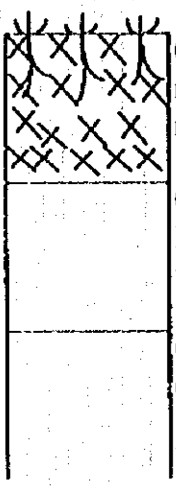
2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

Top layer consists of sandy loam. More grass roots are found at the top 30 cms There is a high calcium carbonate through out the profile Gypsum occurs continously below 30 cms

4) Profile description



Horizon	Description
Apk (0-30cm)	Color is bright brown (7.5 YR 5/8) ; coarse sandy ; moist and very friable ; > 30% gravel; single grains ; more roots are concentrated; strong reaction to HCl.
B1k (30-65 cm)	Color is yellow orange (7.5 YR 7/8) Loamy sand ; moist and friable ; platy; Violent reaction to HCl
B12k (65 - 100 cm)	Color is dull yellowish brown (10 YR 5/3) More clayey ; subangular blocky structure; this layer is more harder than the upper layer. Violent reaction to HCl

Appendix A - 3.2 (2) Summary of Pit Excavation Survey (Pit - 2)

Date : May 1, 1995
Location : Nejd Agricultural Research Station, Center pivot Southern direction

1) Site Information

USDA Classification : Typic Calciorthids (Calcids)
FAO Classification : Calcic Yemosols
Elevation : 282 m
Slope : < 1%
Micro relief : Even
Landuse : Rhodes grass

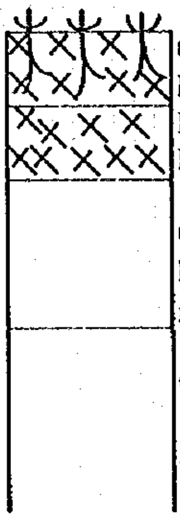
2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well ; water standing in some locations nearby after the irrigation
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

Top layer consists of sandy loam. More grass roots are found at the top 30 cms
There is a high calcium carbonate through out the profile Gypsum occurs
continously below 15 cms.

4) Profile description



Horizon	Description
Ap (0-15 cm)	Color is bright brown (7.5 YR 5/6) ; coarse sandy ; Moist and friable ; more roots
A1 (15-35 cm)	Dull brown (10YR 5/4); gravelly sandy; Moist and friable; some roots; violent reaction to H
B11km (35-65 cm)	Color is yellowish brown (10 YR 5/6) hard layer; Moist and very firm ; gypsum is found; violent reaction to HCl
B12 (65 - 100 cm)	Color is dull yellowish brown (10 YR 5/3) More clayey ; gypsum layers are found and the layer is more harder than the upper layer Violent reaction to HCl

Appendix A - 3.2 (3) Summary of Pit Excavation Survey (Pit - 3)

Date : May 2, 1995
Location : Nejd Agricultural Research Station, Near meteorological station

1) Site Information

USDA Classification : Typic Calciorthids
FAO Classification : Calcic Yemosols
Elevation : 283 m
Slope : < 1%
Micro relief : Even
Landuse : No crop as on May 2, 1995

2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

Virgin soil and no cultivation is done until now.
Top layer consists of sandy loam.
There is a high calcium carbonate through out the profile continously below 30 cms. The layers are very hard after 30 cms and is slightly more harder after 80 cms.

4) Profile description

Horizon	Description
Ak (0-30cm)	Color is bright brown (7.5 YR 5/6) ; Sandy loam ; dry and slightly hard ; > 30% gravel; single grains ; violent reaction to HCl; no crop growth
B11km (30-80 cm)	Color is dull orange (7.5 YR 6/4) gravelly loamy sand ; dry and very hard subangular blocky; Violent reaction to HCl
B12km (65 - 100 cm)	Color is dull orange (7.5 YR 6/4) gravelly loamy sand ; dry and very hard subangular blocky; More harder than the upper layer; violent reaction to HCl

Appendix A - 3.2 (4) Summary of Pit Excavation Survey (Pit - 4)

Date of Survey : September 10, 1995
Location : Nejd Agricultural Research Station, Center pivot northern direction

1) Site Information

USDA Classification : Typic Calciorthids (Calcids)
FAO Classification : Calcic Yemosols
Elevation : 282 m
Slope : < 1%
Micro relief : Even
Landuse : Rhodes grass

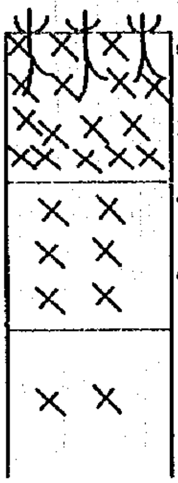
2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

More grass roots (70%) are found at the top 20 cms.
Fewer roots (25%) were observed at the second layer.
There is a high calcium carbonate through out the profile.

4) Profile description



Horizon	Description
Apk (0-20cm)	Color is bright yellowish brown (10 YR 6/6) ; Sandy loam; loose and very friable ; more roots are concentrated; violent reaction to HCl.
B1k (20-61 cm)	Color is Yellowish Brown (10 YR 5/8) Sandy clay loam ; Loose and friable ; Fewer roots (25%) are concentrated ; Violent reaction to HCl.
B12k (61 - 100 cm)	Color is yellow orange (10 YR 8/6); Loam ; subangular blocky structure; this layer is more harder than the upper layer. Violent reaction to HCl

Appendix A - 3.2 (5) Summary of Pit Excavation Survey (Pit - 5)

Date of Survey : September 10, 1995
Location : Nejd Agricultural Research Station, Center pivot western direction

1) Site Information

USDA Classification : Typic Calciorthids (Calcids)
FAO Classification : Calcic Yemosols
Elevation : 282 m
Slope : < 1%
Micro relief : Even
Landuse : Rhodes grass

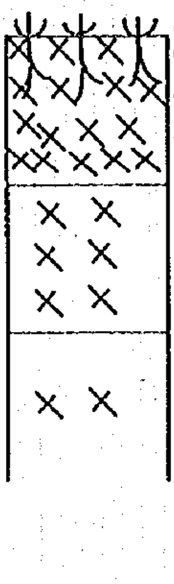
2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

More grass roots (70%) are found at the top 30 cms.
Fewer roots (20%) were observed at the second layer.
There is a high calcium carbonate through out the profile.

4) Profile description



Horizon	Description
Apk (0-32 cm)	Color is dull yellowish orange (10 YR 6/4) ; Sandy loam; loose and very friable ; more roots are concentrated; Violent reaction to HCl
B1k (32-70 cm)	Color is bright yellowish brown (10 YR 6/6); Sandy loam ; Loose and friable ; Fewer roots (20%) are concentrated ; Violent reaction to HCl.
B12k (70 - 100 cm)	Color is bright yellowish brown (10 YR 6/6); Sandy loam ; Loose and friable ; Violent reaction to HCl

Appendix A - 3.2 (6) Summary of Pit Excavation Survey (Pit - 6)

Date of Survey : September 11, 1995
Location : Nejd Agricultural Research Station, Center pivot northern direction

1) Site Information

USDA Classification : Typic Calciorthids (Calcids)
FAO Classification : Calcic Yemosols
Elevation : 282 m
Slope : < 1%
Micro relief : Even
Landuse : Rhodes grass

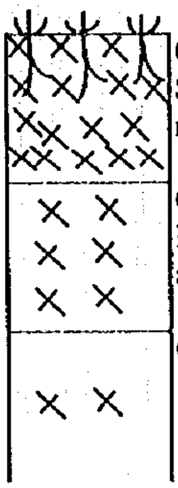
2) Information of the Soil

Surface feature : Loose sand and gravel
Drainage : Moderately well
Evidence of erosion : None
Sand hazard by wind : Slight

3) Brief description of the profile

More grass roots (70%) are found at the top 30 cms.
Fewer roots (10-12%) were observed at the second layer.
There is a high calcium carbonate through out the profile.

4) Profile description



Horizon	Description
Apk (0-25 cm)	Color is dull yellowish orange (10 YR 7/2) ; Sandy loam; loose and very friable ; more roots are concentrated; Violent reaction to HCl.
B1k (25-57 cm)	Color is orange (7.5 YR 7/6); Loam ; Loose and friable ; Fewer roots (10-12%) are concentrated ; Violent reaction to HCl.
B12k (57 - 100 cm)	Color is dul yellow orange (10 YR 7/3); Loam ; Loose and friable ; Violent reaction to HCl

Table A - 3.3 (1) Results of Soil Chemical Analysis

Date : May 1, 1995

Sampling No.	Sampling Location	pH (1:2.5)	EC (1:5) mS/cm	ECe mS/cm	Total N (%)	Avail. P (ppm)	Micro Nutrients, ppm Fe	Mn	Cu	Zn	$CaCO_3$ (%)	Gypsum (%)	Organic matter(%)	Exch. Na^+	CEC (me/100g)
1	P1-H1	7.5	0.320	2.80	0.006	Trace	1.54	1.48	0.22	0.20	51.4	Trace	Trace	2.2	4.8
2	P1-H2	7.7	0.250	2.60	0.006	Trace	1.20	0.74	0.16	0.08	50.6	Trace	Trace	2.0	4.9
3	P1-H3	7.7	0.330	2.40	0.004	Trace	1.18	0.68	0.16	0.04	53.6	Trace	Trace	2.4	5.8
4	P2A-H1	7.3	2.200	4.00	0.007	Trace	0.90	0.40	0.12	0.08	35.1	8.2	Trace	2.5	6.5
5	P2-H1	7.4	2.200	5.00	0.010	Trace	1.44	0.64	0.14	0.08	40.7	2.5	Trace	1.8	4.3
6	P2-H2	7.3	2.400	6.80	0.006	Trace	0.78	0.40	0.12	0.36	39.8	5.2	Trace	2.5	5.7
7	P2-H3	7.4	6.200	38.00	0.011	Trace	0.86	0.06	0.14	0.16	43.4	1.1	Trace	1.6	4.5
8	P3-H1	7.5	1.600	14.00	0.010	Trace	0.82	0.34	0.16	0.62	52.3	Trace	Trace	1.9	4.1
9	P3-H2	7.6	1.000	10.00	0.005	Trace	0.84	0.40	0.16	0.90	55.7	Trace	Trace	2.1	3.5
10	P3-H3	7.6	1.000	12.00	0.008	Trace	0.98	0.26	0.26	0.30	57.8	Trace	Trace	2.0	3.3

Sampling No.	Sat'n %	Soluble cations (meq/l) Ca^{++}	Mg^{++}	Na^+	K^+	SAR	Soluble anions (me/l) Cl^-	$SO4^{--}$	HCO_3^-	C.Sand	F.Sand	Silt	Clay	Texture
1	34.4	12.0	32.0	9.9	1.0	2.1	20.0	24.9	10.0	14.66	62.1	13.1	10.1	Sandy loam
2	39.1	8.0	20.0	9.9	0.8	2.6	10.0	24.6	4.0	7.80	71.1	1.0	20.1	Sandy clay loam
3	45.5	10.0	24.0	9.2	0.8	2.2	20.0	21.9	2.0	5.28	45.4	21.2	28.1	Sandy clay loam
4	40.1	12.0	50.0	9.0	1.0	1.6	20.0	60.0	2.0	5.80	55.9	6.6	31.7	Sandy clay loam
5	31.6	32.0	50.0	13.2	0.8	2.1	30.0	64.0	2.0	7.76	64.5	6.0	21.7	Sandy clay loam
6	42.8	34.0	58.0	22.0	1.5	3.2	40.0	73.6	2.0	7.58	51.3	11.0	30.1	Sandy clay loam
7	42.6	86.0	170.0	21.7	6.7	1.9	400.0	117.6	4.0	4.20	60.7	9.4	25.7	Sandy clay loam
8	32.0	62.0	108.0	46.7	1.8	5.1	80.0	133.9	4.0	10.86	48.0	15.0	26.1	Sandy clay loam
9	36.4	32.0	80.0	41.1	2.1	5.5	100.0	51.2	2.0	6.20	40.7	29.0	24.1	Sandy clay loam
10	31.6	30.0	62.0	47.0	2.6	6.9	100.0	39.5	4.0	8.90	42.0	27.0	22.1	Loam

Note : P1, P2 and P3 correspond to profiles 1,2, and 3; H1, H2 and H3 correspond to Horizons 1, 2 and 3.
Locations : P1 - Northern side of Center pivot; Profile P2 - Southwestern corner of center pivot where there is high gypsum.
P3 - Virgin soil near the meteorological station

Table A - 3.3 (2) Results of Soil Chemical Analysis

Date : May 1, 1995

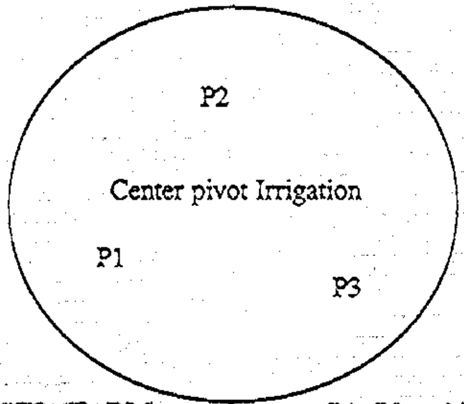
Sampling No.	Sampling Location	pH (1:2.5)	EC (1:5 mS/cm	ECe mS/cm	Total N (%)	Avail. P (ppm)	Micro Nutrients, ppm Fe	Mn	Cu	Zn	CaCO3 (%)	Gypsum (%)	Organic matter(%)	Exch. Na^+ (me/100g)	CEC (me/100g)
11	L1	7.9	0.280	3.200	0.011	Trace	1.60	0.98	0.22	0.18	47.6	Trace	Trace	2.17	4.26
12	L2	8.0	0.200	1.600	0.009	Trace	2.68	0.56	0.12	0.26	43.3	Trace	Trace	1.91	4.00
13	L3	8.0	0.230	1.800	0.010	Trace	2.64	1.12	0.20	0.56	47.1	Trace	Trace	2.09	4.26
14	L4	7.9	0.240	2.700	0.014	Trace	3.32	1.30	0.16	0.38	57.8	Trace	Trace	1.74	4.96
15	L5	7.9	0.380	4.400	0.012	Trace	2.20	0.92	0.16	0.20	53.6	Trace	Trace	2.17	8.09
16	L6	8.0	0.220	2.200	0.014	Trace	3.86	1.02	0.14	0.44	47.1	Trace	Trace	2.00	8.61
17	L7	7.9	0.370	3.600	0.014	Trace	1.96	3.04	0.26	0.48	43.7	Trace	Trace	2.35	4.70
18	L8	8.0	0.320	3.800	0.014	Trace	2.50	1.14	0.18	0.34	57.8	Trace	Trace	2.00	3.48
19	L9	7.5	2.100	4.000	0.034	Trace	2.02	1.06	0.18	0.82	44.6	1.3	Trace	2.17	6.70
20	L10	8.0	0.230	2.000	0.011	Trace	3.72	1.98	0.20	1.28	53.6	Trace	Trace	1.91	8.43

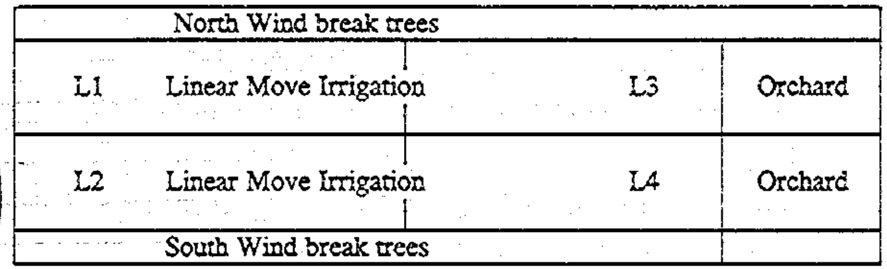
Sampling No.	Sat'n %	Soluble cations (me/l) Ca^{++}	Mg^{++}	Na^+	K^+	SAR	Soluble anions (me/l) Cl^-	$SO4^{--}$	HCO_3^-	C.Sand	F.Sand	Silt	Clay	Texture
11	31.0	8.0	32.0	11.78	0.77	2.6	20.0	28.6	4.0	10.8	68.1	9.0	12.1	Loamy Sand
12	27.3	4.0	20.0	6.17	0.25	1.8	10.0	16.4	4.0	9.3	77.6	3.0	10.1	Loamy Sand
13	26.6	4.0	16.0	7.04	0.51	2.2	20.0	3.6	4.0	25.0	55.9	7.0	12.1	Loamy Sand
14	24.2	12.0	28.0	10.04	0.77	2.2	20.0	26.8	4.0	25.0	57.9	5.0	12.1	Loamy Sand
15	24.5	14.0	46.0	13.61	1.79	2.5	30.0	41.4	4.0	21.4	57.5	1.0	20.1	Sandy clay loam
16	22.8	12.0	20.0	5.13	0.77	1.3	20.0	15.9	2.0	23.7	55.2	3.0	18.1	Sandy loam
17	32.4	10.0	46.0	12.26	1.54	2.3	30.0	33.8	6.0	11.0	55.9	15.0	18.1	Sandy loam
18	25.8	8.0	34.0	13.50	1.54	2.9	30.0	23.0	4.0	27.5	41.4	13.0	18.1	Sandy loam
19	32.2	16.0	64.0	8.26	0.77	1.3	20.0	65.0	4.0	4.0	54.9	15.0	26.1	Sandy clay loam
20	30.0	6.0	20.0	6.91	0.51	1.9	20.0	9.4	4.0	18.6	56.3	7.0	18.1	Sandy loam

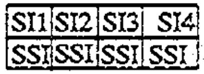
The samples were collected at the upper horizons at various locations of the field.
Locations : L1 - Eastern side of C.P; L2 - Northern side of C.P; L3 - Western side of C.P; L4 - Southern side of C.P.
L5 - Southeast quater of L.M; L6 - Northeast quater of L.M; L7 - Northweast quater of L.M; L8 - Southwest quater of L.M
L9 - Southern side windbreak trees; L10 - Northern side windbreak trees

Appendix A - 3.3 (3) Soil Sampling Locations - (1/2)

Date : September 23, 1995



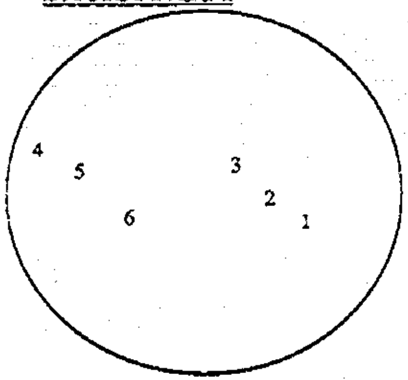




SI - Lysimeter with Sprinkler Irrigation
SSI - Lysimeter with Subsurface Irrigation

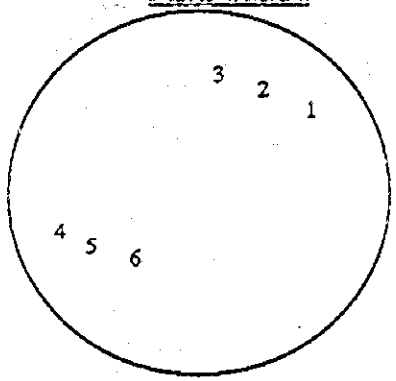
P1, P2 and P3 represent the locations of the three profiles

<u>DAUKA FARM</u>



1 to 6 represents the sampling locations

<u>NEJD FARM</u>



Dauka farm is located at around 40 km from NARS

Nejd farm is located at around 8 km from NARS

Appendix Table A - 3.3 (3) Soil Sampling Locations - (2/2)

Date : September 23, 1995

Sample No	Sampling Location	Sample No	Sampling Location	Sample No	Sampling Location
Center pivot irrigation location		**Lysimeter**		**Dauka Farm**	**Center Pivot**
NARS-1	Profile 1, Horizon 1 (0-20cm)	NARS-22	Subsurface Irrigation 3 (0-30cm)	DAUKA-1	Location 1, 0-30 cm
NARS-2	Profile 1, Horizon 2 (20-61cm)	NARS-23	Subsurface Irrigation 3 (60-90cm)	DAUKA-2	Location 2, 0-30 cm
NARS-3	Profile 1, Horizon 3 (61-100cm)	NARS-24	Subsurface Irrigation 4 (0-30cm)	DAUKA-3	Location 3, 0-30 cm
NARS-4	Profile 2, Horizon 1 (0-32cm)	NARS-25	Subsurface Irrigation 4 (60-90cm)	DAUKA-4	Location 4, 0-30 cm
NARS-5	Profile 2, Horizon 2 (32-70cm)			DAUKA-5	Location 5, 0-30 cm
NARS-6	Profile 3, Horizon 3 (70-100cm)	**Windbreak trees locations**		DAUKA-6	Location 6, 0-30 cm
NARS-7	Profile 3, Horizon 1 (0-25cm)				
NARS-8	Profile 3, Horizon 2 (25-57cm)	NARS-26	Southern side, sample 1	**Nejd Farm**	**Center Pivot**
NARS-9	Profile 3, Horizon 3 (57-100cm)	NARS-27	Southern side, sample 2		
		NARS-28	Southern side, sample 3	NEJD-1	Location 1, 0-30 cm
Lysimeter		NARS-29	Northern side, sample 1	NEJD-2	Location 2, 0-30 cm
		NARS-30	Northern side, sample 2	NEJD-3	Location 3, 0-30 cm
NARS-10	Surface Irrigation 1 (0-30cm)	NARS-31	Northern side, sample 3	NEJD-4	Location 4, 0-30 cm
NARS-11	Surface Irrigation 1 (60-90cm)			NEJD-5	Location 5, 0-30 cm
NARS-12	Surface Irrigation 2 (0-30cm)	**Orchard**		NEJD-6	Location 6, 0-30 cm
NARS-13	Surface Irrigation 2 (60-90cm)				
NARS-14	Surface Irrigation 3 (0-30cm)	NARS-32	Orchard, Sample 1		
NARS-15	Surface Irrigation 3 (60-90cm)	NARS-33	Orchard, Sample 2		
NARS-16	Surface Irrigation 4 (0-30cm)	NARS-34	Orchard, Sample 3		
NARS-17	Surface Irrigation 4 (60-90cm)				
NARS-18	Subsurface Irrigation 1 (0-30cm	**Linear Move Irrigation**			
NARS-19	Subsurface Irrigation 1 (60-90cm)				
NARS-20	Subsurface Irrigation 2 (0-30cm	NARS-35	Linear Move Irrigation, L1		
NARS-21	Subsurface Irrigation 2 (60-90c	NARS-36	Linear Move Irrigation, L2		
		NARS-37	Linear Move Irrigation, L3		
		NARS-38	Linear Move Irrigation, L4		

Table A - 3.3 (4) Results of Soil Chemical Analysis

Date : September 23, 1995

Sampling No.	Sampling Location	pH (1:2.5)	C (1:5 mS/cm	ECe mS/cm	Total N (%)	Avail. P (ppm)	Micro Nutrients, ppm				$CaCO_3$ (%)	Gypsum (%)	Organic matter(%)
							Fe	Mn	Cu	Zn			
1	NARS 10	6.7	2.100	6.700	0.000	0.54	1.50	0.50	0.24	0.40	55.71	Trace	0.02
2	NARS 11	6.6	1.800	6.200	0.002	1.34	1.50	0.44	0.24	0.30	51.32	Trace	0.16
3	NARS 18	7.0	2.800	22.000	0.008	7.53	1.60	1.12	0.28	0.62	60.53	Trace	0.03
4	NARS 19	6.8	1.800	6.600	0.000	6.08	1.26	0.48	0.26	0.22	53.08	Trace	0.02
5	NARS 26	7.2	0.420	4.400	0.053	23.76	8.24	3.30	0.48	1.90	49.13	Trace	0.13
6	NARS 29	7.2	0.360	4.000	0.061	23.05	7.66	6.46	0.42	2.62	43.86	Trace	0.18
7	NARS 35	7.2	0.480	5.600	0.001	20.99	3.42	2.00	0.36	0.52	56.60	Trace	0.02
8	DAUKA 1	7.3	0.460	4.300	0.038	20.34	3.64	2.18	0.32	0.40	63.16	Trace	0.15
9	DAUKA 2	7.3	0.610	5.400	0.065	21.46	4.76	2.98	0.32	0.56	80.27	Trace	0.05
10	NEJD 1	7.4	0.770	5.300	0.022	25.26	2.64	3.18	0.42	0.30	44.74	Trace	0.01
11	NEJD 2	7.0	1.700	4.900	0.015	24.77	1.78	2.56	0.48	0.50	38.16	Trace	0.14

Sampling No.	Sampling Location	Exchangeable cations (me/100g)				CEC	ESP	Soluble cations (me/l)				Soluble anions (me/l)			SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	c/100	(%)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO_4^{--}	HCO_3^{-}	
1	NARS 10	2.9	1.6	0.40	0.31	5.04	7.94	28.0	30.0	30.9	1.54	45.0	43.84	1.6	5.74
2	NARS 11	2.2	1.9	0.40	0.56	4.17	9.59	16.0	34.0	37.0	1.03	40.0	45.43	2.6	7.40
3	NARS 18	2.7	1.6	1.10	0.72	6.00	18.33	51.0	63.0	167.8	9.00	21.5	72.60	3.2	22.23
4	NARS 19	3.0	1.5	0.45	0.62	4.87	9.24	11.0	45.0	38.3	1.30	40.0	52.20	3.4	7.24
5	NARS 26	3.0	1.3	0.25	0.56	5.52	4.53	15.0	21.0	16.1	0.26	35.0	10.36	7.0	3.79
6	NARS 29	2.9	1.2	0.30	0.56	5.22	5.75	12.0	16.0	16.1	0.26	40.0	7.44	11.8	4.30
7	NARS 35	3.1	0.6	0.30	0.46	4.43	6.77	12.0	27.0	29.1	0.77	45.0	17.77	6.1	6.59
8	DAUKA 1	2.3	1.2	0.30	0.41	4.10	7.32	14.0	15.0	19.6	0.26	30.0	11.06	7.8	5.15
9	DAUKA 2	3.2	1.3	0.50	0.41	5.80	8.62	13.0	26.0	31.3	0.26	45.0	14.66	10.9	7.09
10	NEJD 1	2.4	2.6	0.30	0.46	5.39	5.57	25.0	33.0	25.7	0.26	30.0	49.16	4.8	4.77
11	NEJD 2	3.2	1.6	0.35	0.46	6.43	5.44	17.0	33.0	20.9	0.26	25.0	40.76	5.4	4.18

The samples were collected at the following locations :
Locations : NARS 10 - Lysimeter surface irrigation (0-30cm), NARS 11- Lysimeter surface irrigation (60-90cm),
NARS 18 - Lysimeter Subsurface irrigation (0-30cm), NARS 11- Lysimeter Subsurface irrigation (60-90cm),
NARS 26 - Southern side windbreak trees, NARS 29 - Northern side windbreak trees, NARS 35 - Fruit trees
DAUKA1,2 - Dauka Farm Center Pivot Irrigation system, NEJD1,2 - Nejd Farm Center Pivot Irrigation system

Table A - 3.3 (5) Results of Soil Chemical Analysis (1/2)

Date : September 23, 1995

Sl. No.	Sampling Location	pH (1:2.5)	EC (1:5) mS/cm	% C.Sand	% F.Sand	% Silt	% Clay	Texure	$CaCO_3$ (%)
1	NARS - 1	7.7	0.540	35.6	42.1	10.6	11.7	Sandy Loam	54.9
2	NARS - 2	7.7	0.480	15.6	43.9	18.6	21.7	Sandy Clay Loam	50.0
3	NARS - 3	7.1	2.200	7.3	44.9	38.1	8.7	Loam	50.4
4	NARS - 4	7.7	0.300	12.0	67.7	8.6	11.7	Sandy Loam	57.0
5	NARS - 5	7.8	0.400	9.6	58.1	16.6	15.7	Sandy Loam	42.1
6	NARS - 6	7.9	0.320	5.7	60.2	14.4	19.7	Sandy Loam	44.7
7	NARS - 7	7.8	0.420	15.0	50.3	20.4	13.7	Sandy Loam	54.8
8	NARS - 8	7.7	0.540	6.7	43.2	30.4	19.7	Loam	57.5
9	NARS - 9	7.8	0.520	4.6	43.3	32.4	19.7	Loam	60.1
10	NARS - 10	7.5	2.200	20.3	51.6	14.4	13.7	Sandy Loam	53.1
11	NARS - 11	7.6	1.700	18.5	51.4	18.4	11.7	Sandy Loam	56.1
12	NARS - 12	7.6	2.000	21.5	54.4	12.4	11.7	Sandy Loam	54.8
13	NARS - 13	7.4	2.200	14.4	53.5	16.4	15.7	Sandy Loam	52.2
14	NARS - 14	7.6	1.500	22.2	53.7	10.4	13.7	Sandy Loam	60.1
15	NARS - 15	7.5	2.200	18.5	47.8	20.0	13.7	Sandy Loam	48.7
16	NARS - 16	7.6	1.800	14.6	50.5	17.8	17.1	Sandy Loam	61.8
17	NARS - 17	7.6	2.600	10.3	57.8	12.2	19.7	Sandy Loam	54.8
18	NARS - 18	7.5	3.000	21.7	54.2	10.4	13.7	Sandy Loam	58.3
19	NARS - 19	7.6	2.000	18.9	53.0	20.0	13.7	Sandy Loam	61.8
20	NARS - 20	7.6	2.400	19.9	51.2	17.8	13.1	Sandy Loam	64.4
21	NARS - 21	7.6	2.400	11.0	53.3	18.0	17.7	Sandy Loam	65.3
22	NARS - 22	7.5	3.600	16.8	53.5	18.0	11.7	Sandy Loam	63.1
23	NARS - 23	7.6	2.000	44.8	26.9	12.6	15.7	Sandy Loam	54.8
24	NARS - 24	7.5	2.600	21.6	53.1	11.6	13.7	Sandy Loam	58.8
25	NARS - 25	7.0	2.200	6.5	61.8	20.0	11.7	Sandy Loam	54.8
26	NARS - 26	7.5	0.420	26.3	45.4	17.6	9.7	Sandy Loam	52.7
27	NARS - 27	7.5	0.300	13.2	54.9	10.2	11.7	Sandy Loam	44.4
28	NARS - 28	7.4	1.800	9.8	55.9	20.6	13.7	Sandy Loam	46.6
29	NARS - 29	7.4	0.360	14.9	53.2	20.2	11.7	Sandy Loam	46.1
30	NARS - 30	7.5	0.600	12.2	68.7	9.4	9.7	Loamy Sand	54.4

Table A - 3.3 (5) Results of Soil Chemical Analysis (2/2)

Date : September 23, 1995

Sl. No.	Sampling Location	pH (1:2.5)	EC (1:5) mS/cm	% C.Sand	% F.Sand	% Silt	% Clay	Texure	$CaCO_3$ (%)
31	NARS - 31	7.5	0.400	23.0	57.9	15.4	3.7	Loamy Sand	57.0
32	NARS - 32	7.8	0.560	33.3	44.8	11.2	11.7	Sandy Loam	49.6
33	NARS - 33	7.7	0.260	31.0	53.9	7.4	7.7	Loamy Sand	51.3
34	NARS - 34	7.6	0.300	33.6	48.7	8.0	9.7	Loamy Sand	36.0
35	NARS - 35	7.5	0.350	16.9	67.4	12.0	3.7	Loamy Sand	63.7
36	NARS - 36	7.5	0.700	38.8	53.5	6.6	1.1	Loamy Sand	57.9
37	NARS - 37	7.7	0.280	37.1	58.9	2.9	1.1	Loamy Sand	59.9
38	NARS - 38	7.1	0.620	35.0	55.0	2.9	7.1	Loamy Sand	63.6
39	NEJD - 1	7.5	0.700	4.3	69.4	14.3	12.0	Sandy Loam	38.6
40	NEJD - 2	7.4	1.600	6.3	70.0	13.4	10.3	Sandy Loam	37.7
41	NEJD - 3	7.3	2.400	9.1	68.6	11.2	11.1	Sandy Loam	41.2
42	NEJD - 4	7.2	0.620	6.9	75.1	4.9	13.1	Sandy Loam	64.5
43	NEJD - 5	7.2	1.300	6.8	73.5	15.7	4.0	Loamy Sand	46.5
44	NEJD - 6	7.0	2.800	8.2	72.8	5.9	13.1	Loamy Sand	39.5
45	DAUKA -1	7.5	0.350	38.3	44.5	8.1	9.1	Loamy Sand	60.5
46	DAUKA -2	7.2	0.560	39.9	47.5	5.5	7.1	Loamy Sand	43.4
47	DAUKA -3	7.4	0.500	25.4	60.9	5.4	8.3	Loamy Sand	55.3
48	DAUKA -4	7.1	2.200	31.3	52.4	8.0	8.3	Loamy Sand	51.8
49	DAUKA -5	7.5	2.100	25.6	64.5	11.7	8.3	Loamy Sand	53.1
50	DAUKA -6	7.4	1.600	42.6	40.5	11.8	5.1	Loamy Sand	60.1

Table A - 3.3 (6) Results of Soil Chemical Analysis

Date : July, 1996

Sampling No.	pH (1:2.5)	EC (1:5) mS/cm	ECe mS/cm	Avail. P (ppm)	Micro Nutrients, ppm Fe	Mn	Cu	Zn	B	$CaCO_3$ (%)	Gypsum (%)	Organic matter(%)	Exch. Na^+ (me/100g)	CEC (me/100g	ESP (%)
A-1	7.5	0.64	6.81	0.03	1.16	0.46	0.12	0.32	0.20	51.57	trace	0.98	1.13	8.70	12.99
A-2	7.6	0.80	8.96	0.02	0.76	0.50	0.30	0.34	0.30	44.09	trace	0.93	0.96	10.17	9.44
B-1	7.7	0.45	3.55	0.01	0.96	0.46	0.52	0.24	0.30	56.15	trace	0.93	1.30	6.70	19.40
B-2	7.7	0.53	3.95	0.01	0.96	0.52	0.34	0.30	0.50	54.07	trace	1.03	0.87	9.91	8.78
C-1	7.7	0.56	4.68	0.02	0.58	0.52	0.24	0.32	trace	46.58	trace	1.09	1.04	9.74	10.68
C-2	7.7	0.53	4.38	0.01	0.68	0.54	0.26	0.32	trace	45.33	trace	1.03	1.22	11.65	10.47
D-1	7.5	1.20	8.62	0.04	1.04	0.56	0.28	0.26	trace	49.66	trace	0.98	0.70	10.52	6.65
D-2	7.7	0.65	4.41	0.04	1.04	0.60	0.12	0.40	trace	52.68	trace	0.88	0.78	10.35	7.54
L3C	7.7	0.45	2.74	0.04	1.82	1.10	0.18	1.34	0.40	54.19	trace	1.55	1.04	11.83	8.79
L4C	7.7	0.38	1.97	0.04	2.02	0.86	0.46	1.00	trace	51.82	trace	1.50	1.13	8.35	13.53
L7N	7.7	0.50	3.91	0.02	1.28	1.08	0.28	1.00	1.60	47.07	trace	1.34	1.04	13.30	7.82
L2N	7.7	0.68	5.54	0.04	2.48	1.24	0.36	1.00	2.10	52.25	trace	1.40	0.87	12.17	7.15

Sampling No.	Sat'n %	Soluble cations (me/l) Ca^{++}	Mg^{++}	Na^+	K^+	SAR	Soluble anions (me/l) Cl^-	$SO4^{--}$	HCO_3^-	C.Sand	F.Sand	Silt	Clay	Texture
A-1	18.30	12.00	23.50	40.30	6.59	9.57	42.50	37.40	2.50	24.36	60.74	10.60	4.30	Loamy sand
A-2	20.30	15.50	31.50	47.74	4.59	9.85	65.00	32.30	2.00	14.00	67.10	12.60	6.30	Loamy sand
B-1	16.90	7.00	13.00	23.30	4.82	7.37	22.50	23.60	2.00	29.76	66.34	1.60	2.30	Sand
B-2	18.40	7.00	13.50	25.61	6.33	8.00	22.50	27.40	2.50	23.40	67.70	6.60	2.30	Sand
C-1	20.00	8.00	16.00	29.13	9.64	8.41	27.50	32.80	2.50	11.96	69.14	12.60	6.30	Loamy sand
C-2	20.60	8.50	16.00	27.70	8.38	7.91	30.00	26.10	2.50	12.80	74.30	9.60	3.30	Sand
D-1	20.40	31.00	34.50	40.52	7.62	7.08	50.00	61.60	2.00	22.16	68.94	6.60	2.30	Sand
D-2	19.60	9.00	15.50	27.52	6.49	7.86	30.00	26.10	2.50	15.60	66.50	8.60	9.30	Loamy sand
L3C	22.50	8.00	12.00	13.87	5.80	4.39	12.50	24.20	3.00	12.42	60.66	17.60	9.30	Sandy loam
L4C	20.90	3.50	9.50	10.70	3.64	4.20	7.50	16.80	3.00	11.46	62.64	19.60	6.30	Sandy loam
L7N	22.00	9.50	12.50	22.78	7.79	6.87	27.50	21.10	4.00	12.28	68.82	14.60	4.30	Loamy sand
L2N	20.90	11.00	18.50	33.83	10.90	8.81	35.00	35.70	3.50	15.14	61.96	4.30	18.60	Loamy sand

The samples were collected at the Nejd Agricultural Research Station, in the top layer (0-30 cm)
Locations : 1,2 - Eastern side of Center Pivot (C.P); 3,4 - Northern side of C.P; 5,6 - Western side of C.P; 7,8 - Southern side of C.P.
L3C,L4C - Southern side windbreak trees; L7N,L2N - Northern side windbreak trees

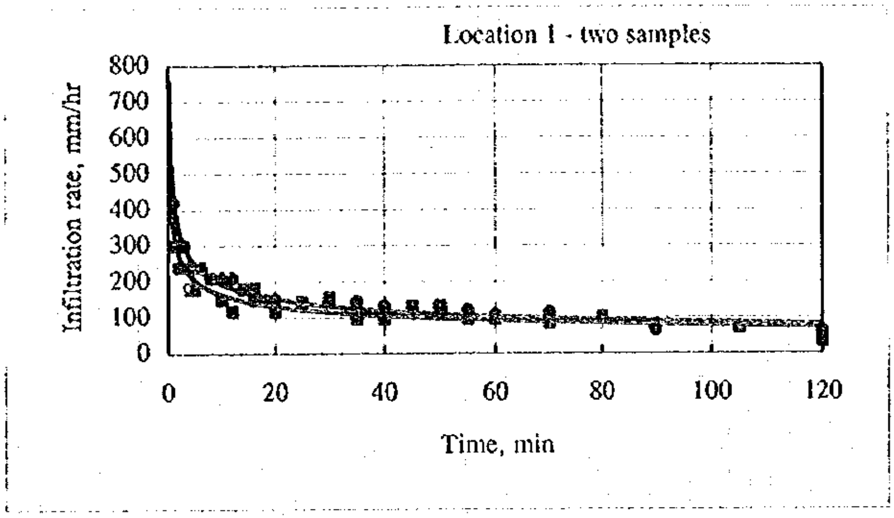
Table A - 3.3 (7) Results of Soil Chemical Analysis

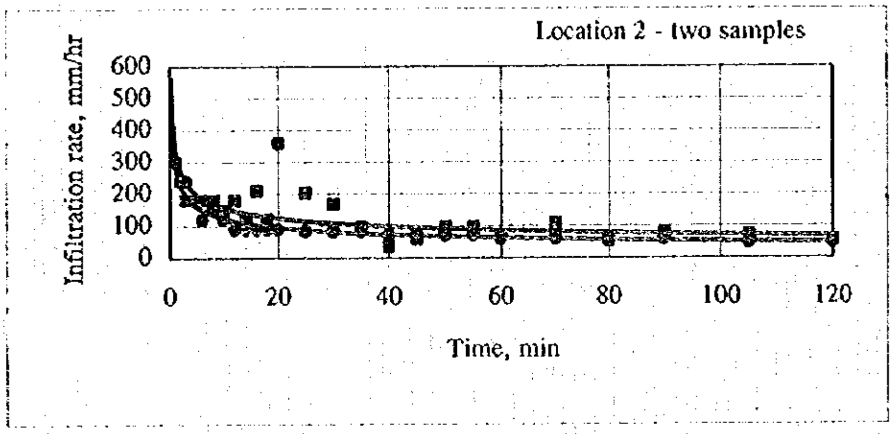
Date of sampling : September 25, 1996

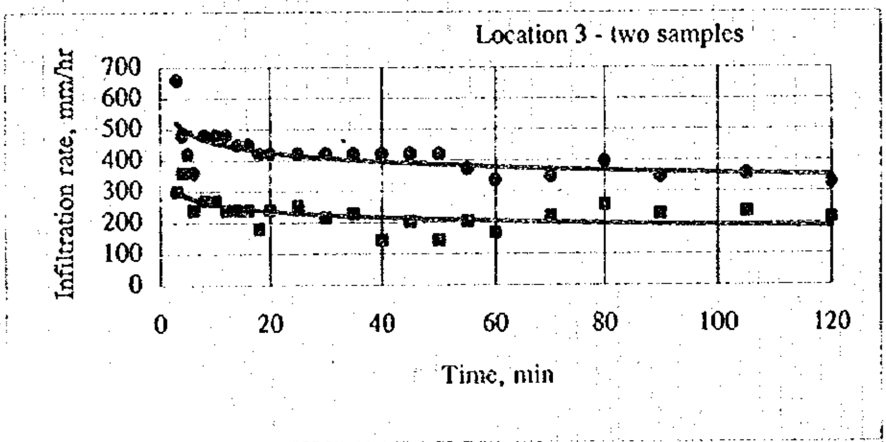
Sampling No.	pH (1:2.5)	EC (1:5) mS/cm	ECe mS/cm	Total N (%)	Avail. P (ppm)	Micro Nutrients, ppm					Exchangeable Cations (me/100g)				CEC me/100g	Sat'n %
						Fe	Mn	Cu	Zn	B	Ca^{++}	Mg^{++}	Na^{+}	K^{+}		
P1-H1	8.9	4.34	6.60	0.014	2.90	2.90	0.40	0.70	1.60	1.70	0.10	3.40	1.30	0.20	5.00	50.10
P1-H2	7.2	2.78	5.44	0.003	0.70	2.30	0.30	0.50	1.10	2.00	1.60	2.80	2.00	0.20	6.60	59.50
P1-H3	7.4	2.60	4.37	0.002	0.70	1.80	0.20	0.60	1.60	4.50	0.80	3.00	1.90	0.20	5.90	54.90
P2-H1	7.9	0.33	1.76	0.006	2.70	3.50	1.00	0.70	1.40	1.70	3.00	1.00	1.10	0.20	5.30	42.50
P2-H2	7.7	0.23	1.32	0.006	3.90	2.70	0.30	1.50	2.40	0.90	8.30	0.40	1.10	0.20	10.00	41.00
P2-H3	7.6	0.59	2.21	0.004	4.70	2.60	0.30	1.00	1.50	0.90	2.50	1.40	1.20	0.30	5.40	38.20
P3-H1	7.7	0.35	2.35	0.004	5.90	3.30	0.90	0.60	1.60	1.10	1.50	3.80	1.10	0.20	6.60	44.40
P3-H2	7.7	0.26	1.68	0.004	5.70	2.90	0.60	1.20	1.70	1.40	1.40	3.60	1.00	0.30	6.30	44.20
P3-H3	7.8	0.33	2.24	0.003	5.70	2.30	0.40	1.10	1.90	0.40	3.60	2.00	1.30	0.30	7.20	43.20

Sampling No.	Soluble cations (me/l)				SAR	Soluble anions (me/l)			$CaCO_3$ (%)	Gypsum (%)	C.Sand	F.Sand	Silt	Clay	Texture
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}		Cl^{-}	SO_4^{--}	HCO_3^{-}							
P1-H1	26.00	18.00	26.80	1.50	5.71	34.00	40.90	1.40	44.70	5.02	6.80	60.30	13.00	19.90	Sandy loam
P1-H2	27.00	18.00	21.60	1.80	4.55	36.00	31.20	1.20	36.80	18.71	7.20	56.90	9.00	26.90	Sandy clay loam
P1-H3	29.00	10.00	17.80	1.80	4.03	17.00	41.00	0.60	38.80	14.62	7.80	58.30	13.00	20.90	Sandy clay loam
P2-H1	7.80	4.40	8.70	0.50	3.52	11.00	8.80	1.60	56.80	1.27	13.00	62.10	18.00	6.90	Sandy loam
P2-H2	4.40	3.60	7.90	0.40	3.95	17.00	1.90	1.20	54.80	0.43	5.40	52.70	31.00	10.90	Sandy loam
P2-H3	7.20	6.20	12.60	0.70	4.87	9.00	16.70	1.00	56.80	0.29	8.00	56.10	29.00	6.90	Sandy loam
P3-H1	8.60	6.80	11.50	0.60	4.14	12.00	14.30	1.20	62.30	0.29	4.20	63.90	28.00	3.90	Sandy loam
P3-H2	5.20	4.60	11.00	0.60	4.97	10.00	9.20	1.20	58.30	0.43	6.40	46.70	36.00	10.90	Sandy loam
P3-H3	5.40	4.40	15.40	1.10	6.96	10.00	14.90	1.40	61.40	0.29	15.80	38.30	39.00	6.90	Sandy loam

The samples were collected at the Nejd Agricultural Research Station; P1, P2 and P3 correspond to profiles 1,2, and 3;
H1, H2 and H3 correspond to Horizons 1, 2 and 3. Locations : Profile P1–Southwestern corner of center pivot where there is high gypsum;
P2 – Western Side of the Centerpivot and P3 – Northern side of Centerpivot







Appendix A - 3.4 Infiltration Rate of the Center pivot field of NARS

Location	Basic Infiltration Rate(BIR), mm/h		Time required to reach BIR, min	
	Sample 1	Sample 2	Sample 1	Sample 2
L1	66.3	63.2	211.3	193.0
L2	57.5	37.8	199.7	227.0
L3	375.5	198.0	63.5	77.3

Table A-3.5 Measurement of Saturated Hydraulic Conductivity

Location	Saturated K cm/sec			
	Sample 1	Sample 2	Sample 3	Average
Profile 1				
Horizon 1	1.93×10^{-3}	0.30×10^{-3}	0.67×10^{-3}	0.97×10^{-3}
Horizon 2	4.58×10^{-3}	4.44×10^{-3}	2.34×10^{-3}	3.79×10^{-3}
Horizon 3	0.54×10^{-3}	0.29×10^{-3}	0.55×10^{-3}	0.46×10^{-3}
Profile 2				
Horizon 1	0.97×10^{-3}	0.73×10^{-3}	1.06×10^{-3}	0.92×10^{-3}
Horizon 2	1.75×10^{-3}	0.98×10^{-3}	0.56×10^{-3}	1.10×10^{-3}
Horizon 3	1.67×10^{-3}	4.23×10^{-3}	1.64×10^{-3}	0.92×10^{-3}
Profile 3				
Horizon 1	1.83×10^{-3}	1.29×10^{-3}	1.57×10^{-3}	1.53×10^{-3}
Horizon 2	1.69×10^{-3}	0.78×10^{-3}	1.38×10^{-3}	1.28×10^{-3}
Horizon 3	3.55×10^{-3}	2.75×10^{-3}	2.50×10^{-3}	2.93×10^{-3}

Table A-3.6 Available Water Capacity (AWC) of NARS Soil

Soil Water Tension		Soil Moisture (%)	AWC (%)	Soil Moisture (%)	AWC (%)
(Bar)	kPa	Sample A1		Sample D1	
0.1	10.0	16.06		16.33	
0.3	30.0	12.28	6.29	12.51	7.14
0.6	60.0	10.51		10.38	
1.0	100.0	9.56		9.32	
5.0	500.0	6.45		5.82	
10.0	1000.0	6.35		5.81	
15.0	1500.0	5.98		5.37	
		Sample A2		Sample D2	
0.1	10.0	18.23		19.71	
0.3	30.0	14.64	8.25	15.69	8.43
0.6	60.0	11.95		13.56	
1.0	100.0	10.40		8.29	
5.0	500.0	6.69		8.01	
10.0	1000.0	6.74		7.64	
15.0	1500.0	6.39		7.26	
		Sample B1		Sample L3C	
0.1	10.0	18.23		22.33	
0.3	30.0	7.56	3.70	18.25	8.95
0.6	60.0	6.48		15.85	
1.0	100.0	5.82		14.52	
5.0	500.0	4.07		10.01	
10.0	1000.0	4.07		9.85	
15.0	1500.0	3.87		9.30	
		Sample B2		Sample L4C	
0.1	10.0	10.21		20.29	
0.3	30.0	11.50	6.07	16.52	7.59
0.6	60.0	9.48		14.32	
1.0	100.0	6.00		13.21	
5.0	500.0	6.00		9.73	
10.0	1000.0	5.95		9.12	
15.0	1500.0	5.43		8.93	
		Sample C1		Sample L7N	
0.1	10.0	19.56		16.91	
0.3	30.0	15.01	7.20	13.05	6.78
0.6	60.0	13.74		11.00	
1.0	100.0	12.22		9.58	
5.0	500.0	8.48		6.71	
10.0	1000.0	8.26		6.50	
15.0	1500.0	7.80		6.27	
		Sample C2		Sample L2N	
0.1	10.0	16.75		19.19	
0.3	30.0	12.95	6.51	14.46	6.83
0.6	60.0	11.82		13.06	
1.0	100.0	10.63		11.87	
5.0	500.0	7.18		7.96	
10.0	1000.0	6.93		7.96	
15.0	1500.0	6.45		7.63	
Average Available Water Capacity (AWC)					6.98

AWC = 6.98 x 1.60 (Bulk density) = 11.17 % = 111.7 mm/m of soil

Table A-3.7 Soil Moisture Tension (pF) Measurement in the Center Pivot Field by Tensiometers

Date	Time	A-1	A-2	B-1	B-2	C-1	D-2
20/10/96	6:00	-	-	-	-	-	-
	12:00	1.92	1.80	1.81	1.91	2.10	1.82
	18:00	2.22	2.31	2.25	2.30	2.42	2.28
21/10/96	6:00	2.12	1.90	1.50	1.92	2.10	1.80
	12:00	2.10	1.70	1.70	1.82	1.91	1.88
	18:00	2.20	2.26	2.20	2.25	2.39	2.25
22/10/96	6:00	2.14	1.92	1.50	1.70	2.10	1.70
	12:00	2.10	1.72	1.80	1.92	2.01	1.95
	18:00	2.25	2.26	2.22	2.26	2.33	2.20
23/10/96	6:00	2.10	1.50	1.50	1.70	2.10	1.81
	12:00	2.00	1.70	1.50	1.80	2.10	1.80
	18:00	2.25	2.20	2.20	2.25	2.30	2.20
24/10/96	6:00	2.00	1.54	1.80	1.90	2.10	1.90
	12:00	2.10	1.70	1.82	1.90	2.12	1.90
	18:00	2.20	2.20	2.20	2.25	2.30	2.20
25/10/96	6:00	2.00	1.50	1.50	1.80	2.04	1.80
	12:00	2.00	1.55	1.70	1.84	2.10	1.84
	18:00	2.25	2.23	2.20	2.38	2.35	2.25
26/10/96	6:00	2.00	1.70	1.80	1.90	2.00	1.80
	12:00	2.10	1.80	1.84	1.92	2.10	1.80
	18:00	2.20	2.35	2.25	2.35	2.35	2.13
27/10/96	6:00	2.12	1.50	1.50	1.80	2.04	1.80
	12:00	2.04	1.80	1.80	1.90	2.10	1.90
	18:00	2.35	2.35	2.25	2.35	2.35	2.35
28/10/96	6:00	2.10	1.50	1.50	1.70	2.09	1.84
	12:00	2.01	1.50	1.50	1.82	2.10	1.80
	18:00	2.33	2.30	2.22	2.33	2.32	2.21
29/10/96	6:00	2.02	1.50	1.50	1.52	2.10	1.80
	12:00	2.00	1.70	1.70	1.80	2.08	1.90
	18:00	2.25	2.20	2.20	2.35	2.30	2.20
30/10/96	6:00	2.00	1.50	1.50	1.70	2.09	1.70
	12:00	2.10	1.70	1.80	1.93	2.10	1.90
	18:00	2.25	2.20	2.15	2.25	2.35	2.19
Average	6:00	2.06	1.61	1.56	1.76	2.08	1.80
	12:00	2.04	1.70	1.72	1.87	2.07	1.86
	18:00	2.25	2.26	2.21	2.30	2.34	2.22

Note : A,B,C, and D represent the four quarters of the Center Pivot Field

Table A-3.8 Soil Moisture Contents Measured Before and After Irrigation

BEFORE IRRIGATION

Location	Depth	14/10/96	21/10/96	27/10/96	Average
Location A	0-30	12.42	12.07	13.91	12.80
	30-60	13.66	13.44	14.14	13.74
	60-90	16.06	16.50	17.53	16.69
	-90	14.90	16.30	17.15	16.12
Location B	0-30	12.96	14.95	11.88	13.26
	30-60	15.10	14.58	15.12	14.93
	60-90	16.90	16.96	16.44	16.77
	-90	15.52	16.48	16.05	16.02
Location C	0-30	13.22	14.95	15.95	14.71
	30-60	15.81	16.84	15.51	16.05
	60-90	15.19	16.13	18.05	16.46
	-90	17.11	16.82	19.11	17.68
Location D	0-30	9.64	15.10	13.44	12.73
	30-60	12.56	13.86	16.50	14.30
	60-90	14.25	13.87	16.20	14.77
	-90	13.26	14.84	17.21	15.10

AFTER IRRIGATION

Location	Depth	14/10/96	21/10/96	27/10/96	Average
Location A	0-30	11.51	11.07	14.26	12.28
	30-60	-	13.86	15.84	14.85
	60-90	19.15	16.55	15.65	17.12
	-90	19.15	15.56	16.46	17.05
Location B	0-30	15.55	13.26	13.98	14.26
	30-60	14.80	13.83	14.02	14.22
	60-90	17.26	16.26	14.86	16.13
	-90	16.74	16.00	14.77	15.84
Location C	0-30	-	15.89	15.62	15.75
	30-60	13.01	15.03	14.17	14.07
	60-90	15.28	16.58	18.63	16.83
	-90	15.80	16.85	20.10	17.58
Location D	0-30	10.75	14.99	22.61	16.11
	30-60	13.50	13.67	18.55	15.24
	60-90	15.00	13.63	19.02	15.88
	-90	14.51	13.70	17.54	15.25

Table A-3.9 Measurement of Field Capacity in the Center Pivot Field

Location	Depth	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug
Location 1	0-30	17.81	14.85	12.21	13.57	16.13	15.79	14.25	13.14
	30-60	17.73	14.86	15.61	17.32	17.01	15.90	14.27	14.28
	60-90	17.82	13.76	15.49	15.27	15.17	15.05	14.08	14.91
	-90	17.36	14.14	15.92	15.59	15.51	14.89	14.80	15.21
Location 2	0-30	15.62	15.31	13.13	15.97	14.22	14.74	14.98	11.22
	30-60	15.28	14.73	15.65	16.28	16.39	15.15	16.41	14.70
	60-90	14.59	14.83	14.73	16.35	14.78	15.31	14.94	13.76
	-90	15.59	14.63	16.30	16.92	15.79	16.57	14.68	15.43
Location 3	0-30	18.62	15.09	13.61	13.55	15.36	14.23	14.38	13.85
	30-60	16.48	16.08	15.11	16.67	15.51	15.31	15.19	15.43
	60-90	15.37	15.29	15.62	9.49	14.77	14.09	14.34	14.95
	-90	15.78	16.48	15.97	17.09	15.18	13.95	15.30	16.21
Average	0-30	17.35	15.08	12.99	14.36	15.23	14.92	14.54	12.73
	30-60	16.50	15.22	15.46	16.76	16.30	15.45	15.29	14.80
	60-90	15.93	14.63	15.28	13.70	14.91	14.82	14.45	14.54
	-90	16.25	15.08	16.06	16.53	15.50	15.14	14.92	15.62

Appendix A-3.10 Previous Soil Surveys

Various preliminary and detailed soil surveys have been carried out in the Study Area by MAF (1996), GRM International (1995), MMI (Mott MacDonald International, 1992), JICA (phase-I, 1989), GDC (1987), Gibb (1984) and other agencies and these reports provide a good and valid information on the soil conditions of the study area. The locations of the previous soil surveys are shown in Fig. A-3.10 (1). A brief summary of these surveys are discussed below :

1) Halcrow Study (1975)

Purpose : To examine the land and water resources in Dhofar
Area : Dauka (10ha), Wadi Dauka (50 ha), Shasr (5ha), Wadi Quitbeet (100ha)
Method : Auger hole / soil pit investigation
Conclusion : Marginally suitable soils/land for irrigation does not match with the availability of suitable water quality.

2) MAF Survey (1982)

Purpose : To delineate the soils suitable for irrigated agriculture
Area : Wadi Quitbeet and Hanfeet
Survey and results : Wadi Quitbeet
Gravel, 4 sites, 4 pits excavated and investigated
shallow to moderately deep (0.3 - 1.0m), irrigation quality 2.520 mS/cm
Unsuitable / marginally suitable
Hanfeet
Loose sand and gravel, low CEC, clay content is proportional to soil depth
Moderately/ marginally suitable for agriculture

3) Gibb Study (1984)

Purpose : To justify the funds required for detailed soil and water investigations in 93,000 ha
Area : 17°20' to 17°48' N, 53°32' to 53°56' E
Conclusions : 73% unsuitable, 25,400 ha have some potential
9400 ha - Moderately suitable (S2), 16,000 ha - restricted suitability (S3)

4) Harza Study (1985)

Purpose: To determine whether or not soil and water resources of the Nejd region are adequate for refined evaluation
Area : Dauka, Shasr and Wadi Mokhwarim
Conclusion : 16 soil types were identified
- 9 soil types, 80% of the area (42,020ha) not suitable for agriculture
- 7 soil types, 20% of the area (14,160ha) suitable for agriculture
- Dauka - 2450 ha, Shasr - 4920 ha and Wadi Mokhawrim-6790 ha

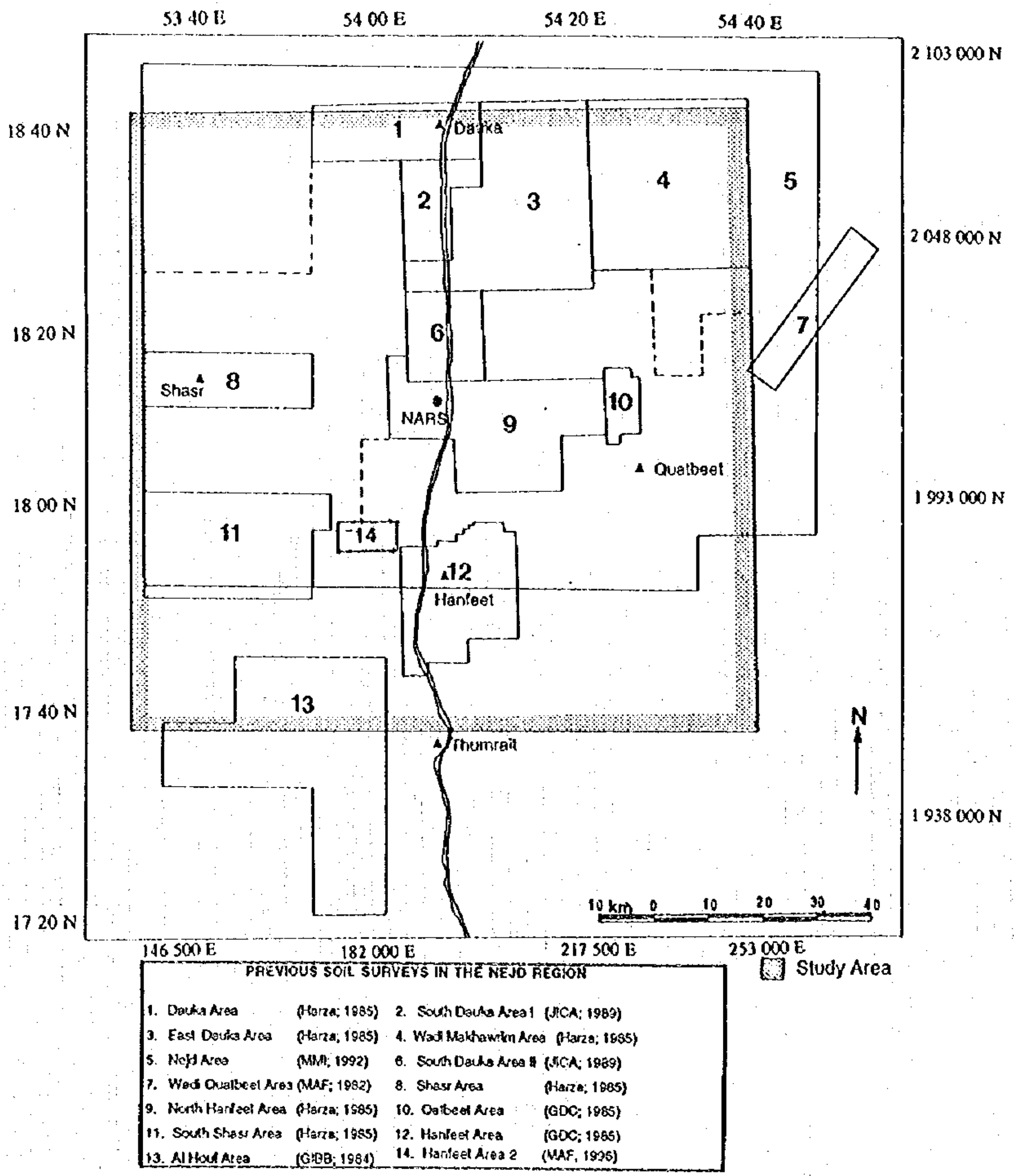


Fig. A-3.10 (1) Locations of Previous Soil Surveys

5) GDC Study (1987)

Purpose : To determine the potential for irrigated agriculture (400 sq.km)
Area : Hanfeet and Quitbeet
Conclusion : 12% of the Hanfeet block is suitable for irrigated agriculture
S1- 40 ha (require flood protection), S2 - 585 ha (high in $CaCO_3$)
S3 - 4260 ha (high ESP), 88% (35,115 ha is not suitable)
Quitbeet
Out of 100 sq.km, 6% is suitable for agriculture; 140 ha - S2 and 420 ha - S3.

6. JICA Study (Phase - I, 1989)

Purpose: To survey groundwater and soil resources in 5 areas from the view point of agricultural development
Area : Nagha area (Hilat-Al-Rakah), Dauka, Shasr and Wadi Mokhawrim
Conclusion: 550 sq.km suitable for irrigated agriculture; 361 sq.km marginally suitable
Detailed survey of 120 ha & 50 ha is entirely suitable where Nejd Agriculture Research Station is established. Soil Classification map and Land suitability map are shown in Fig A-3.10 (2) and Fig A-3.10 (3).

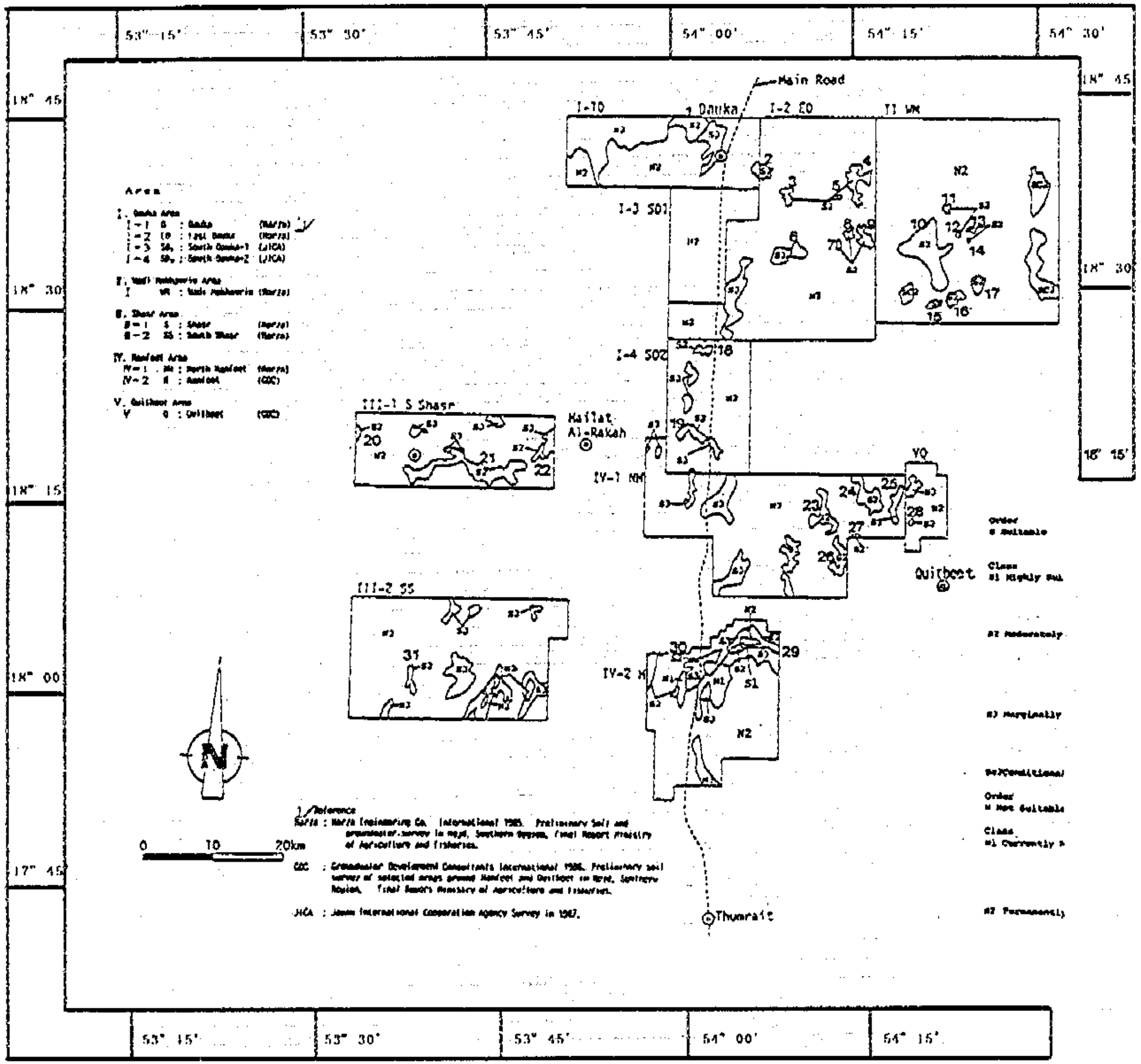
7. MMI (1992)

Purpose : To select and develop upto 1000 ha of virgin desert land in the Nejd
Area : Hanfeet west - 800 ha, Hanfeet east - 300 ha, Shasr - 300 ha,
Dauka - 620 ha, Total - 2020 ha
Conclusion : Land suitable (S3) for development is distributed as follows :

Survey block	Area	
	ha	%
Hanfeet west	746	93
Hanfeet east	196	65
Shasr	131	44
Dauka	510	82
Total	1,583	78

General conclusions and recommendations of this survey are as follows :

- All suitable lands are only marginally suitable
- The soil is not suitable for basin irrigation due to high infiltration rate
- Not suitable for root crops due to gravel content
- Land evaluation concludes that the soil is suitable for Rhodes grass with center pivot irrigation, tomatoes with drip irrigation and lime trees with bubbler irrigation.
- With careful management several crops can be cultivated; however poorly controlled irrigation can lead to severe salinisation.
- Nejd land suitability as defined by MMI is shown in Table A-3.10 (5)



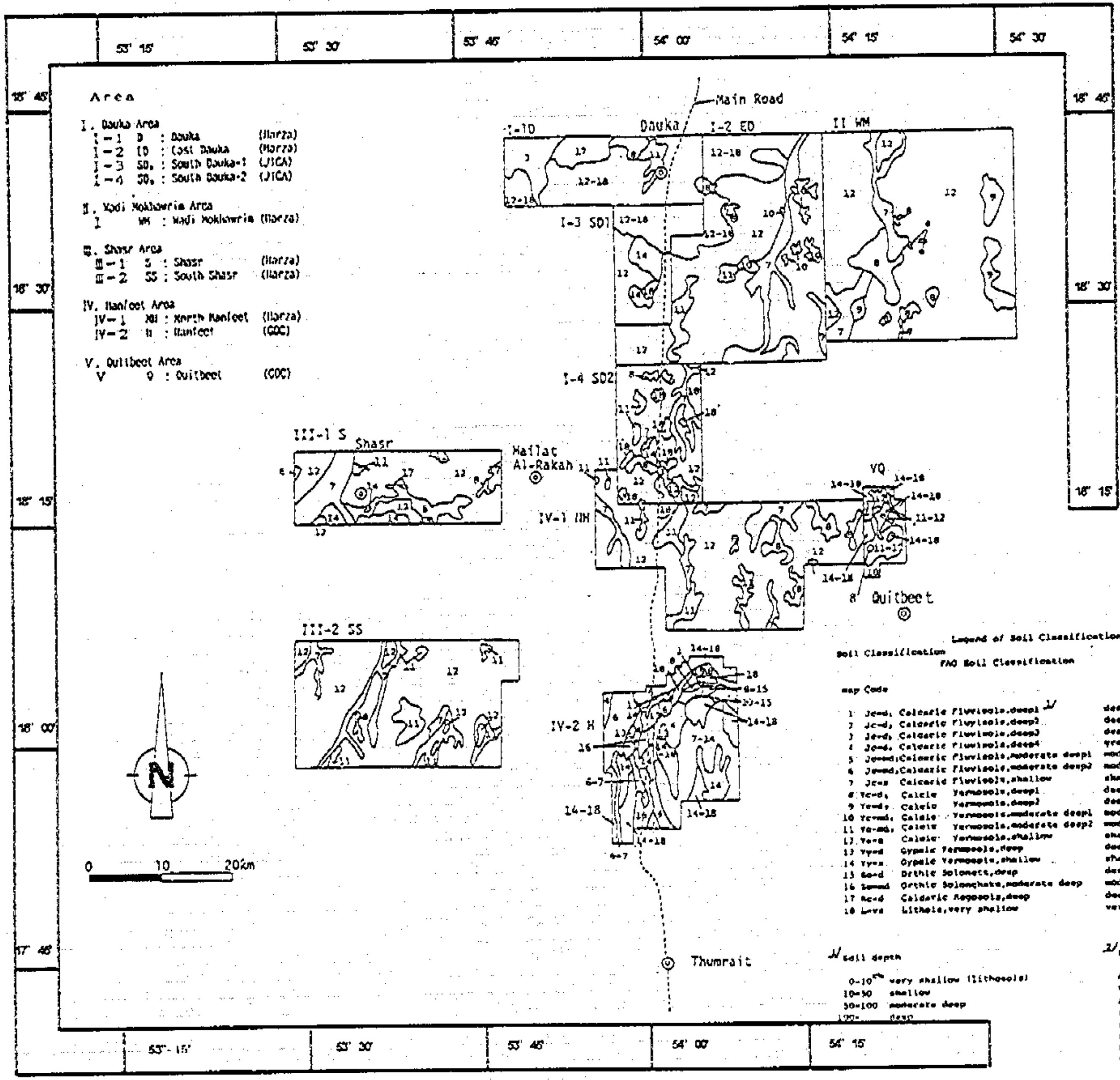
S1, S2 Class Area

No.	Area		No.	Area	
1	1330	D 1330	18	190	SD2 620
2	570*	ED 3560	19	430	
3	350		20	250	S 4180
4	1010		21	3830	
5	30		22	100	
6	120		23	820	NH 2810
7	290		24	1260	
8	180		25	250	
9	1010		26	430	
10	3720	WM 5490	27	50	
11	100		28	140	Q 140
12	90		29	540	M 620
13	80		30	80	
14	40		31	150	SS 150
15	240				
16	480		Total	18,900 ha	
17	740				

*100 ha of 570 ha belongs to Dauka

Fig. A-3.10 (2)
Land Suitability Classification Map

Fig. A-3.10 (3)
Soil Classification Map



Legend of Soil Classification

Map Code	Soil Classification	FAO Soil Classification	Soil Characteristics
1	Jcm-d1	Calcaric Fluvisols, deep1 [1]	deep loamy calcarious soil on AT [2]
2	Jc-d2	Calcaric Fluvisols, deep2	deep sandy to loamy calcarious soil in W
3	Jc-d3	Calcaric Fluvisols, deep3	deep gravelly coarse sandy calcarious soil in W
4	Jc-d4	Calcaric Fluvisols, deep4	gravelly surface over old gravelly calcarious alluvium soil on AF
5	Jc-md1	Calcaric Fluvisols, moderate deep1	moderate deep loamy calcarious soil in W
6	Jc-md2	Calcaric Fluvisols, moderate deep2	moderate deep gravelly to loamy calcarious soil in W and on AF
7	Jc-s	Calcaric Fluvisols, shallow	shallow gravelly sandy calcarious soil in wadi and on AF
8	Yc-d1	Calcic Yermosols, deep1	deep sandy to loamy calcarious soil on FP
9	Yc-d2	Calcic Yermosols, deep2	deep gravelly sandy calcarious soil on FP
10	Yc-md1	Calcic Yermosols, moderate deep1	moderate deep loamy calcarious soil to weathered marl of FP
11	Yc-md2	Calcic Yermosols, moderate deep2	moderate deep gravelly to loamy calcarious soil on weathered rock of FP
12	Yc-s	Calcic Yermosols, shallow	shallow loamy calcarious soil on weathered rock of FP
13	Yy-d	Gypsic Yermosols, deep	deep gypsic loamy calcarious soil on AF
14	Yy-s	Gypsic Yermosols, shallow	shallow gypsic gravelly loamy calcarious soil on CT
15	So-d	Orthic Solonetz, deep	deep loamy high alkali soil with natric B horizon on FT and in W
16	Zo-md	Orthic Solonchaks, moderate deep	moderate deep gravelly loamy high salinity soil on UP
17	Rc-d	Calcaric Regosols, deep	deep very young undeveloped calcarious soil on RAT
18	L-vs	Lithosols, very shallow	very shallow loamy soil over lithic bedrock on CT

[1] Soil depth

0-10cm very shallow (lithosols)
10-50 shallow
50-100 moderate deep
100- deep

[2] Land form

AT : alluvial toeslope
W : wadi
AF : alluvial fan
FP : flat plain of old alluvium over weathered limestone
CT : eroded gravel terraces and hills
FT : flat terrain of old alluvial fan
UP : undulating gravel terraces on bedrock plain
RAT : recent alluvial terraces, outwash fans and deep eolian deposits

Table A-3.10 (4) Land Suitability Classes according to FAO Classification

Order	Class	Designation	Description
S		Suitable	Land on which the sustained use of the kind under consideration is expected to yield benefits which justify the inputs and development costs, without unacceptable risk of damage to land resources.
	S1	Highly Suitable	Land having no significant limitations to sustained application of a given use. It may include minor limitations that will not reduce productivity, benefits or costs below the lower boundary set for the class.
	S2	Moderately Suitable	Land having limitations which, in aggregate, are moderately severe for sustained application of a given use. It may The limitations may reduce physical productivity, benefits or costs compared with S1 land to a lower limit set for the class.
	S3	Marginally Suitable	Land having limitations which, in aggregate, are severe for sustained application of a given use and will so reduce physical productivity, benefits or costs compared with S1 land to a lower limit set for the class.
	Sc	Conditionally Suitable	Land having a conditional suitability for agriculture or they are limited to a special agricultural use.
N		Not Suitable	Land having the qualities which appear to preclude sustained use of the kind under consideration.
	N1	Currently not Suitable	Land is marginally not suitable and having limitations which may be surmountable in time, but can not be corrected under present social conditions to give acceptable physical productivity.
	N2	Permanently not Suitable	Land is permanently not suitable for the given use usually because of physical limitations.

Source ; Guidelines : Land evaluation for irrigated agriculture,
FAO Soils Bulletin 55, 1985

Table A-3.10 (5) Nejd Land Suitability

Land suitability classes and subclasses	Soil characteristics	Area (ha)			
		Hanfeet West	Hanfeet East	Shasr	Dawkah
Marginally Suitable Land - Class S3 S3w-*limitations of low AWC, very rapid infiltration and gravelliness*	Deep permeable gravelly sands and gravelly sand over sandy clay loam	746			
$S3d^1w$ - *as above, plus slowly to moderately permeable substrata*	Deep gravelly sand over sandy clay loam, but hard and ± gypsic below 2m		5	131	
S3wxy - *as* S3w, *plus saline -sodic soils*	Deep gravelly sands and stratified gravelly sandy and loamy soils with saline-sodic subsoil horizons				440
$S3wxyd^1$- *as above, but limestone at 1.5-2.0 m*	As above, with limestone at 1.5-2.0 m				70
$S3d^1x^1y^1$- *limitations of slowly to moderately permeable substrata, and saline sodic soils requiring leaching/reclamation*	Deep loamy saline-sodic soils ± gypsum, but hard and gypsic below 2 m		191		
Unsuitable Land - Class N2 $N2d^1$-*very slowly permeable clay subsoil, very poor drainage*	Gravelly sands overlying clay within 1.0 - 1.5 m	54		32	
$N2d^1r$-*restricted drainage and rooting*	rock or gypcrete within 1.5 m		104	137	110

8. GRM Study (1995)

Purpose: Soil and land suitability assessments of land at Dameet and Wadi Bani Khwater

Area : Wadi Bani Khwatar (1300ha), Dameet (800ha)

Conclusion : 1640 ha is suitable for irrigated agricultural development

This study also reviews the MMI findings for the Hanfeet and Dauka areas. The highest level of suitability identified in this study and in the MMI study is Marginally Suitable (S3) and encompasses lands that can technically produce acceptable yields but would require substantially high levels of management and material inputs to obtain those yields. Soils allocated to class S3 are usually physically suitable for irrigation and in arid regions where suitable soils and water are scarce their coexistence then be enough justification for agricultural development regardless of purely economic considerations.

The major land attributes considered important in the Nejd for spray and trickle irrigation systems are as follows :

-adequate soil permeability to allow leaching of salts - most soil series other than those with a contact to limestone or mudstone within 1.5m of the land surface would meet this criteria

-an appreciable available soil water capacity - this is a consistent limitation across all soils

-an effective rooting depth adequate for most crops - soils with a lithic contact or hard cemented pan would fail this criteria

-low salinity levels

Applying these types of criteria within the FAO UNESCO framework for land suitability classification results in the following areas being ranked as overall marginally suitable (S3) for irrigation development :

Hanfeet - 1002 ha ; this includes 700 ha previously nominated by MMI as a development area, Dauka - 505 ha of soils identified by MMI as S3 rating. 300 ha of this area had been previously nominated by MMI as a development area. Much of these areas can not be recommended for development without extensive subsoil drainage works.

Even on the suited soils, a number of crop and water related variables have to be carefully managed if crops are to yield to their maximum. Key areas of attention include :

- the need to regularly monitor irrigation water quality
- the need to maintain maximum levels of soil nutrients in these highly permeable, easily leached soils
- the careful matching of irrigation capacity to crop water requirement

9. MAF (1996)

Purpose : To examine in detail the soils of 2000 ha, and to evaluate them for a range of potential irrigated cropping systems.

Area : The survey area is located at 17°54'Nand 53°58'E, about 2.5km to the south west of a track that leaves the Salalah-Muscat highway.

Conclusion : This study identified a marginally suitable land (S3) of 1530 ha. Hanfeet west land suitability as defined by MAF is shown in Table A-3.10 (6)

Table A -3.10 (6) Hanfeet West Land Suitability

Land suitability classes	Soil characteristics of subclasses	Area (ha)
Marginally Suitable Land - Class S3 *Land with one or more limitations which are so severe for sustained application of overhead irrigated Rhodes grass that expenditure will only be marginally justified*	S3g - High gravel content in the topsoil and subsurface horizons are the limiting factors to the given use	696.4
	S3wg - Limited available water capacity and high gravel content are the limiting factors	836.2
Unsuitable Land - Class N2 *Land with extreme physical conditions that permanently preclude its application for overhead irrigated Rhodes grass*	N2z - High salinity is the limiting factor	221.0
	N2rz - Very high salinity and restricted rooting volume are the limiting factors	202.5
	N2wr - Restricted rooting volume and low available water capacity are the limiting factors	25.8
	N2wry - High gypsum content, restricted rooting volume and low available water capacity are the limiting factors	18.1

It is important for the future planning of agricultural development and of further soil surveys to know how much suitable land has been identified in the Nejd. Because of overlapping field areas and also because of the cautionary notes of the authors, it is best to treat the estimates of the reconnaissance and semi-detailed surveys only as recommendations for the detailed soil surveys.

Appendix A-3.11 Abbreviations and Glossary (Soil)

Aridic : A moisture regime that characterizes soils that have no moisture available for plants for long period of time. Crops can not be grown under such a climate without irrigation.

Calcareous Soil : Soil containing sufficient free CaCO3 and or MgCO3 usually contain 100 to 200 g per kg of CaCO3 equivalent.

Cation Exchange Capacity (CEC) : The sum of exchangeable cations that a soil can adsorb, expressed in centimoles per kg of soil.

Available Water Capacity : Available Water Capacity (AWC), also called as Available Water Holding Capacity or Available Water Retention Capacity is defined as the volume of water retained in the root zone between field Capacity and wilting point. The classes of AWC are as follows : low - less than 60mm, Moderate - 60-120mm, Moderately high - 120- 180 mm and High - above 180 mm.

Field Capacity : Field Capacity (FC) is the term used to describe the maximum water content that the soil will hold following free drainage.

Permanent Wilting Point : Permanent Wilting Point (PWP) is arbitrarily defined as the soil water content at which the plants wilt permanently.
the dry soil.

pH, soil : It is an indication of acidity or basicity (alkalinity) of the soil. Ranges of pH are as follows : Low - Less than 5.5 (acid soils); Medium - 5.5-7.0 (preferred range for most crops); High - 7.0-8.5, Very High - >8.5 (Alkaline soils).

Salinity : The concentration of dissolved solids or salts in water ; **Salination** is the process whereby soluble salts accumulate in soil. The electrical conductivity of the saturation extract is the standard measure of salinity. The classes of the salinity are Non-saline 0 to 4 dS/m, Slightly saline - 4-8 dS/m, Moderately Saline - 8 - 16 dS/m and Strongly saline - above 16 dS/m.

Saline-Sodic Soil : A soil containing sufficient exchangeable sodium to interfere with growth of most plants and containing appreciable quantities of soluble salts. The Exchangeable Sodium Percentage (ESP) is greater than 15 (or SAR greater than 13), the conductivity of the saturation extract greater than 4 dS/m.

Sodic Soil : Sodic soil has an SAR of the saturation extract of 13 or more but has low salt content.

APPENDIX - 4
GROUNDWATER

Appendix A - 4.1 Depth of Water Surface at NARS

Table A - 4.1(1) Depth of Water Surface in Nejd 1 (1993)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1												1.56
2												1.55
3												1.56
4												1.58
5												1.59
6												1.60
7												1.61
8												1.62
9												1.62
10												1.61
11												
12												
13												
14												1.66
15												1.63
16										1.44		1.67
17										1.42	1.55	1.69
18										1.42		1.72
19										1.42		1.74
20										1.42		1.72
21										1.43		1.70
22										1.40		1.69
23										1.38		1.68
24										1.38		1.66
25										1.38		1.64
26										1.38		1.68
27										1.39		1.68
28										1.39		1.66
29		--------								1.40		1.66
30		--------									1.59	1.67
31		--------		--------		--------			--------		--------	
Average										1.40	1.57	1.65
MAX.										1.44	1.59	1.74
MIN.										1.38	1.55	1.55

Table A - 4.1(2) Depth of Water Surface in NJD1 (1994)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.67	1.66	1.64	1.60	1.47	1.64	1.74	1.84	1.87	1.49		
2	1.66	1.68	1.64		1.48	1.64	1.76	1.82	1.89	1.51		
3	1.66	1.69	1.65		1.51	1.64	1.76	1.82	1.86	1.56		
4	1.66	1.71	1.65		1.54	1.63	1.75	1.80	1.98	1.65		
5	1.67			1.75	1.56	1.64	1.74	1.76	2.08	1.20		
6	1.64			1.71		1.65	1.74	1.74	2.09			
7	1.64	1.68	1.62	1.64	1.56	1.64	1.74	1.77	2.02			
8	1.70	1.68	1.60	1.57	1.59	1.64	1.71	1.78	2.05			
9	1.65	1.72	1.59	1.54	1.58	1.62	1.70		2.05			
10		1.72	1.60	1.56	1.56	1.64	1.70	1.79	2.04			
11		1.70	1.56		1.55	1.65	1.72	1.80	2.01			
12		1.66	1.56		1.57	1.66	1.71	1.78	2.02			
13		1.66	1.58		1.59	1.70	1.72	1.78	2.03		2.12	1.12
14		1.67	1.58		1.60	1.72	1.74	1.78	2.03		1.62	
15		1.66	1.58		1.64	1.72		1.77			1.46	
16		1.68	1.58		1.64	1.72	1.72	1.77			1.36	
17		1.70	1.60		1.65	1.72	1.72	1.76			1.31	
18		1.69	1.64	1.56	1.64	1.72	1.70	1.74	2.23		1.10	
19		1.67	1.64	1.54	1.64	1.74	1.70	1.71	1.87		1.04	
20		1.70	1.62	1.52	1.62	1.74	1.70	1.70	1.89		2.10	
21		1.69	1.60	1.51	1.63	1.74	1.70	1.69	1.94		1.12	
22		1.65	1.58	1.48	1.64	1.75	1.70	1.71	1.90		1.11	
23		1.63	1.59		1.64	1.76	1.68	1.72	1.80			
24	1.68	1.62	1.59	1.48	1.63	1.75	1.70	1.76	1.64			
25	1.62	1.64	1.57	1.47	1.65	1.72	1.71	1.78	1.89			
26	1.62	1.66	1.57	1.46	1.66	1.72	1.70	1.74	1.86			
27	1.63	1.64	1.59	1.44	1.64	1.72	1.70	1.74	1.76			
28	1.66	1.64	1.62	1.46	1.65	1.72	1.73	1.88	1.54			
29	1.66	--------	1.64	1.46	1.68	1.72	1.72	1.90	1.68			
30	1.65	--------	1.64	1.46	1.66	1.74	1.72	1.87	1.44			
31	1.66	--------	1.62	--------	1.66	--------	1.86	1.90	--------		--------	
Average	1.65	1.67	1.60	1.54	1.60	1.69	1.72	1.78	1.91	1.48	1.43	1.12
MAX.	1.70	1.72	1.65	1.75	1.68	1.76	1.86	1.90	2.23	1.65	2.12	1.12
MIN.	1.62	1.62	1.56	1.44	1.47	1.62	1.68	1.69	1.44	1.20	1.04	1.12

Table A - 4.1(3) Depth to Water Surface in NJD1 (1995)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					10.10	10.88	12.25	11.20		13.71	14.28	13.75
2						10.86	11.60	11.85		13.80	14.60	13.73
3						10.96	11.08	12.35		13.94	14.44	13.81
4						10.77	10.97	12.18		14.05	14.33	13.80
5						10.98	11.54	12.61		14.20	14.02	13.99
6						10.55	11.55	12.76		14.16	13.91	14.02
7						10.51	11.82	12.59		14.07	13.91	14.02
8					9.87	10.28	11.97	12.68		13.59	13.80	14.02
9					9.86	10.27	11.80	12.85		14.00	14.10	14.04
10					10.21	10.15	12.39	12.69		14.12		14.02
11					10.15	11.67	12.05	12.98		14.15	13.52	13.99
12					10.30	11.01	12.10	12.96		14.25	13.43	13.94
13					10.50	11.79	12.06	12.57	13.18	13.74	13.49	14.01
14					10.48	11.88	12.19	12.28	13.01	14.05	13.54	14.05
15					10.32	11.27	12.22		13.34	14.23	13.56	14.12
16					10.33	10.89	11.89		13.21	14.20	13.50	14.06
17					10.35	11.84	11.85		13.25	14.28	13.74	14.16
18					10.36	11.86	11.75		13.84	14.22	13.78	14.19
19					10.31	11.08	11.70		13.85	14.35	13.85	14.25
20					10.48	10.95	11.77		13.63	14.35	13.87	14.24
21					10.80	11.70	11.69		13.59	14.42	13.89	14.26
22					10.49	11.72	11.69		13.50	14.48	13.85	14.31
23					10.45	12.04	11.64		13.64	14.48	13.86	14.36
24				10.64	10.60	11.89	11.46		13.71	14.50	13.86	14.31
25				10.48	10.64	12.04	11.64		13.68	14.55	13.88	14.32
26				10.46	10.55	12.10	11.76		13.27	14.45	13.86	14.43
27				9.85	10.54	12.08	11.77		13.29	14.48	13.82	14.42
28				9.43	10.75	11.94	11.65		12.92	14.52	13.83	14.45
29		--------		9.31	10.78	12.24	11.39		13.47	14.59	13.84	14.47
30		--------		10.15	10.81	12.04	11.22		13.76	14.47	13.80	14.51
31		--------		--------	10.81	--------	11.12		--------	14.37	--------	14.50
Average				10.05	10.43	11.34	11.73	12.47	13.45	14.22	13.87	14.15
MAX.				10.64	10.81	12.24	12.39	12.98	13.85	14.59	14.60	14.51
MIN.				9.31	9.86	10.15	10.97	11.20	12.92	13.59	13.43	13.73

Table A - 4.1(4) Depth to Water Surface in NJD1 (1996)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	14.46	14.89	14.92	17.06	17.66	18.18	19.65	19.64	22.16		22.35	
2	14.22	14.83	15.04	17.02	17.66	18.18	19.30	19.58	22.24		22.33	
3	14.08	14.86	15.08	17.02	17.78	18.22	19.22	19.91	22.32			
4	13.97	14.90	15.13	17.04	17.68	18.68	19.22	19.66	22.30	22.40		
5	14.06	14.94	15.11	17.06	17.63	18.82	19.36	19.63	22.26	22.50	22.36	
6	14.09	14.98	15.44	17.08	17.65	18.86	19.26	20.50	22.33	22.18	22.46	
7	14.06	15.05	15.45	17.14	17.61	18.78	19.66	20.76	22.30	22.22		
8	14.31	15.04	15.56	17.16	17.72	18.72	19.36	20.86	22.32	22.44		
9	14.52	15.11	15.69	17.16	17.82	19.10	19.26	21.08	22.33	22.12		
10	14.60	15.15	15.88	17.08	17.59	18.94	19.48	21.00	22.36	21.99		
11	14.50	15.21	15.82	17.13	17.68	18.83	19.28	21.19	22.34	22.02		
12	14.59	15.22	16.48	17.06	17.98	18.62	19.24	21.08	22.32	21.99		
13	14.65	15.23	16.18	17.07	17.90	18.44	19.74	20.97	22.48	22.00		
14	14.68	15.19	16.14	17.04	17.97	18.35	19.54	21.01		21.92		
15	14.64	15.20	16.06	17.09	18.09	18.32	19.50	21.36		22.02		
16	14.70	15.22	15.79	17.02	18.16	18.64	19.84			22.03		
17	14.75	15.26	16.18	17.06	18.32	18.47	19.58			21.96		
18	14.74	15.18	16.25	17.13	18.38	18.42	19.54			21.94		
19	14.70	15.02	16.28	17.16	18.42	18.78	19.70			21.94		
20	14.70	15.01	16.42	17.23	18.46	18.59	19.52			21.83		
21	14.65	15.12		17.36	18.44	18.54	19.38			21.93		
22	14.65	15.16	16.36	17.37	18.48	18.96	19.52			22.02		
23	14.67	15.20	16.44	17.57	18.54	18.82	19.30		22.14	21.93		
24	14.70	15.20	16.50	17.64	18.57	18.82	19.26		22.22	22.03		
25	14.74	15.21	16.56	17.75	18.51	19.32	19.50		22.22	22.08		
26	14.77	15.18	16.58	17.60	18.56	19.06	19.46		22.10	21.99		
27	14.79	15.02	16.68	17.68	18.56	19.02	19.40	22.26	22.16	22.10		
28	14.81	15.00	16.84	17.70	18.56	19.36	19.63	22.15	22.28	22.08		
29	14.80	14.93	16.92	17.74	18.40	19.18	19.55	22.00	22.31	22.15		
30	14.82	---------	16.97	17.66	18.28	19.12	19.58	22.08	22.18	22.32		
31	14.81	---------	16.96	---------	18.25	---------	19.89	21.99	---------	22.27	---------	
Average	14.56	15.09	16.06	17.26	18.11	18.74	19.47	20.94	22.27	22.09	22.38	
MAX.	14.82	15.26	16.97	17.75	18.57	19.36	19.89	22.26	22.48	22.50	22.46	
MIN.	13.97	14.83	14.92	17.02	17.59	18.18	19.22	19.58	22.10	21.83	22.33	

Table A - 4.1(5) Depth to Water Surface in NJD3 (1993)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1											2.22	2.40
2											2.22	2.39
3											2.23	2.39
4											2.23	2.40
5										2.01		2.42
6										2.00	2.21	2.43
7										2.01	2.22	2.44
8										2.01	2.23	2.44
9										2.00	2.22	2.44
10										2.07	2.23	2.44
11										2.12	2.24	2.44
12										2.15	2.25	2.45
13										2.22	2.24	2.46
14										2.30	2.22	2.49
15										2.33	2.27	2.47
16										2.30	2.29	2.50
17										2.26	2.31	2.53
18										2.24	2.32	2.55
19										2.24	2.32	2.57
20										2.24	2.33	2.55
21										2.25	2.33	2.54
22										2.22	2.36	2.52
23										2.22	2.35	2.52
24										2.20	2.38	2.50
25										2.20	2.38	2.48
26										2.22	2.38	2.51
27										2.22	2.35	2.52
28										2.21	2.36	2.50
29		--------								2.22	2.38	2.49
30		--------								2.22	2.40	2.50
31		--------		--------		--------			--------	2.22	--------	
Average										2.18	2.29	2.48
MAX.										2.33	2.40	2.57
MIN.										2.00	2.21	2.39

Table A - 4.1(6) Depth to Water Surface in NJD3 (1994)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.50	2.47	2.46	2.49	2.36	2.52	2.60	2.89	2.90	2.49	3.42	2.10
2	2.49	2.50	2.46	3.40		2.52	2.62	2.86	2.94	2.50	3.21	2.02
3	2.49	2.50	2.48	3.02		2.52	2.62	2.84	2.90	2.55	3.06	1.96
4	2.49	2.52	2.48	2.92		2.51	2.62	2.82	3.00	2.64	3.02	2.02
5	2.49	2.50	2.46	2.83		2.51	2.62	2.80	3.10	2.26	2.98	2.13
6	2.46	2.49	2.44	2.78		2.52	2.60	2.76	3.14	2.14	3.70	2.17
7	2.47	2.49	2.44	2.70		2.52	2.60	2.78	3.07	2.52	3.38	2.14
8	2.47	2.50	2.42	2.64		2.52	2.58	2.80	3.10	2.62	3.12	2.07
9	2.48	2.52	2.41	2.62		2.50	2.58	2.78	3.11	2.63	3.06	2.03
10		2.52	2.42	2.60		2.51	2.58	2.80	3.09	2.35	3.04	1.94
11		2.50	2.39	2.57		2.52	2.58	2.82	3.06	2.45	3.44	1.88
12		2.48	2.38	2.53		2.54	2.58	2.80	3.08	2.39	3.14	1.89
13		2.48	2.39	2.52		2.56	2.58	2.79	3.09	2.15	2.90	2.12
14		2.48	2.40	2.50		2.59	2.60	2.80	3.09	2.12	2.72	2.80
15		2.48	2.40	2.49		2.58		2.80	3.11	2.02	2.57	2.19
16		2.50	2.40	2.48		2.58	2.59	2.79		1.98	2.48	2.24
17		2.52	2.42	2.46	2.53	2.58	2.60	2.78		1.95	2.41	2.03
18		2.51	2.46	2.44	2.52	2.58	2.56	2.76	3.15	2.25	2.21	2.12
19		2.48	2.46	2.44	2.52	2.60	2.56	2.73	2.85	2.34	2.13	2.18
20		2.51	2.44	2.42	2.51	2.60	2.56	2.72	2.86	2.30	2.33	2.21
21		2.50	2.41	2.40	2.52	2.60	2.56	2.72	2.90	2.19	2.09	1.94
22		2.47	2.40	2.38	2.52	2.60	2.56	2.74	2.88	2.02	2.18	2.03
23		2.46	2.41	2.37	2.51	2.61	2.55	2.74	2.77	2.54	2.16	2.12
24	2.48	2.44	2.40	2.36	2.52	2.61	2.56	2.79	2.64	2.86	2.19	2.04
25	2.44	2.46	2.38	2.36	2.53	2.58	2.57	2.70	2.76		1.84	2.25
26	2.44	2.48	2.38	2.34	2.54	2.58	2.56	2.78	2.83		1.74	2.21
27	2.45	2.46	2.40	2.34	2.53	2.59	2.56	2.78	2.71		1.93	2.22
28	2.48	2.46	2.43	2.33	2.54	2.59	2.58	2.90	2.54		2.10	2.24
29	2.48	--------	2.45	2.36	2.55	2.59	2.58	2.94	2.67		2.12	2.18
30	2.46	--------	2.45	2.36	2.55	2.62	2.58	2.90	2.45		2.13	2.18
31	2.48	--------	2.42	--------	2.54	--------	2.76	2.93	--------		--------	
Average	2.47	2.49	2.42	2.55	2.52	2.56	2.59	2.80	2.92	2.34	2.63	2.12
MAX.	2.50	2.52	2.48	3.40	2.55	2.62	2.76	2.94	3.15	2.86	3.70	2.80
MIN.	2.44	2.44	2.38	2.33	2.36	2.50	2.55	2.70	2.45	1.95	1.74	1.88

Table A - 4.1(7) Depth of Water Surface in NJD3 (1995)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					10.38		12.34	11.51		14.05	14.61	14.14
2					10.10		11.66	12.18		14.14	14.91	14.15
3					10.14		11.29	12.66		14.26	14.78	14.18
4					10.10		11.56	12.50		14.38	14.68	14.16
5					10.15		11.81	12.93		14.50	14.36	14.15
6					10.20		11.83	13.06		14.49	14.27	14.19
7					10.09		12.08	12.91		14.32	14.25	14.20
8					10.27		12.20	13.02		13.94	14.17	14.19
9					10.27		12.08	13.18		14.33	14.44	14.20
10					10.56		12.40	13.04		14.41		14.20
11					10.57	11.26	12.35	13.30		14.49	13.89	14.18
12					10.58	12.06	12.43	13.29		14.55	13.81	14.12
13					10.78	11.96	12.40	12.95	13.54	14.10	13.88	14.19
14					10.75	12.06	12.51	12.65	13.39	14.49	13.91	14.21
15					10.62	11.30	12.54		13.68	14.55	13.95	14.28
16					10.63	11.18	12.25		13.58	14.54	13.90	14.23
17					10.65	12.04	12.28		13.62	14.61	14.11	14.32
18				10.50	10.66	11.69	12.15		14.14	14.55	14.16	14.34
19				9.55	10.61	11.26	12.09		14.17	14.59	14.22	14.40
20				9.64	10.78	11.69	12.05		13.99	14.68	14.24	14.40
21			3.50	9.77	10.99	11.94	12.08		13.95	14.73	14.26	14.42
22	2.64			9.86	10.79	11.95	12.08		13.96	14.79	14.24	14.46
23	2.21			9.94	10.75	12.24	12.02		14.00	14.81	14.23	14.51
24	2.24			9.99	10.90	12.14	11.85		14.07	14.84	14.24	14.47
25	2.25			10.63	10.94	12.26	12.01		13.95	14.91	14.26	14.48
26	2.27			10.70	10.95	12.34	12.14		13.64	14.78	14.25	14.57
27	2.54			10.11	10.95	12.31	12.14		13.59	14.82	14.21	14.57
28	2.58			9.74	11.05	12.20	12.11		13.32	14.86	14.20	14.60
29	2.56	--------		9.64		12.45	11.76		13.79	14.91	14.21	14.62
30		--------		10.42		12.28	11.60		14.09	14.82	14.16	14.65
31		--------		--------		--------	11.49		--------	14.71	--------	14.55
Average	2.41		3.50	10.04	10.58	11.93	12.05	12.80	13.80	14.55	14.23	14.33
MAX.	2.64		3.50	10.70	11.05	12.45	12.54	13.30	14.17	14.91	14.91	14.65
MIN.	2.21		3.50	9.55	10.09	11.18	11.29	11.51	13.32	13.94	13.81	14.12

Table A - 4.1(8) Depth to Water Surface in NJD3 (1996)

(The recorded figure is the highest level in the day) (meters)

Date	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	14.46	15.05	15.22	17.34	17.97	18.35	19.84	19.42	22.08	22.24	22.44	
2	14.25	14.99	15.32	17.30	17.98	18.22	19.28	19.36	22.17	22.04	22.43	
3	14.14	15.04	15.36	17.30	18.07	18.22	19.20	19.68	22.24	22.05	22.40	
4	14.05	15.06	15.40	17.31	18.04	18.60	19.18	19.46	22.22	22.26	22.36	
5	14.14	15.09	15.38	17.34	17.98	18.80	19.34	19.41	22.18	22.36	22.46	
6	14.16	15.13	15.70	17.36	18.00	18.88	19.23	20.28	22.24	22.16	22.55	
7	14.14	15.19	15.72	17.41	17.95	18.74	19.64	20.55	22.23	22.20		
8	14.39	15.19	15.85	17.44	18.16	18.70	19.36	20.64	22.25	22.42		
9	14.57	15.26	15.97	17.44	18.24	19.13	19.24	20.88	22.25	22.12		
10	14.66	15.30	16.15	17.38	18.02	18.89	19.46	20.88	22.30	21.99		
11	14.59	15.35	16.10	17.42	18.08	18.87	19.24	21.00	22.28	22.02		
12	14.65	15.36	16.70	17.36	18.10	18.68	19.20	21.10	22.38	21.99		
13	14.73	15.38	16.45	17.35	18.02	18.50	19.68	20.98	22.51	22.00		
14	14.77	15.34	16.41	17.32	18.10	18.38	19.50	21.08	22.25	21.93		
15	14.74	15.36	16.32	17.36	18.21	18.32	19.44	21.42	22.48	22.03		
16	14.79	15.39	16.06	17.28	18.27	18.76	19.78	21.26	22.43	21.96		
17	14.81	15.42	16.44	17.32	18.43	18.51	19.52	21.42	22.79	21.98		
18	14.80		16.51	17.40	18.50	18.45	19.47	21.38	22.42	21.96		
19	14.76	15.34	16.55	17.42	18.53	18.87	19.69	21.46	22.65	21.95		
20	14.78	15.32	16.70	17.50	18.58	18.61	19.50	21.48	22.52	21.92		
21	14.73	15.42		17.62	18.56	18.54	19.46	21.56	22.36	22.00		
22	14.74	15.45	16.60	17.64	18.61	19.04	19.50		22.22	22.08		
23	14.75	15.50	16.69	17.65	18.66	18.82	19.32		22.05	22.00		
24	14.76	15.50	16.74	17.71	18.68	18.80	19.24		22.20	22.10		
25	14.79	15.51	16.80	17.81	18.64	19.47	19.46		22.15	22.15		
26	14.84	15.49	16.84	17.80	18.68	19.06	19.40		22.04	22.05		
27	14.85	15.32	16.96	17.86	18.79	18.97	19.36	22.32		22.17		
28	14.96	15.31	17.12	17.92	18.87	19.39	19.59	22.07	22.18	22.16		
29	14.96	15.26	17.20	17.93	18.50	19.13	19.51	21.93	22.20	22.14		
30	15.00	--------	17.24	17.96	18.30	19.06	19.55	22.00	22.10	22.40		
31	14.98	--------	17.24	--------	18.32	--------	19.68	21.92	--------	22.35	--------	
Average	14.64	15.30	16.32	17.51	18.32	18.76	19.45	20.96	22.29	22.10	22.44	
MAX.	15.00	15.51	17.24	17.96	18.87	19.47	19.84	22.32	22.79	22.42	22.55	
MIN.	14.05	14.99	15.22	17.28	17.95	18.22	19.18	19.36	22.04	21.92	22.36	

Table A-4.2 Hydrogeology in the Study Area

Formation	Thickness (meters)	Lithology	Comments
Dammam Formation	0-90	Interbedded white pink crystalline limestone, red-yellow marl, dolomaite and soft chalky limestone	Dammam base picked at first appearance yellow-white limestone. Locally aquifer forming (also called Hashiba)
Rus Formation			
Upper	30-50	Limestone, cream brown or yellow-pink, with dolomite, chalk and marl	A aquifer ; Resistive beds of gypsum occur within 5-20 m of UER contact. Poor quality water associated with gypsic Rus
Lower	50-100	Dolomite, chalky limestone with gypsum interbeds	
Umm Er Radhuma			
Upper	100-150	White-gray marly limestone with interbedded gray -green marl and shale	B aquifer zone ; associated with distinctive 3 gamma peak marker. First appearance of index fossils (Sakesaria cofferi; Nummultites deserti)
Lower	250-300	Fossiliferous, sparry massive, hard, gray sparry limestone with thin black carbonaceous laminae	Major C aquifer, in top of lower UER ; associated with strong gamma marker zone. Abundant index fossils (Sakesaria dukhani, Dictyokathina simplex) appear at Paleocene boundary. D aquifer developed in isolated fissures in mid lower part
Shammar	5-20 (locally 0)	Shale-marl	Geophysical gamma log marker

source: Mott MacDonald (1994)

Fig. A-4.3 Hydrogeological Cross Section