3.7 Experimental Cultivation Trials

3.7.1 Rhodes Grass Cultivation Trials

The trials in the reclamation phase aimed to obtain valuable information on Rhodes grass cultivation and to train Omani counterparts.

These trials are finished after the harvest in December 1996, and subsequently the whole Center Pivot field are irrigated and fertilized at level similar to that of last year because the whole field should be made to have even growth of Rhodes grass as a homogeneous unit for the following years.

(1) Trial 1. Reasonable methods of irrigation and fertilization for Rhodes grass cultivation

1) Purpose

The objective of the trial is to clarify the effect of changes in irrigation water and urea application on growth and yield of Rhodes grass and to determine a standard for effective irrigation water use and fertilization.

2) Design

This trial consists of treatments as shown in the following table.

Factors / Season	Level 1 (High level)		Level 2 (Low level)	
	Irrigation	Urea*	Irrigation	Urea*
Mar. ~ May	12mm/day	1.0 ton/15 ha	8mm/day	0.7 ton/15 ha
Jun. ~ Aug.	15mm/day	1.2 ton/15 ha	10mm/day	0.8 ton/15 ha
Sep.** ~ Nov.	12mm/day	1.0 ton/15 ha	8mm/day	0.7 ton/15 ha
Dec. ~ Feb.	9mm/day	0.9 ton/15 ha	6mm/day	0.6 ton/15 ha

Note: *Amount of urea shows ton per 15ha every 2 weeks.

**The level in June to August was applied until September because of delayed harvest in September.

The high level is allocated to 15 ha of the western site and low level is allocated to 15 ha of the eastern site of the Center Pivot field. The amount and timing of irrigation water and urea application were modified because change was made after harvesting (Appendix A-7.1).

3) Trial period From March to December, 1996

4) Treatment method

Irrigator goes around 15 ha field first with the speed of level 1, and then goes around half with the changed speed of level 2 every day. The irrigator's speeds in each level are shown in Appendix II of Progress Report I. Urea is applied by injection system. Amount of urea in level 1 and level 2 is applied automatically in proportion to the hours of application of irrigation water at each treatment level.

5) Results of the trial

a. The amount of irrigation water in the plan and in actual agreed nearly with each other except low level in March to May, which is 8 mm/day in the plan and 6.4 mm /day in actual, as a result, of interrupted irrigation (Appendix A-2.5).

On the other hand, the amount of urea actual applied was about 40 to 50 % of the planned amount except during interrupted irrigation. The difference was caused by interruption of irrigation and problems accredited to farm management as mentioned in paragraph 3.2 of Chapter 3. Therefore, the trial was carried out under lower level of urea than that of the plan (Table A-2.4.4).

b. The growth of Rhodes grass was affected by water shortage from late of May to 5 August. According to the detailed observation of growth on 31 August, when it was about one month from the restart of daily irrigation, the growth difference between high level and low level treatments were still clear.

Dry matter weight per m^2 of top above 10 cm of grass in the low level treatment is less than that of the high level treatment, and ratio of top for bottom top and root in 20 cm depth is less in the low level treatment. Increase of dry matter weight during 14 days from 18 August to 31 August is also less in the low level location. And low level treatment portion has had many vacant spaces which was caused by dead stocks of grass (Table A -2.6.2).

c. In May, dry matter production with low level treatment was 68 % of yield with high level treatment. However, in July the yield with high level treatment in the midst of interrupted irrigation due to water shortage decreased to 36 % of the yield in the same month of last year, and dry matter yield under low level treatment was only 37 % of the yield with high level treatment due to damages of water shortage.

The yield at high level treatment in September, which is on 46th day from the restart of the daily irrigation, decreased to 52 % of the yield in the same month of last year, and dry matter yield per ha of the low level was 50 % of the yield of high level by recovering from the damage of water shortage (Table 3.7.1).

6) Conclusion

a. As stated in section 3.2, it is considered that applying irrigation water of about 12 mm once in every three days for two months in summer causes yield decrease, but the stocks of Rhodes grass do not die and growth recovers rapidly by restart of daily irrigation. On the other hand, applying irrigation water of 8 mm once in every three days in summer damages grasses and stocks of Rhodes grass die in some places. Recovery of growth depends only on spread of stolons and it might take about three months to recover sufficiently. These facts suggest us a water saving method of Rhodes grass cultivation in summer.

Table 3.7.1 Effect of various treatments on yield of Rhodes grass in 1996

Treatment			Items / Location	Dry matter yield (ton/ha)			
Irrigation and urea	Potassium	Manure		May	July	September	November
High level	Applied	-	B-1			3.69	
High level	Applied	Applied	B-2			2.77	
			Average			**3.23**	
High level	-	-	C-1			2.60	
High level	-	Applied	C-2			1.79	
			Average			**2.19**	
		Average		5.77	1.84	2.71	
Low level	Applied	-	A-1			1.95	
Low level	Applied	Applied	A-2			1.38	
			Average			**1.67**	
Low level	-	-	D-1			1.59	
Low level	-	Applied	D-2			0.52	
			Average			1.05	
		Average		3.91	0.68	1.36	

b. Amount of irrigation water and urea applied in the low level treatment is about 60 % of that in high level treatment, and yield in the low level treatment is also about 50 to 70 % of that of the high level except in July harvest when the yield was damaged by water shortage. Therefore, it is considered that the relationship between amount of water and urea applied and yield is still linear, and yield in the high level treatment in this trial do not yet reach the maximum level (Figure 3.2.1).

(2) Trial 2. Effect of Subsoiling on growth of Rhodes grass

The trial has been suspended until the machinery is introduced in NARS.

(3) Trial 3. Effect of manure application on growth of Rhodes grass

1) Purpose

The objective of the trial is to clarify the effects of manure application on growth of Rhodes grass.

2) Design

Manure of 15 ton per ha was applied in the area (2.4 ha) between the 1st track and 2nd track of irrigator in the Center Pivot field.

3) Trial period From 30 July to December, 1996

4) Treatment method Manure was spread by hand on 30 July.

5) Results of the trial

The effect of manure application on the yield of Rhodes grass in this trial was not recognized in the September harvest. The difference between the mean yield of "with manure application" and that of "without manure application" is not statistically significant at 95 % confidence level(t-test). The more precise and repeated trials are required to reconfirm the results. (Table 3.7.1, Table A-7.2.1)

(4) Trial 4. Effect of potassium application on growth of Rhodes grass

1) Purpose

The objective of the trial is to clarify the effects of potassium application on growth of Rhodes grass.

2) Design

The area for the treatment "with potassium application" is allocated to 15 ha in western side (location A and B) and for the treatment "without potassium application" is allocated to 15 ha in eastern half (location C and D) of the Center Pivot field. Potassium is applied 30 kg per ha (450 kg per 15 ha) of K_2SO_4 after every harvest.

3) Trial period From 13 August to December, 1996

4) Treatment method

After harvest in July, potassium was applied at a rate of 450 kg of K_2SO_4/15 ha in location A and B by hand on 13 August, and the same amount was applied again with broadcaster on 19 August.
After harvest in September, 450 kg/15 ha is applied with broadcaster within 10 days after harvesting.

5) Results of the trial

The effect of potassium application for the yield of Rhodes grass in this trial was recognized in the September harvest. However, the difference between the mean yield of "with potassium application" and "without potassium application" is not statistically significant at 95 % confidence level (t-test) (Table 3.7.1, Table A-7.2.2). The more precise and repeated trials are required to reconfirm the results.

(5) Trial 5. Diagnoses of microelement deficiency and fertilization

1) Purpose

The objective of the trial is to clarify the effects of microelements application on the growth of Rhodes grass.

2) Design

The trial is carried out at small plots (3 m x 3 m) in two replications at location C of the Center Pivot field. Plot size is 3 m square ($9m^2$). The application rates are shown in the following table.

Microelements	Treatment	Amount of application	
		per $9m^2$ (per plot)	per ha
Cu	Applied	70g of $CuSO_4$-$5H_2O$ (0.2% solution)	50kg
	Not applied	-	
Zn	Applied	49g of $ZnSO_4$-$7H_2O$ (0.2% solution)	30kg
	Not applied	-	

3) Trial period From 6 October to December, 1996

4) Treatment method

0.2 % solution of each microelement is manually sprayed with a watering can.

5) Results of the trial

The results of the daily observation of growth, dry matter weight of the grass of each plot just before harvest in December and chemical analysis of microelements including Cu and Zn of plant tissues in each plot will be reported.

3.7.2 Farm management trial

(1) Method of trial

The purpose of the trial is to clarify the effective farm management strategies for harvest works in 30 ha, to realize the economical combination of farm machinery and labors and to reduce the interruption of irrigation during harvesting.

The trial will be carried out by the trial and error method (repeating the observations, planning and trying) after introduction of own farm machinery.

(2) The results of observation of harvest works in NARS

Grass harvesting works have been conducted by private contractor near NARS up to date. The Contractor's works are very effective but have some problems. The summary of the results is as follows;

Farm machines used for harvesting in September were three tractors, one mower, one rake, two balers and two trailers. There were three operators and six labors during the harvesting works. Work time was 3.5 hours in the morning, 3 hours in the afternoon and 6.5 in total.

To reduce interruption periods in irrigation, the Center Pivot field of 30 ha was divided into four parts. After the completion of the whole hay making works in one part, the works of the next part was started so that the interrupted period of irrigation was four days in each divided part of the field.

The days spent on harvesting works, which was composed of cutting, raking, baling and transporting, was about four days for each quarter of 30 ha and 14 days for the whole Center Pivot field of 30 ha.

Troubles arose often during baling work due to defect in the baling mechanism of baler. Therefore, contractor arranged another baler as a spare for mechanical trouble. Main cause of the troubles was the supply of dried grass in excess for baler. To avoid the baler's trouble, operator worked over again to reduce the quantity of a grass windrow. The results of observation are shown in Appendix 7.3.

3.7.3 Lysimeter Trials

(1) Purpose

The primary objective is to estimate the crop water balance for Rhodes grass cultivation by clarifying the amount of water use in irrigation, drainage, stored soil moisture and evapotranspiration. The second objective is to monitor the drainage water quality to make further recommendations on soil salinity and drainage management.

The main aim is to determine the crop water requirement for Rhodes grass and to compare the results with the actual field data.

(2) Design

Lysimeter has 8 plots and size of each plot is 3 m square ($9m^2$). The trial is carried out at 8 plots in two replications and the treatments of experimental plot are shown in the following table;

Plot No.	Organic manure	Irrigation	Fertilizer	
			Urea (g/plot/week)	TSP (g/plot/2 months)
1	Applied	Control	35	108
2	Applied	Low	35	108
3	None	Control	35	108
4	None	Low	35	108
5	Applied	Control	35	108
6	Applied	Low	35	108
7	None	Control	35	108
8	None	Low	35	108

The amount of irrigation was calculated from the water requirement of Rhodes grass based on the meteorological data. The control treatment was carried out with the amount of crop water requirement. Low treatment was selected as the 2/3rd of the irrigation amount of the control treatment as shown in the following table;

Month	Control		Low	
	Irrigation in depth (mm/day)	Irrigation amount (liter)	Irrigation in depth (mm/day)	Irrigation amount (liter)
July	15	135	10	90
August	15	135	10	90
September	15	135	10	90
October	12	108	8	72

Manual irrigation was selected and the amount of irrigation was measured by the gauge installed in the irrigation pipeline.

(3) Trial period From 26 June to 20 August, 1996

(4) Items of measurement

Daily water retention by tensiometers at 20 cm and 50 cm deep, soil moisture of layers of 0 to 20 cm, 20 to 50 cm and 50 to 80 cm every week, the daily amount of drainage, water quality of drainage water every week, growth of Rhodes grass.

(5) Results of the trial

1) Soil moisture

The low irrigation treatments showed the low soil moisture contents compared to the control irrigation treatment. The effect of compost was found to be of smaller extent in the water retention during the latter stage of cultivation. However, continued observation is required to clarify the water retention characteristics (Table A-7.4.1).

2) Drainage quantity

Drainage of excess water from lysimeter was observed and its amount decreased during the cultivation period. And from 11 August no drainage was observed in the treatment of low irrigation which was significantly different with that of controlled treatment.

3) The quality of drainage water

The value of pH showed increasing tendencies in each treatment. On the other hand, the values of EC were not changing during observation period in the controlled irrigation treatment, while that in low irrigation treatment were increasing. This tendency implies that the amount of irrigation water in low irrigation is not enough to provide sufficient leaching of the salts in the soil. However further experiments are necessary to clarify the leaching requirements (Table A-7.4.2).

4) The growth of Rhodes grass

The harvest results of harvest for past three cultivations and the results of observation in 50 cm square blocks on 20 August are shown in Table A-7.4.3. The results of these observations were not significant.

It is one of the recommendations that the further experiments should focus on changes only in irrigation amount to optimize the method of water saving, for example, by changing of irrigation amount to four level, such as 100 %, 80 %, 65 % and 50 % of the control treatment.

3.8 Conclusions

The following main conclusions are arrived at from the results of the monitoring surveys held at NARS.

(1) Production of Rhodes Grass

The yield of Rhodes grass in NARS had conformed to the yearly usual yield pattern of Rhodes grass, which is high during high temperature seasons and is low during low temperature seasons. The yearly hay production during one year from May, 1995 to April, 1996 was 33.7 tones/ha and this yield was obtained with a nitrogen application of 613 kg N/ha/year. In the guideline of Rhodes grass cultivation which was provided by the JICA Study Team in May, 1995, it was predicted that a hay yield of 40 tones/year would be produced with a nitrogen supply of 1,000 kg/ha/year.

In summer season, the relationship between the average daily increase of dry matter per ha (growth rate) of Rhodes grass and the total amount of nitrogen applied during cutting interval between each harvest is linear upto the upper limit of an yearly amount of nitrogen application of one ton per ha.

Applying irrigation water of 12 mm per day once in every three days for about two months period in summer, 1996 caused a decrease in yield, but the stocks of Rhodes grass did not die and growth recovered rapidly with the restart of daily irrigation. These facts suggest us a method of saving water for Rhodes grass cultivation in summer.

While *Pioneer*, which is the presently introduced variety in NARS, might have low response to nitrogen, it is a well known fact that *Katanbora* which was proposed by JICA Team, has high response to nitrogen and also more drought resistance. Hence its introduction might contribute to water saving and high productivity in future. Verification of this hypothesis is also to be one of the future activities at NARS. Besides, it might be worthful to conduct experimental trial under seasonal variations of watering and nitrogen application for the above verification as already done in 1996.

(2) Soil Improvement

When the soil monitoring survey was started, the organic matter content was at a very low level and only traces of organic matter have been measured. However after two years of continuous cultivation, the organic matter content of the soil has been increased to approx.1%, which can be considered as a significant improvement in this two years of cultivation. Generally, most of the cultivated soils contain 1-5% organic matter in the root zone, which has a significant influence on the physical properties of the soil and strongly influence its chemical and biological characteristics.

Generally, increment of organic matter contributes to improve the soil physical properties and influence its chemical and biological characteristics. Soil organic matter acts as the nitrogen reservoir and furnishes a large portion of the soil phosphorus and sulfur. It loosens

up the soil to provide better aeration and water movement.

However, in terms of soil development, the soils in the NARS are immature and have a weak development of the soil horizon and soil structure and the soils are expected to develop by continuous cultivation. Chemical Analyses of the soil reveal that Cation Exchange Capacity and the fertility status of the soil is low. Presence of macronutrients such as N,P and micronutrients are also low. In spite of these problems, with good irrigation practices and proper fertilizer management, the soils do not constrain for a range of crops including Rhodes grass, dates, vegetables (onion, carrot, okra etc.), water melon etc.

(3) Linear Drawdown of Groundwater Level in NARS

Groundwater monitoring data observed in NARS from October, 94 to October, 96 reveal the fact that the groundwater draw down is almost linear during these two years period. A general hydrogeological theory indicates that a 50-70% drawdown due to a long term pumping occurs in the first year after starting the abstraction. Although two years have already passed since NARS started to operate, the water level seems to continue declining so far. The decrease in water level in NARS indicates probably that this is a complex phenomenon in the area. It is necessary to clarify the behavior of groundwater in the area, which includes Dauka, Shasr, Hanfeet, Quitbeet and Wadi Mokhawrim for further agriculture development. Not only the continuous monitoring in NARS, but also further monitoring work in the above areas including the continuous measurement of water use is strongly recommended for further agricultural development of the Nejd region.

(4) Meteorological Observation and Water Use at NARS

Meteorological data observed in 1995 and 1996 at NARS, Salalah and Thumrait indicate that the mean evaporation at Salalah is 2/3rd of NARS and the evaporation at Thumrait is approx. 1.35 times of the NARS value. The higher wind speed at Thumrait is the major contributor for its high evaporation value. Potential evapotranspiration at NARS calculated by Penman method indicates that the ETo is approx. 3/4th of the evaporation value. These results reveal two possibilities ; one is that potential evapotranspiration can be referred to as 75% of daily evaporation value and it can be an easy reference to use at the site. And the other is the present reference of water application at NARS can be reduced based on the observed climatological data at NARS, because the present ETcrop was provided using Thumrait climatological data.

Although the amount of water applied in NARS varied between the seasons, the water application rate was not adjusted according the crop growth and almost same amount of water was applied between two harvests. Since ETcrop varies between each stage of the growth, the water application can also be modified according to the stage of the crop and by this method a water saving of approx. 10% can be achieved.

The clarification of its possibility for proper water saving irrigation might be confirmed through comparison among evapotranspiration, soil moisture and crop yield. Hence it is

recommended to place and measure evapotranspiration in grass field and to measure soil moisture change while conducting intermittent irrigation continuously as actual approach.

(5) Irrigation Water Requirement and Possibility of Intermittent Irrigation

It has been repeatedly emphasized that the fossil ground water resource should be utilized effectively and as minimal as possible. In the Nejd region, almost all the Center Pivots are irrigating every day and this is a common irrigation practice by all the farms. However, by irrigating everyday, there are considerable amount of water losses through high evaporation and seepage.

As discussed in section 3.3, it was found out that there is a good possibility to modify the existing practices of daily irrigation to intermittent irrigation, based on the available water holding capacity of the soil and the soil moisture measurements. The average AWC of NARS soil is 112 mm. If the readily available soil moisture is considered as 2/3rd of the AWC, approx. 75mm can be considered as readily available soil water. If the maximum daily water requirement of the crop is considered as 15mm, the crop can obtain its full water requirement for 5 days, even without any irrigation. During every harvest season, irrigation is stopped for almost 5 days to a week period and regrowth is normal even after stopping irrigation for a week time. This practice also reveals the fact that the harm for the crop growth is negligible when sufficient soil moisture is available.

Although the basic data of soil and irrigation reveal the possibility of intermittent irrigation, it should be verified through the experimental trials at NARS. The relationship between yield benefit and water saving through intermittent irrigation need to be verified though cultivation trials. Especially it is required to measure the relation between irrigated water amount and crop yield continuously. Besides, it is more important to do routine soil sampling and chemical analysis than in the previous cases of water saving, because leaching amount might be reduced while doing these trials. If this practice is found to be suitable through the experimental trials at NARS, then the intermittent irrigation method can be adopted in the other farms of the region.

CHAPTER 4

FIELD SURVEY IN THE STUDY AREA

CHAPTER 4

FIELD SURVEY IN THE STUDY AREA

4.1 Existing Conditions of the Study Area

4.1.1 Agriculture

(1) Farm

1) Location of Farming Communities

There are six farming communities in the Study Area, namely Dauka, Hilat Al-Rakah South, Hilat Al-Rakah North, Hanfeet, Shasr and Quitbeet. The following table is a summary of present condition comparing with the previous Study in '88/'89.

Locations	At Previous Survey ('88/'89)	At Present
Dauka	Two center pivots under irrigation depend'g on one Aquifer-C well by a local company farm.	Two center pivots on duty and a 3rd center pivot was abandoned because of lack of water.
	Three small farms depends on Government's free flow well (Aquifer-C) for irrigation	One farm remains and survives with draw-downed free well. Free flow is not sufficient for 1/8 ha farm.
Hilat Al-Raka North	Small traditional farms under irrigation depending on shallow wells (Aquifer-A)	8 center pivots on duty. Cumulated No. of the system there were 12 nos. Demolished ones were caused draw down. 3 companies & 2 privates own the
Hilat Al-Raka South	About 15 small scale traditional farms under developing hand-dug wells with bull-dozer and manual labor	Almost half were closed and survives for self-consumption with foreign labors.
Hanfeet	On both sides of the national road, small scale traditional farm just started water'g.	2 center pivots on east side and 6 Nos. on west side. They are facing on rapid draw down. 4 companies share them.
Shasr	People work as country border patrol with 2ha traditional farm, getting water from cave, sub-surface water. And started farm development around the village.	The 2ha traditional farm reminds, while new developed farms were failed. '96 two center pivots were started with Aquifer-C wells. Village was modernized with new housings.
Quitbeet	Nomads started small habitat with small irrigation.	Initial settlement was shifted to new village near Thumrait

Figures 4.1.1, 4.1.2 and 4.1.3 present the chronological farm development in the Study Area.

2) Farm scale

The farms in the Study area can be clearly categorized into two types. One is a small scale farm with a scale of 0.21 ha (half feddan) to a maximum of 10 ha (about 25 feddan), which is adapting traditional irrigation and cultivation system with one or more foreign laborers. The other type is a big scale company farms from 25ha to 50 ha, with center pivot system with 5 to 10 foreign laborers.

The small traditional type farms are surviving for more than 10 years using their own shallow wells dug by manual digging.(Few farms share and utilize neglected deep well in their compounds). This type farms are noticed mainly in Hilat Al-Rakah and in Dauka, though there is only one farm in Dauka doing cultivation by laborers. Shasr is also a place of traditional farm, where the community depends on a spring which seems to be a sub-surface water flow of Wadi Ghadun. Their farming practices are almost same as reported in Phase I study (1989, JICA), but the number of cultivation plots around the village was decreased than the previous study. Almost all of the farm owners are not staying at the farms and mostly foreign laborers carry out the farming activities. Planted crop varieties in the small farms are mainly vegetables and tree crops. The farm produces are consumed mostly by the farm owners and laborers, and are not sold to the market now.

There is a complete new phenomena presently in the Study Area, comparing with the previous condition of Phase I study, which is the number of increased center pivot irrigation system (Figure 4.1.4). According to the interview survey and field survey, the number has been increased rapidly and reached 24 which are owned and managed by private companies and are concentrating on cultivating Rhodes grass. Each company manages several center pivots at different locations. They have their own agricultural machines and sufficient foreign laborers work in these farms. These labor forces work in the different farms of the same company following with the harvesting schedule.

(2) Agricultural Production

1) Types of Crops

About 15 types of crops are cultivated in the Study area. Tomato, Water melon, Potato, cucumber, Cantaloupe and Okra are the mainly produced vegetable crops. Fruit production like Dates, Lime and Pomegranate plantings can be identified at basin irrigation boundary as substantial. These crops are cultivated mainly at traditional small farms.

On the other hand, Rhodes grass production is concentrated at the rapidly spreading big scale farms. Some of these farms have small plot(s) near big irrigator to produce vegetables for their self-consumption, while selling the hay to the market.

2) Production

According to the agricultural statistics, the production quantities of crops are rather limited, though their productivity per unit area is almost similar with national level. Some owners of small scale farms explain as follows :

a. Initially they developed farms with an expectation to sell crops to market and tried for several years.
b. But they found that the transportation cost to the markets is a major problem
c. If the collecting services are provided, then they would like to sell their crops.
d. They are also expecting technical extension services from the government for proper cultivation.

On the other hand, the company farms are facing lack of proper cultivation techniques. Grass growing condition is rather poor and both of fertilizer / chemical application seem to be not proper. Also they are looking for possibility of reducing the amount of water application to reduce the running costs.

(3) Cultivation Methods

1) Cropping pattern

Several crops are planted and harvested once a year, except water melon. Seeding or replanting is done at the end of summer season and they are harvested from January to the time of beginning of summer season. Among them only Water melon is planted twice a year. Main vegetable crops are Tomato, Egg plant, Onion, Garlic, Cucumber, Carrot, Water melon, and Okra. Rhodes grass is harvested 6 or 7 times in a year in all of the company farms.

Difference of climatological condition between Salalah coastal area and Nejd causes different harvesting time for each vegetable crop. Generally the whole period from seeding / replanting from nursery to harvesting is shorter at the Study area than the coastal area. For example, in the coastal area, tomato is cultivated and harvested from June to October under the monsoon season, where as in the Study Area, it is cultivated from September and is harvested in winter season. Water melon is also harvested in the Study Area after the season of coastal area.

2) Cultivation method

Small farms, keeping the traditional basin irrigation on small plots, are cultivating various types of vegetables. Most farms are managed by one or two foreign laborers. They don't share any machinery and most of the farming activities are done manually.

Company farms are adapting center pivots and sharing their own agricultural machinery for the farm works. Their works are rather rational and systematized with shifting of workers and implements from one place to another place according to the harvesting schedule.

(4) Agricultural Extension Service

Farmers are reporting that at present there is no extension services by the government at both of small and big farms in the study area. As reported in the previous sub-section farmers are expecting government assistance through extension services for proper cultivation of both small traditional farms and company farms.

4.1.2 Soil

The results of the some of the earlier soil surveys were re-examined by JICA phase-I study and have been integrated with the field data. Soil Classification map and Land Suitability Classification map of the Study Area were prepared (Appendix A-3.10).

After JICA phase-I study, soil surveys were carried out by Mott MacDonald International (1992) for the detailed investigations for development up to 1000 ha of irrigated land in Nejd region and a detailed soil survey report was prepared. GRM (1995) did detailed soil surveys in Wadi Bani Khwatar (1300 ha) in the north of Dauka and Dameet (800 ha) in the east. Ministry of Agriculture and Fisheries (MAF, 1996) carried out a detailed soil survey of 2000 ha area in the western Hanfeet. These reports provide good and valid information on the soil conditions of the study area. A review of these soil surveys is discussed in Appendix A-3.10.

The main objectives of the soil survey of the phase-II (work III) study are mainly to do a detailed soil monitoring survey at NARS (as discussed in section 3.3) and to do a preliminary field survey in the Study Area in order to verify the soil conditions of the Study Area.

(1) Center Pivot Farms

A preliminary field Survey was carried out in the Center Pivot Farms, Small Farms and other selected locations of the Study Area. As shown in the Appendix A-8.5.3, the soil pH (1:2.5) values in the Study Area varies between 8.0 to 9.5 and the alkalinity varies from high to very high level. Except for some soils, the EC (1:5) values are normally less than 1.0 mS/cm and can be considered as slightly to moderately saline. For further discussions, the Study Area shall be widely divided into the following areas such as Hilat-Al-Rakah, Hanfeet, Shasr, Dauka, and Quitbeet.

In Hanfeet areas, the Center Pivot (CP) farms have a pH value of 8.0 - 8.5 and an EC value of approx. 0.500 mS/cm. On the other hand, the CP farms in Dauka and Wadi Bani Khwatar, which are in the northern part of the Study Area, have an EC value of above 1.5. It has been reported that an impervious layer exists in these areas, within 2 m level and hence these areas are prone to salinity. However the soils have a lower EC level before starting cultivation and the salinity started building up after starting the cultivation with irrigation. In Dauka, many ponding locations were also observed during the field survey. After evaporation, the salts contained in the water stays on the top of the soil and many white patches were also observed.

In the areas such as Hilat Al-Rakah and Hanfeet, leaching should be carried out regularly along with the irrigation in order to prevent the salinity problem. In Hilat-Al-Rakah, some of the CP farms have soils of higher EC values and one farm was already abandoned. These farms use the water from Aquifer A and it has been reported that the quality of water in Aquifer A in some locations is poorer than Aquifer C and the quantity of water is also limited. These farms have started irrigation from Aquifer A with relatively less quantity. This practice might have lead to the increase in the salinity level of the soils. However, a few farms in Hanfeet areas and Hilat-Al-Rakah are managed well by the private companies and the salinity of soils in these farms are at a low level.

(2) Small Farms

The pH (1:2.5) value of the soils of the small farms surveyed are approx. 8.0 - 8.5 which is considered as moderately alkaline. Except two farms in Hilat-Al-Rakah and one farm in

Dauka (Small Farm 15), the EC (1:5) values are well within 0.5 mS/cm. As explained already, the soils in Dauka are considered to be prone to salinity and the same trend is noted in the case of small farms also. The small farms in the Hilat-Al-Rakah might be irrigating with less amount of irrigation water which might have induced the salinity of the soil.

(3) Other Locations

In general, the pH (1:2.5) of these virgin soils are in the upper range of 8.5 to 9.5 and shall be considered as alkaline (or basic). The major effect of a basic pH is to reduce the solubility of all micronutrients (except chlorine, boron and molybdenum), especially those of iron, zinc, copper and manganese. Also, phosphate is not readily available to some plants because of its precipitation on solid calcium carbonate.

The EC values in Wadi Quitbeet, Hanfeet are low. Some locations at Hilat-Al-Rakah have a higher EC values. In these locations there are observation wells maintained by MWR and some of these wells are free flowing wells. The water from these wells were flooded up in some of these areas and after evaporation, the salts in the water accumulated in the soils. The soil samples collected at Wadi Bani Khwatar also have a higher EC values similar to the center pivot farm at Wadi Bani Khwatar.

(4) Conclusions

Some of the general conclusions made from the field survey are as follows :

i) The initial pH (1:2.5) values of the virgin soils are high in the range of 8.5 - 9.5 and this is common in arid soils of high in calcium (low rainfall areas). However, after cultivation is carried out for a considerable period of time, these pH values tend to decrease.

ii) The initial EC (1:5) values of the virgin soils are also very low in the range of 0.1-0.2 mS/cm. ECe (EC-extract) values for these arid soils are normally 5 to 10 times of EC (1:5) values and the average ECe values before cultivation are approx. 1 to 2 mS/cm. In this range the salinity effect is negligible. However if the ECe values go above 10 mS/cm, then there shall be a considerable yield reduction, depending on the type of crop. Salinity is a major concern in these arid soils and irrigation is required for crop growth although it may itself induce the salinisation unless salts are leached away regularly. Average EC of irrigation water is 1.6 mS/cm, and according to USDA and FAO classification of irrigation water, the intensity of salinity problem to be caused by EC of irrigation water within a range of 0.75 to 3.0 mS/cm is considered as 'moderate'. Unless leaching is carried out regularly, the salt content of the soil would increase.

iii) At some locations in Wadi Quitbeet the soils are alkaline with very low salinity. Plants on soils of pH greater than 9 usually have reduced growth. These soils should be checked for their exchangeable sodium and if SAR (sodium adsorption ratio) is greater than 13 (or an ESP (exchangeable sodium percentage) value of 15) then these soils should be reclaimed. Many deciduous fruit trees can be injured by as little as 5% of exchangeable sodium; citrus is

sodium sensitive and grapes are quite sodium tolerant. Forage, and vegetables are also non-sensitive.

iv) Among the different areas of the Study Area, the soils at the northern areas such as Dauka and Wadi Bani Khwatar are highly prone to salinity. Therefore while identifying areas for the new farms, careful area selection should be made. If an impermeable layer is found within 2m level, a suitable drainage system might be necessary.

v) The soils in the areas of Hanfeet and Hilat-Al-Rakah have relatively low problem of salinity and alkalinity and if proper irrigation with leaching is followed in these two areas, the soils can be maintained at low salinity level.

These conclusions are made only based upon a preliminary field survey held in the Study Area. However, before selecting a suitable area for a new farm, a detailed soil survey will be necessary which will include soil profile survey and detailed physical and chemical analysis of the soil.

4.1.3 Irrigation

(1) Irrigation method

In general, basin irrigation method is adapted at small farms and other methods are followed at few farms. In Shasr, sprinkler system in few farms of 4ha each has been provided under government subsidy programme with water from cave well. Bubbler irrigation system was adapted for dates palm plot at Shasr few years ago, but the plot was already demolished. In Hilat Al-Rakah, a company farm installed drip irrigation system for water melon and melon plot substantially besides a center pivot irrigation system.

All of the company farms are using center pivot system for grass cultivation. These systems are operated by foreign labors and the irrigation application is occasionally adjusted referring to the grass growing condition. There is no record of water use amount by themselves and also there is no regulation to keep the water use records.

(2) Water source

All of the farms in the Study Area depends on groundwater only. But there is no precise information on which aquifer they are depending on and the well location map provided by the MWR indicates the aquifer of the registered well locations only. There are only few monitoring activities by MWR at monthly intervals at the selected well locations.

According to the MWR well location map, the number of wells depending on Aquifer -C is quite limited officially and it is concluded that most of farms are taking out groundwater from Aquifer-A or Aquifer-B.

Condition at Shasr village is different than others since they are depending on subsurface water from the cave. Also farms in Dauka facing to the National Road are conveying water

from government well, which had freely flowing water until recently. Hand dug wells in Hilat Al-Rakah prove that the small scale farms there are depending on shallow groundwater only.

(3) Water application

At small traditional farms, groundwater is first pumped to a reservoir and then is conveyed to farm plots for irrigation. Commonly one irrigation block of several small plots (one plot is about 3 m x 3 m) is irrigated within half an hour or so and alternatively shifting the irrigation block in the evening. It is assumed that water application rate is 7 to 8 mm/day.

All of the company farms are sharing their own well, generally one well for one center pivot system. No information or log data could not be found. During this study period one of the big farms accepted to keep water use log note from July '96 to present. According to the record, the farm is irrigating 10 to 12 mm/day through out the year. It seems that this water application rate is almost common, even though there might be some slight difference among company farms because the farm management is normally carried out by a few private foreign engineers. Estimated water consumption by the big farms are shown in the table shown below.

Estimation of Water Consumption at Big Farms

Location	No. of Center Pivot Nos.	Irrigated Area ha	Estimated Water Use MCM/year
Hanfeet East	2	60	2.42
Hanfeet West	7	248	9.51
Dawkah	2	93	3.56
New Hilat Arrakah	11	395	15.99
Shasr	2	102	4.76
Total	24	898	36.24

Well inventory map shows that most of them are depending on Aquifer-A, which is reported to have a water quality of less than 2 mS/cm normally, except for some high salinity water of more than 10 mS/cm. In the field survey, it was found that most of the EC values of these farm well water is less than 2 mS/cm.

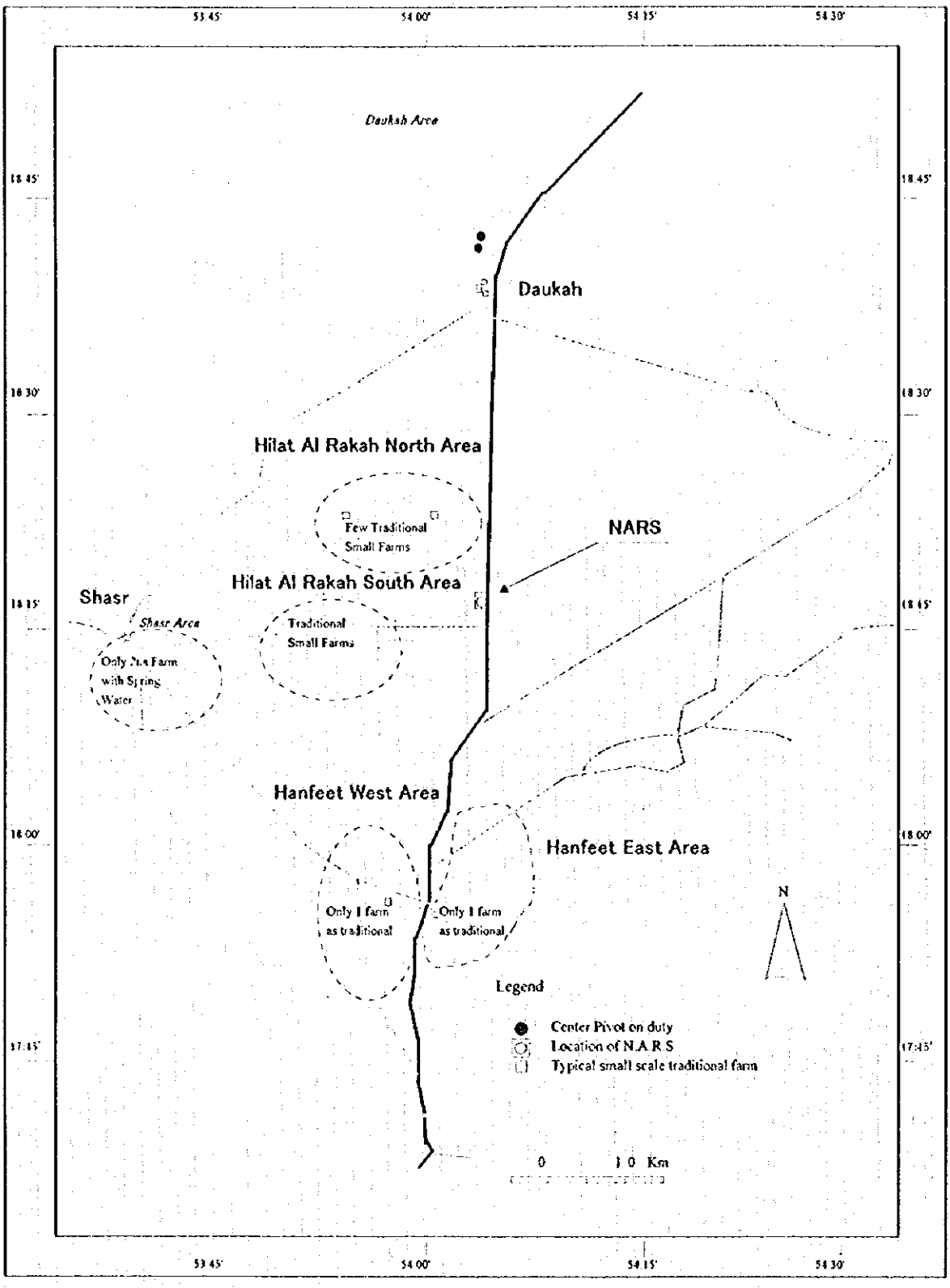


Fig 4.1.1 Initial Farm Development Condition in the Study Area (at '88/'89)

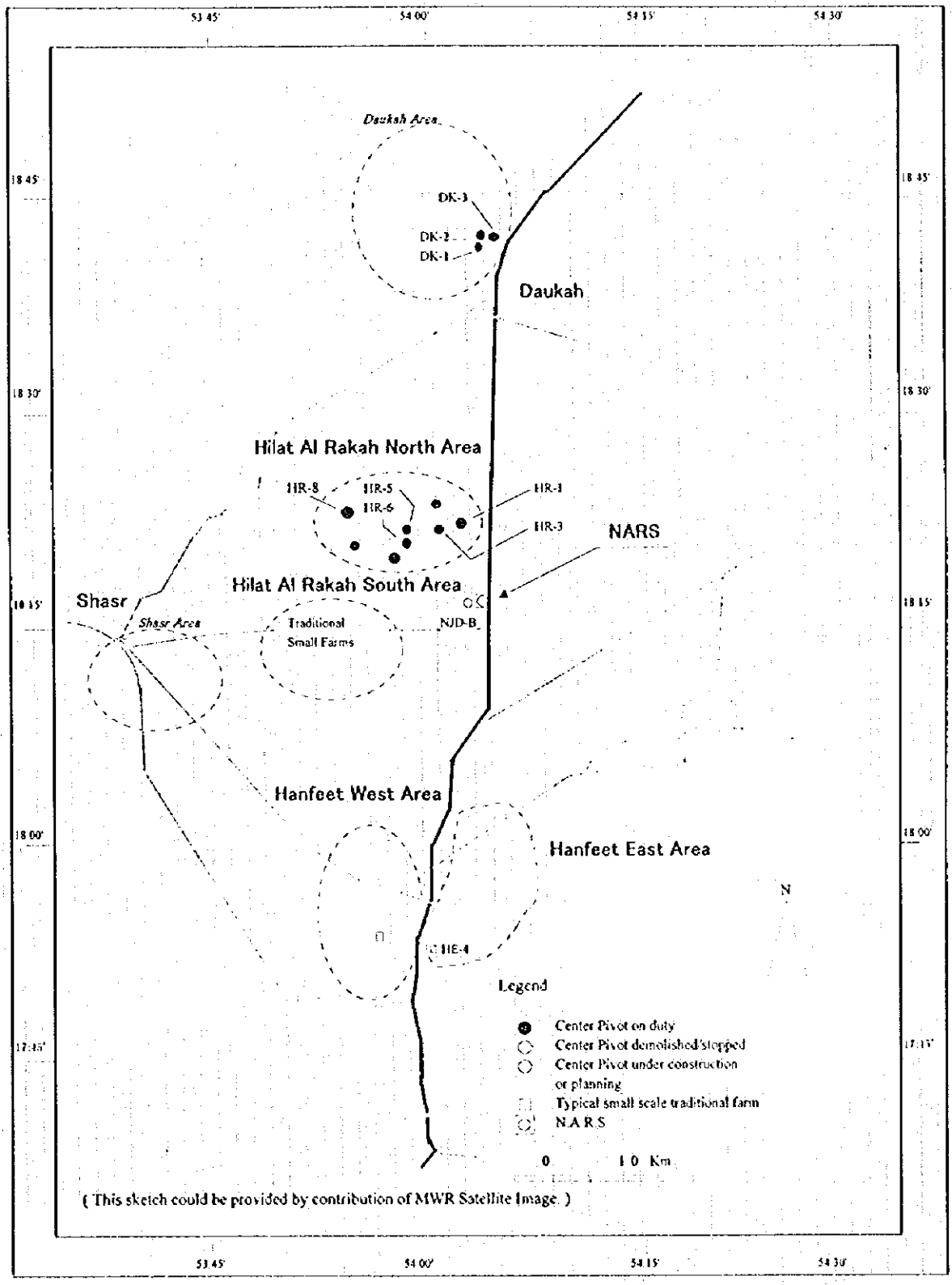


Fig 4.1.2 Interim Farm Development Condition in the Study Area (January '94)

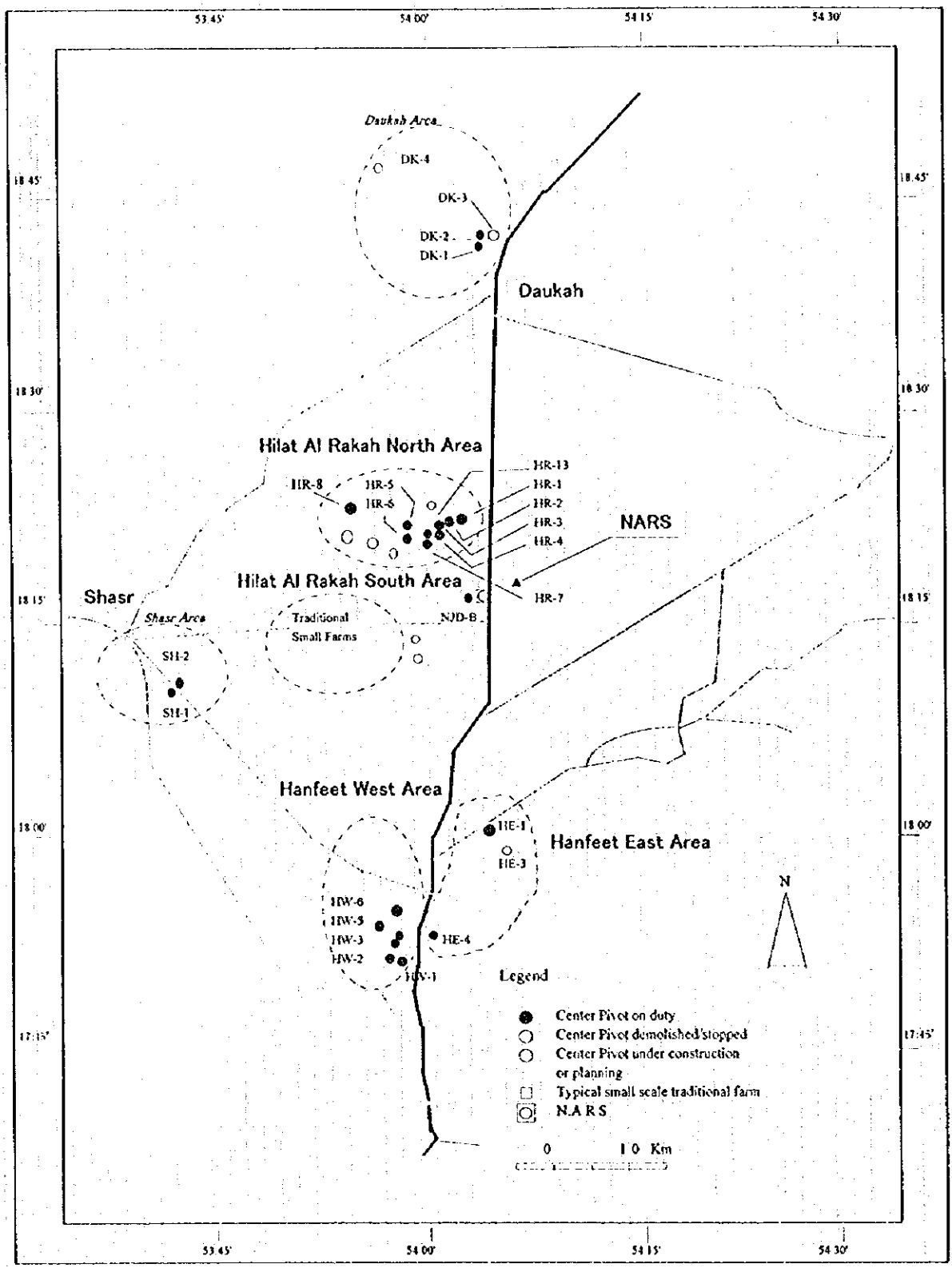


Fig 4.1.3 Present Farm Development Condition in the Study Area (October '96)

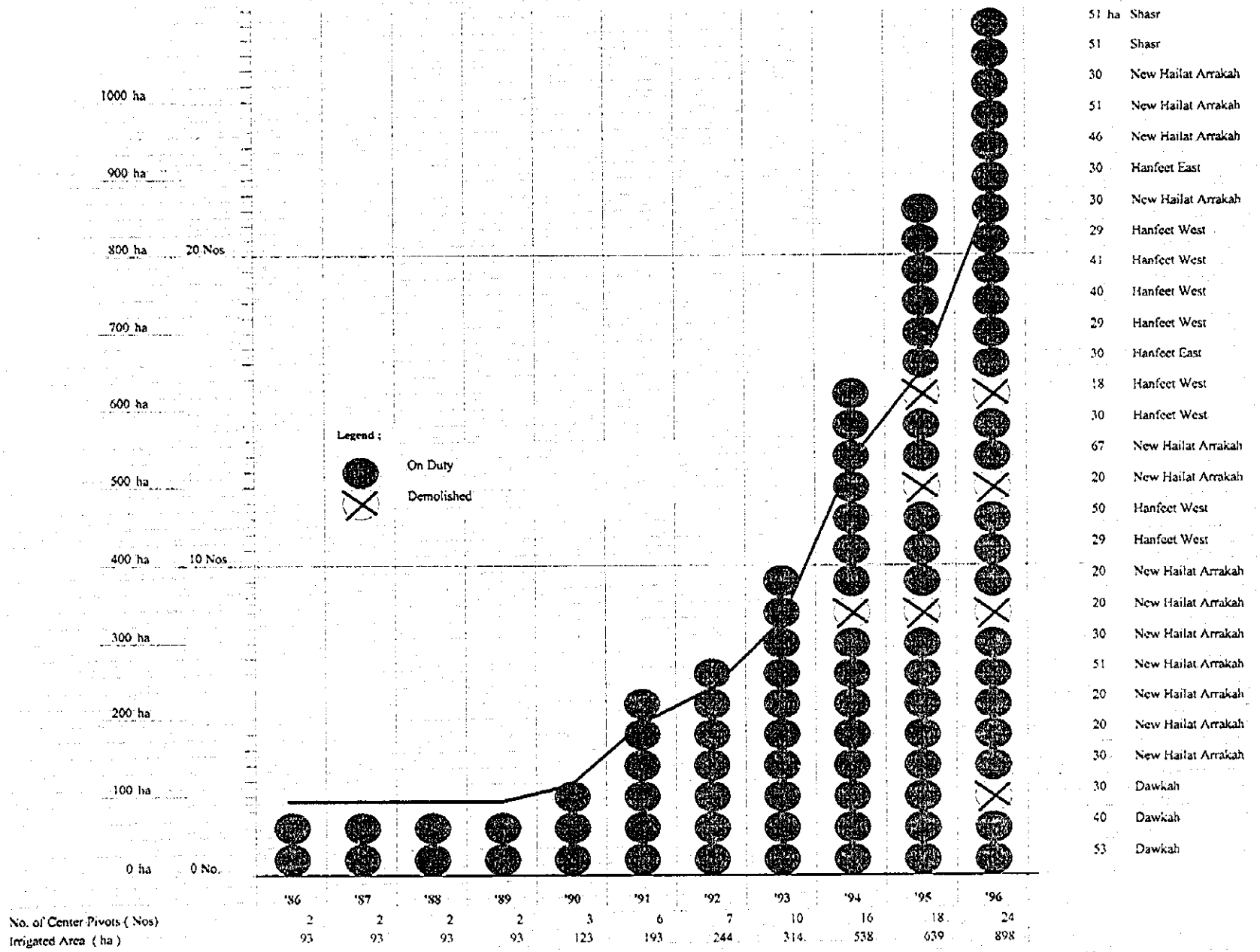


Fig. 4.1.4 Big Farm Development (Center Pivot System) in the Study Area.

4.2 Groundwater

4.2.1 Water Level Changes

The Locations of the wells of the Study Area are plotted in Fig. 4.2.1. The water level data for the MWR observation well network were arranged in hydrographs of Fig. 4.2.2 and Fig. 4.2.3. The water level fluctuations since 1988 is shown in Fig. 4.2.2, and the water level fluctuations around Hanfeet and NARS since 1993 is shown in Fig. 4.2.3. The Aquifers of the observation wells are noted down in the hydrograph.

From 1988 to the middle of 1993 the water levels had fluctuated within a few meters. The water level of C aquifer in YV760834AA (Wadi Rana) and ZV099779BA (Hanfeet) declined and recovered for a short term, from the end of 1991 to 1992. The level of D aquifer observed in BE094486AA (Wadi Ribkut) has slightly lowered since the end of 1991.

In the middle of 1993, the water levels in some wells located near Hanfeet decreased for a while and recovered a little for a few months after. This phenomenon occurred only around Hanfeet area, and hence an artificial factor in the area might have caused these water level changes.

The water levels in ZV099779 BA, ZV193045AA and ZV182823AA had slightly lowered from September 1994 to April 1995 and suddenly started an outstanding decrease from June 1995. Since then the water levels have declined almost 30 meters continuously and linearly. These wells are located around Hanfeet which are 30 to 40 km south of NARS (see Fig. 4.2.1). The following Table 4.2.1 shows the decline of water levels in these wells and NARS observation wells for this one year.

Table 4.2.1 Changes of Water Level (Depth to water surface) in C aquifer (near Hanfeet)

		ZV099779BA/ C aquifer	ZV193045AA/ C aquifer	ZV182823AA/ C aquifer	AF828801AA/ C (NJD1)	AF828801CA/ C (NJD3)
Oct/11/94	(m)	29.27	31.98	39.56	---	---
Oct/21/95		38.85	47.05	54.65	14.42	14.73
Oct/13/96		52.38	62.10	69.73	22.00	22.00
Drawdown	(m)	23.11	30.12	30.17	---	---
Decreasing rate for this one year	(cm/day)	3.78	4.20	4.21	2.12	2.03
	(m/year)	13.79	15.34	15.37	7.73	7.41

However, recently there were no changes in the water levels of the wells of ZV182823BA and ZV19035AA which are also located in Hanfeet. Actually they have recovered for this two years (Table 4.2.2). It is reported that these wells are drawing water from B aquifer.

Table 4.2.2 Changes of Water Level (Depth to water surface) in B aquifer (near Hanfeet)

		ZV193035AA/B aquifer	ZV182823BA/B aquifer
Oct/26/'94	(m)	56.98	60.56
Oct/21/'95		56.90	60.43
Oct/13/'96		56.66	60.45
Drawdown	(m)	(0.32)	(0.11)
Decreasing Rate	(cm/day)	(0.04)	(0.02)
	(m/year)	(0.16)	(0.06)

A figure in brackets ; Recovery

The levels of AF828801AA and BA (NJD1 and 3 in NARS) have declined since NARS started the operation as described in section 3.4.

The record of BF040020AA located about 20 km northeast of NARS also shows the water level down in C aquifer. The level has decreased by about 2.6 meters in these four months, at a rate of 2 cm/day, or 7.3 m/year. The well was flowing in 1993. Now the water level is 5.07 meters below g.l.

These water level changes which have occurred recently are certainly effected by artificial factors. The condition of water consumption in the area is described in the following section.

The water levels of other wells observing C aquifer have not changed sharply. The record of YV760834AA which is located at about 95 km southwest of NARS shows moderate decline, 1.5 meters drawdown from 25.2 to 27.7 meters, for eight years after observation was started. BF840101AA which is located in 95 km east of NARS does not show any decline of the water level. The level of BF000000AA located in Wadi Ribkut, 30 km southeast of NARS and 25 km northeast of Hanfeet, has decreased by 3.5 meters for about three years.

BF410641AA observing B+C aquifer is located in Wadi Quitbeet south, 54 km west of NARS and 65 km northeast of Hanfeet. The water level of the well has lowered by about one meter since 1988 when the observation started.

- Seasonal Fluctuation

Apart from the long term change of water level, it seems that there are seasonal fluctuations in Hanfeet area. The hydrograph in Fig. 4.2.2 show a little gentle slope during the end of 1995 and 1996. The factors which caused the changes are unknown for the present. The changes may suggest that recharge to C aquifer occurs seasonally. But the fact that the tendency was not so clear before 1994 and in the other wells, may indicate that it is caused by an artificial factor such as seasonal variation of groundwater consumption in the area. A detailed survey and long term monitoring of abstraction and water level in the area, especially around farms in Hanfeet, are necessary to reveal the cause.

4.2.2 Groundwater Use

Before 1990, there were no farm adapting center pivots except three farms in Dauka. From 1991 to 1993, seven farms with center pivots were constructed in Hilat Al-Rakah north. Two more farms in Hilat Al-Rakah North and also two farms in Hanfeet West were constructed in 1994. NARS started irrigation in September, 1994. And four more farms in Hanfeet West and one farm in Hanfeet East started their operation in 1995. Furthermore three farms in Hilat Al-Rakah North, one farms in Hanfeet East and two farms in Shasr were constructed during 1996. Now more than 20 farms with center pivots are working though some farms were already abandoned.

It is reported that nearly all the center pivots in Hilat Al-Rakah North are pumping from A aquifer and most likely the other center pivots in other areas are pumping from C aquifer. The estimated total volume of consumed water in Hilat Al-Rakah is 15.99 MCM/year. The total volume of water pumped up from C aquifer is estimated to be 20 MCM /year including 0.91 MCM/year consumed in NARS. About 54 %, or 10.8 MCM/year, of that quantity is used in around Hanfeet area, where the estimated total irrigated area is 278 ha., with 8 wells at present.

Some of the farms in Hanfeet were constructed in the middle of 1995 when the sharp decline of water levels in the observation wells started as described the previous section. Abstraction from the production wells in these farms clearly have affected C aquifer.
Two farms which are constructed before 1990 have been working in Dauka. The total irrigated area and the water consumption are estimated as 93 ha. and 3.56 MCM/year respectively.

4.2.3 Water Level Contour Maps

On the basis of the data from MWR and the field survey, the two water level contour (piezometric contour) maps of C aquifer was prepared. Fig. 4.2.4 shows the water level contours before 1994 and Fig. 4.2.5 shows the water level contours in 1996.

Before 1994, the piezometric head sloped from southwest to northeast except around Dauka where the piezometric head seemed to drop more than surrounding area.
In 1996 the contours have moved toward southwest, especially in the area bounded by Dauka - Hanfeet - Shasr. It means that the piezometric head of C aquifer has dropped in the area for these two years. The schematic profile in the area (Fig. 4.2.6) shows that the piezometric head dropped most in the area from Hanfeet to NARS.

The decline of piezometric head in recent two years is shown in Fig. 4.2.7. It is obvious that the decreasing of piezometric head has occurred in the extended area. The area in which the piezometric head dropped more than five meters is extended almost 60 km east and west and 100 km northeast and southwest. It should be noticed that the Fig. 4.2.7 was prepared only by the data of existing observation wells. All farms in Hanfeet have no observation well in itself . It is reported that one farm had to stop irrigation recently because the water level reached 100 meters below ground level. There may be a possibility that the critical decrease

of the piezometric head in C aquifer is occurring around Hanfeet.

It is reported that the groundwater reserve in the area is on the order of billions of cubic meters. However, it must be remembered that accelerating drawdown causes significant increases in pumping cost. The economical depth to water surface for pumping is considered to be 100 meters below g.l.

4.2.4 Need for further Study

The phenomenon such as the continuous and linear water level fall occurring in Hanfeet is not considered to support the well-field model provided by MAF. The model indicated that over 85 % of drawdown at the well-fields would be established in the first year of operation. The model should be calibrated on the basis of the recent result or a new model should be constructed. It requires further monitoring work and a detailed survey of water use in the area.

There are still uncertainties about the behavior of C aquifer. At present it cannot be said when the level will be stable and how much is the sustainable yield of the aquifer. It is necessary to develop gradually and carefully while obtaining the data concerning to the water resources. At that time a drilling site for a new production well should be decided based on the water level decline map (Fig. 4.2.7). Naturally the area where the piezometric head has dropped less than other areas should be selected as the new drilling site. It is outside of the area bounded by Dauka - Hanfeet - Shasr.

The proper groundwater management is necessary in order to optimize the use of the aquifer and forward agriculture development in Nejd. The monitoring of groundwater level is essential for that purpose. The sustainable agriculture development in the area is depending on the efficient groundwater management, which should be established on the basis of understanding the behavior of the aquifer.

4.2.5 Directory for Conservation and Development of Groundwater

(1) Points to be clarified

Establishing groundwater management setup is essentially indispensable to realize appropriate water use in the area. The management system should be founded on the reliable evaluation of the groundwater basin. However, there are some unknown factors to evaluate accurately the groundwater basin at present as follows;

a. The outline of groundwater-bearing formations in Nejd has been clarified. However, the regional details of hydrogeological properties such as Transmissivity vary at large because of fractured aquifers in the carbonaceous sediments. It is not clear how the details are.
b. The area and amount of recharge to the aquifers have been estimated roughly but not on basis of hydrogeological study.
c. There are no reliable data of discharge from the aquifers in the area.

d. The regional decline of water level are reported, but the correlation between decline and consumption of water have not been revealed because of unknown pumping rate of production wells.

Grasping of the water use condition, the continuous and extensive monitoring of groundwater, and the further detailed hydrogeological study are necessary to clarify the above points.

(2) Technical Aspects

MWR has conducted the groundwater monitoring and hydrogeological studies in the area so far. The works will be carried out successively by MWR. It is recommended that the construction plan of observation well network which is suspended now also should be resumed in the near future. These works will inform the detailed condition of groundwater occurrence in the area. Expected subjects of researches and studies are summarized as followed;

a. Resumption of the plan of establishing observation well network
b. Analysis of hydro-geological structure of the region
   (Thickness, depth and locations of aquifer, Transmissivity, discharge and recharge)
c. Provision of aquifer model

(3) Establishment of a Ground Water Management System

It will take time to obtain the final results for those subjects. Hence the agricultural development should be a plan to assist the above study. Consequently the plan should be decentralized and on a small scale which can obtain the correct data of water level fluctuations due to withdrawal. Besides MAF should construct a system to observe continuously the discharge rate of each production well for existing farms in the area. It is also recommended that MAF should monitor constantly the water levels of the wells belonging to MAF. As a result the data concerning water level fluctuations depending on water consumption for agricultural development will be obtained in detail. The reliable evaluation of aquifers in Nejd and the management system should be constructed on basis of the data from MAF as described above and the result of the hydrogeological study by MWR. The management system should include the functions as follows;

a. Development control including temporary stoppage of new groundwater development by private sectors.
b. Establishment of monitoring system, including of obligation to measure daily abstraction volume and reporting the log-record
c. Water use monitoring system with remote sensing system map, which might be provided twice a year.
d. Extension services to reduce water consumption at farms
e. Continuous monitoring on both of water use and groundwater level fluctuation.

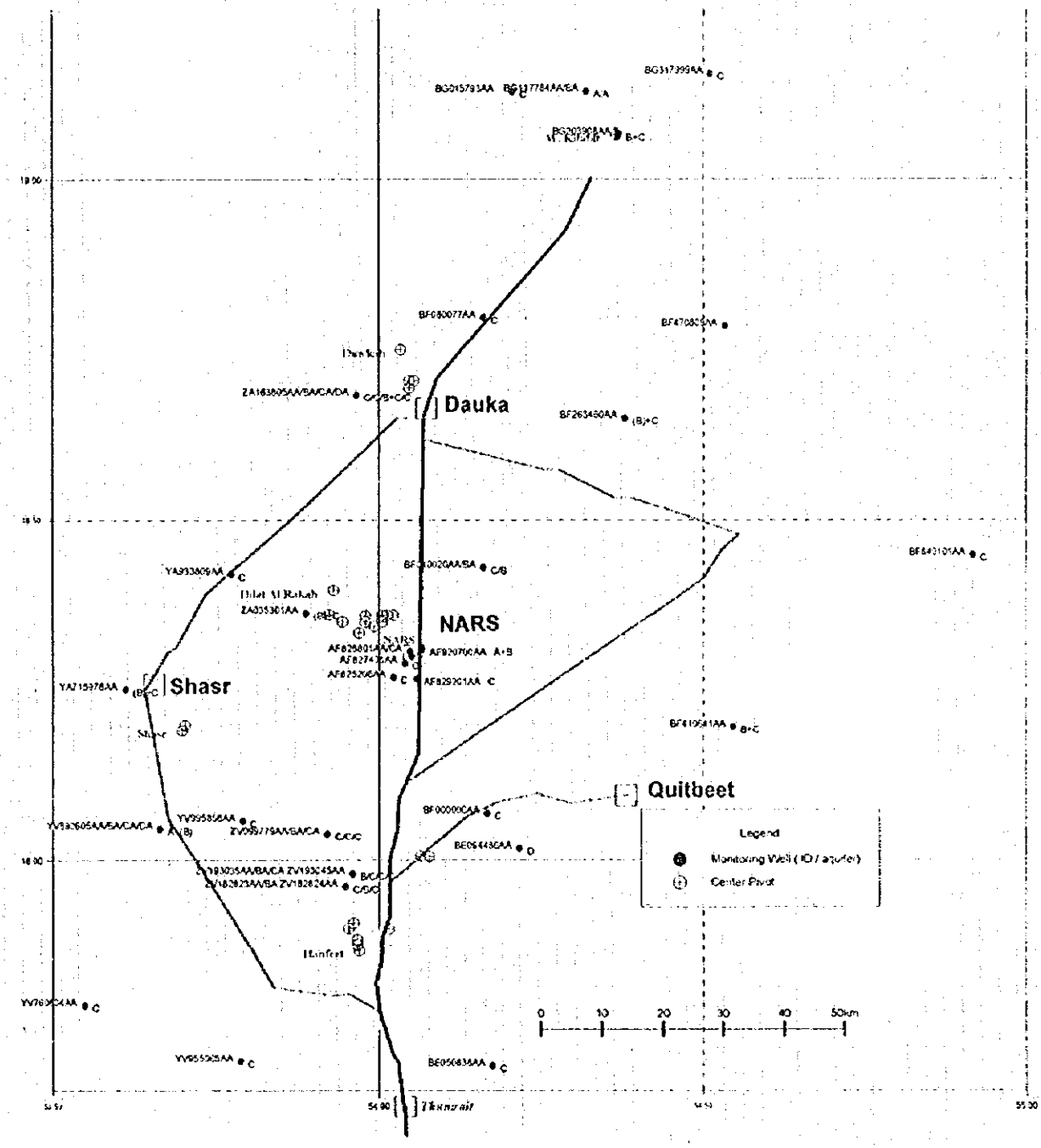


Fig. 4.2.1 Location map of MWR observation wells

Fig.4.2.2 Groundwater Levels in the Study Area (1988 - 1996)

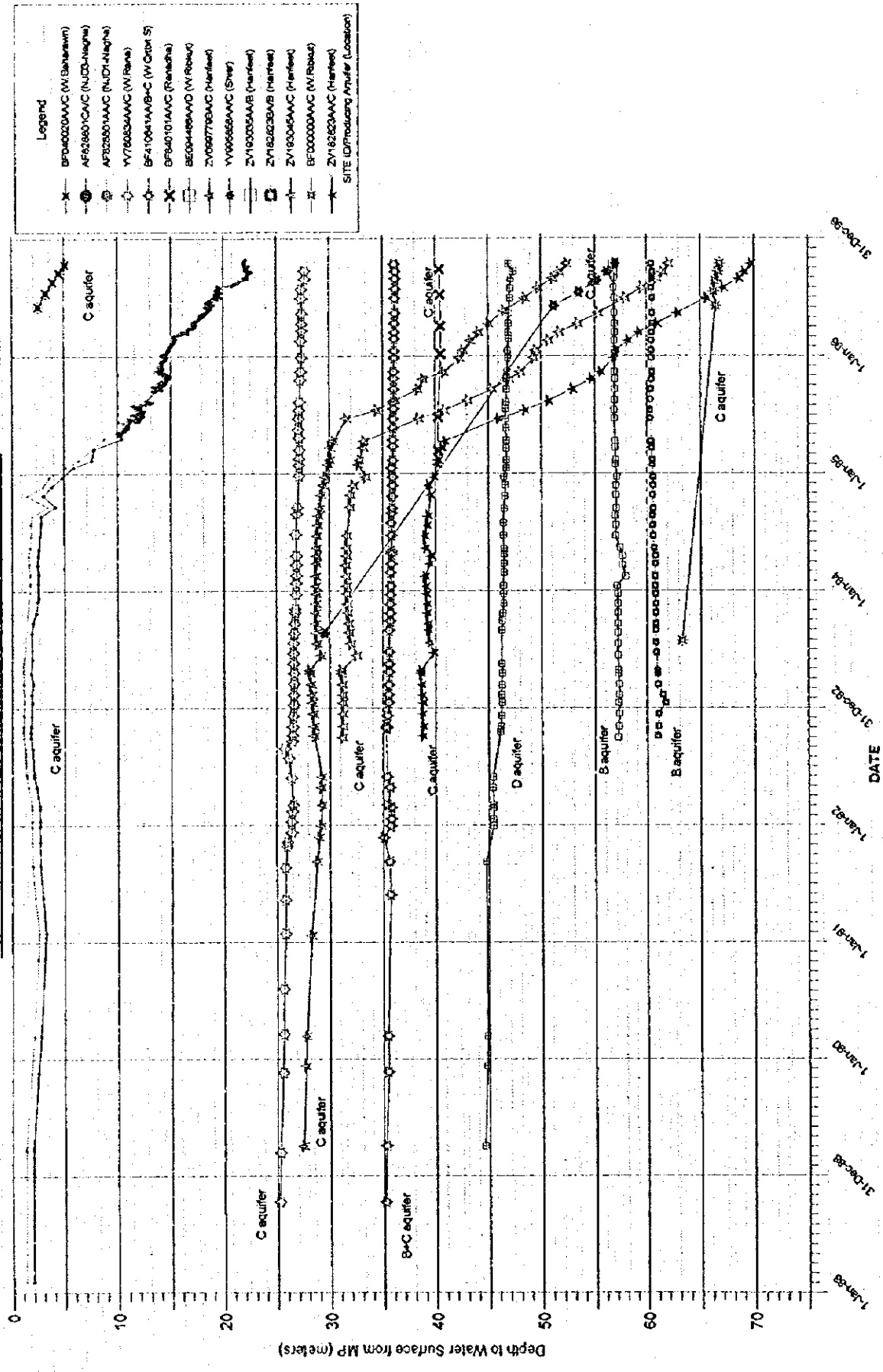
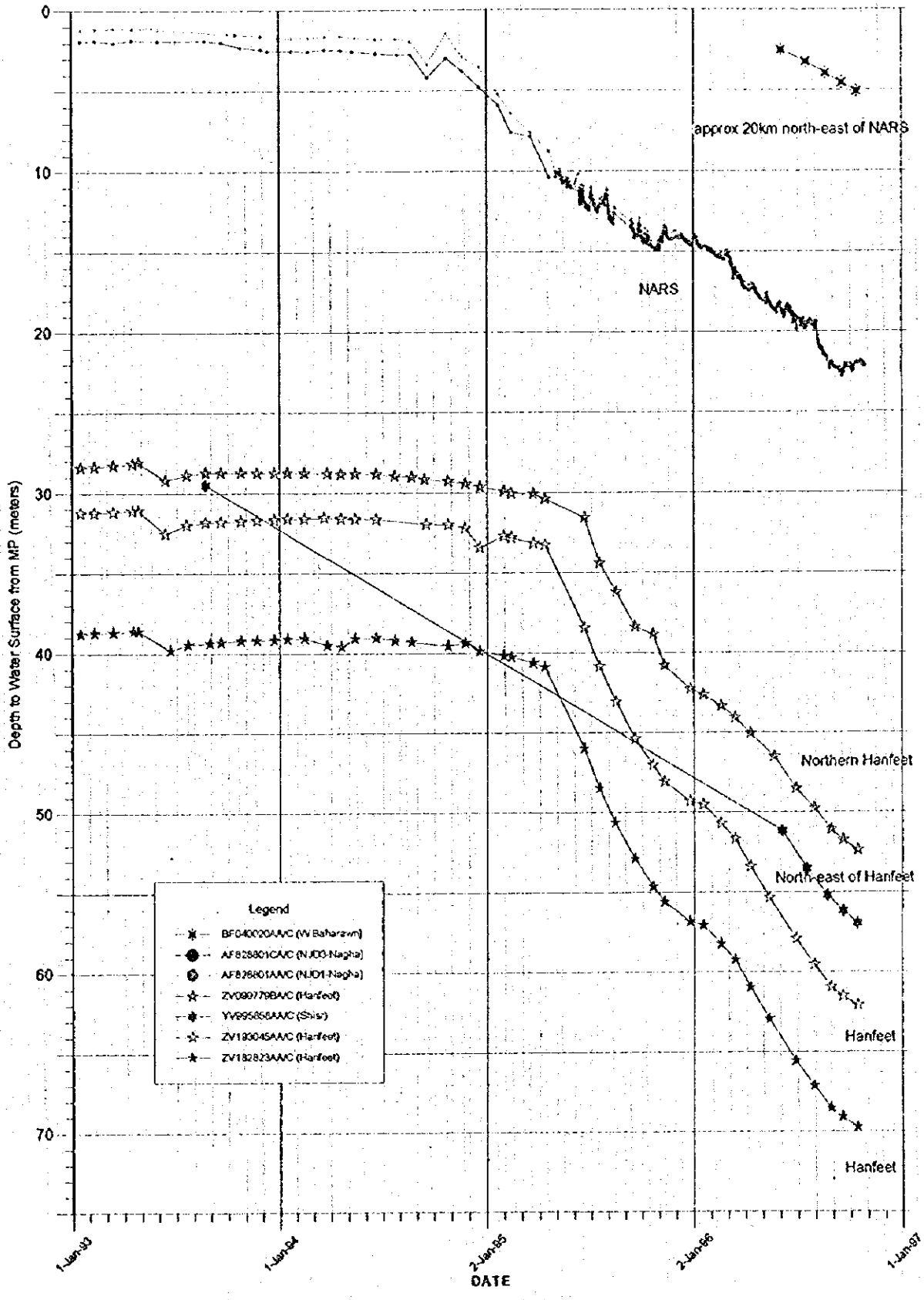


Fig.4.2.3 Groundwater Levels (NARS, Hanfeet '93 - '96)



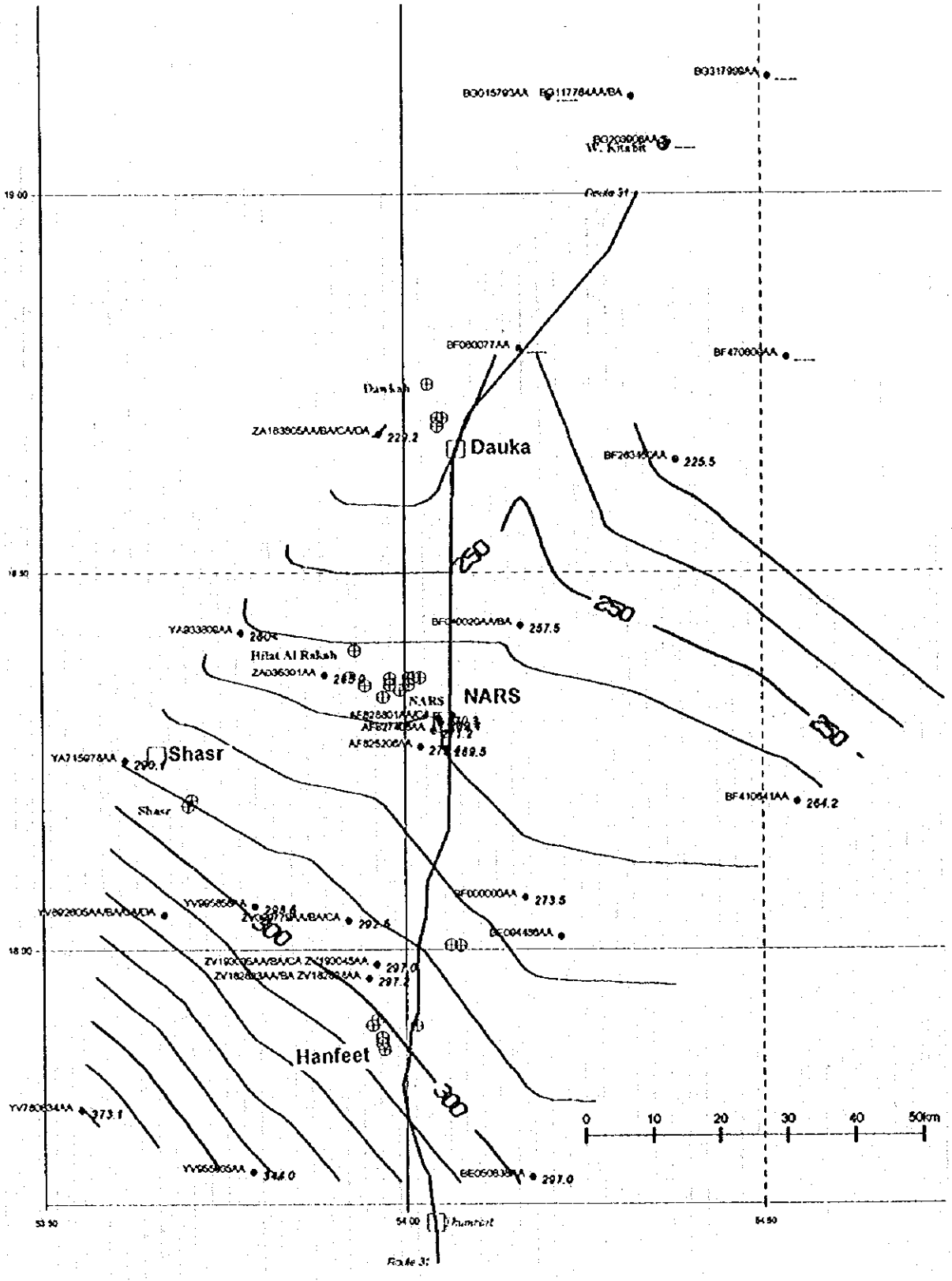


Fig.4.2.4 W.L. Contour Map before '94 (Piezometric Head in C aquifer: altitude(m))

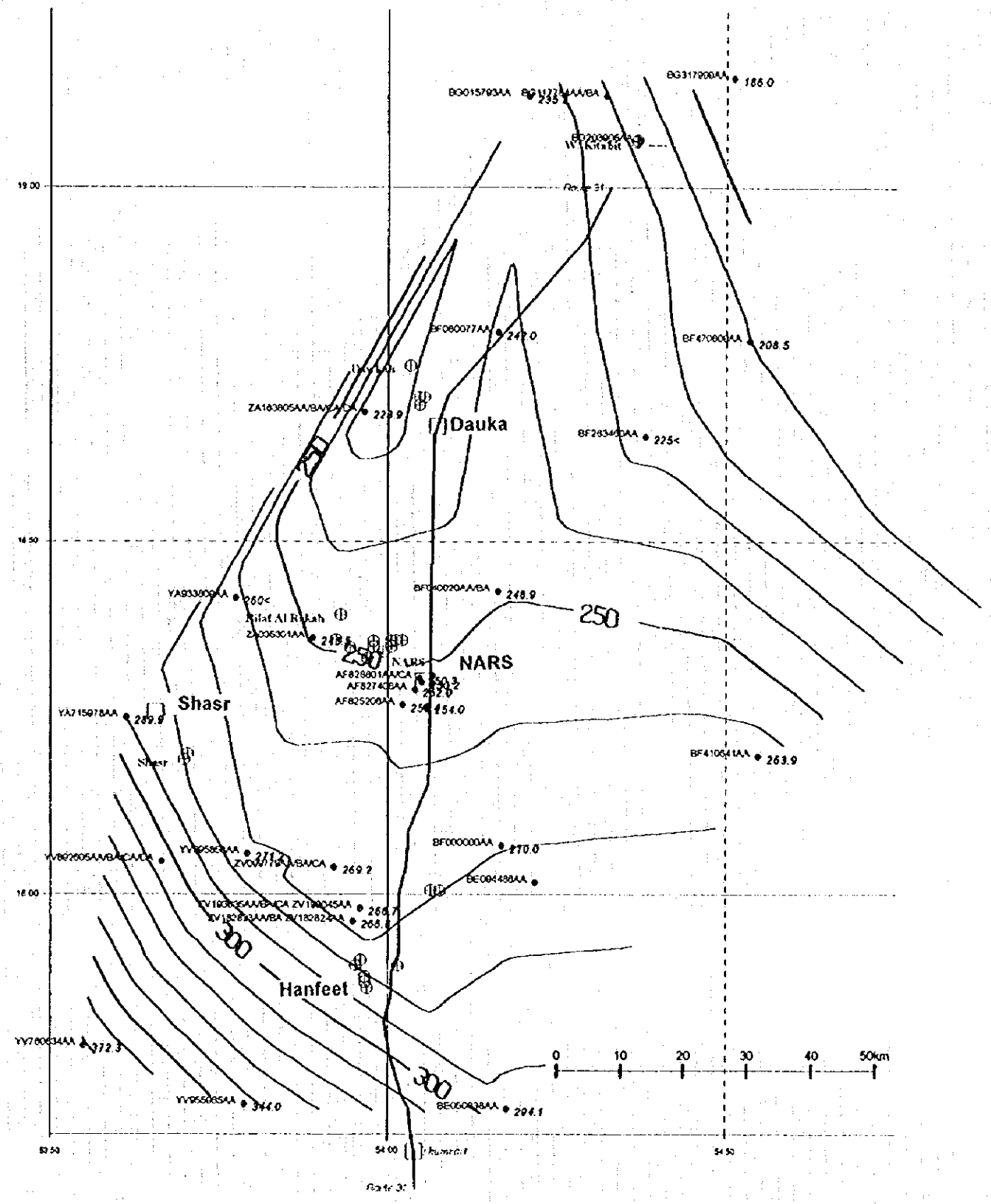
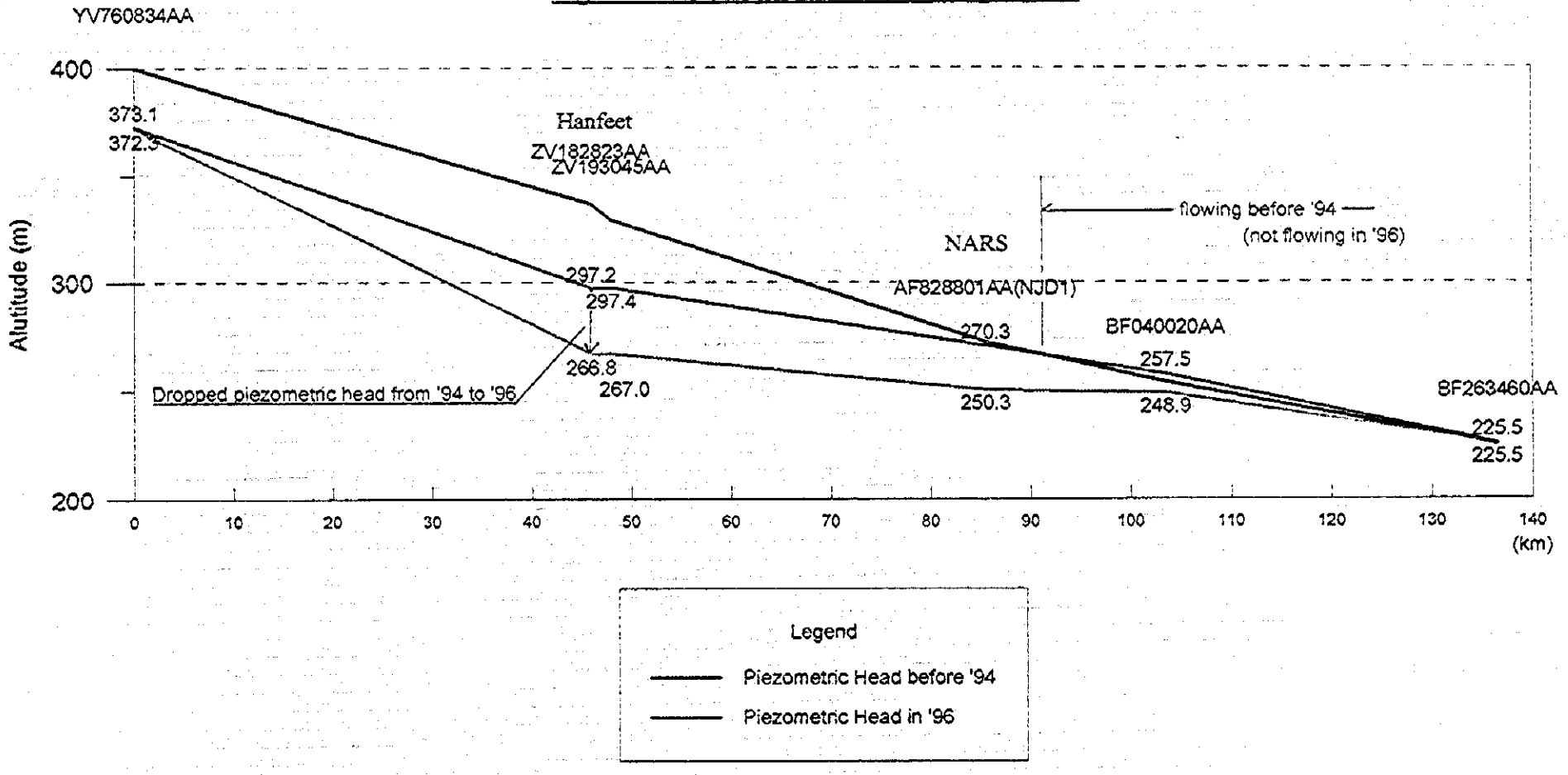


Fig.4.2.5 W.L. Contour Map in '96 (Piezometric Head in C aquifer : altitude(m))

Fig. 4.2.6 Schematic Profile in the Area



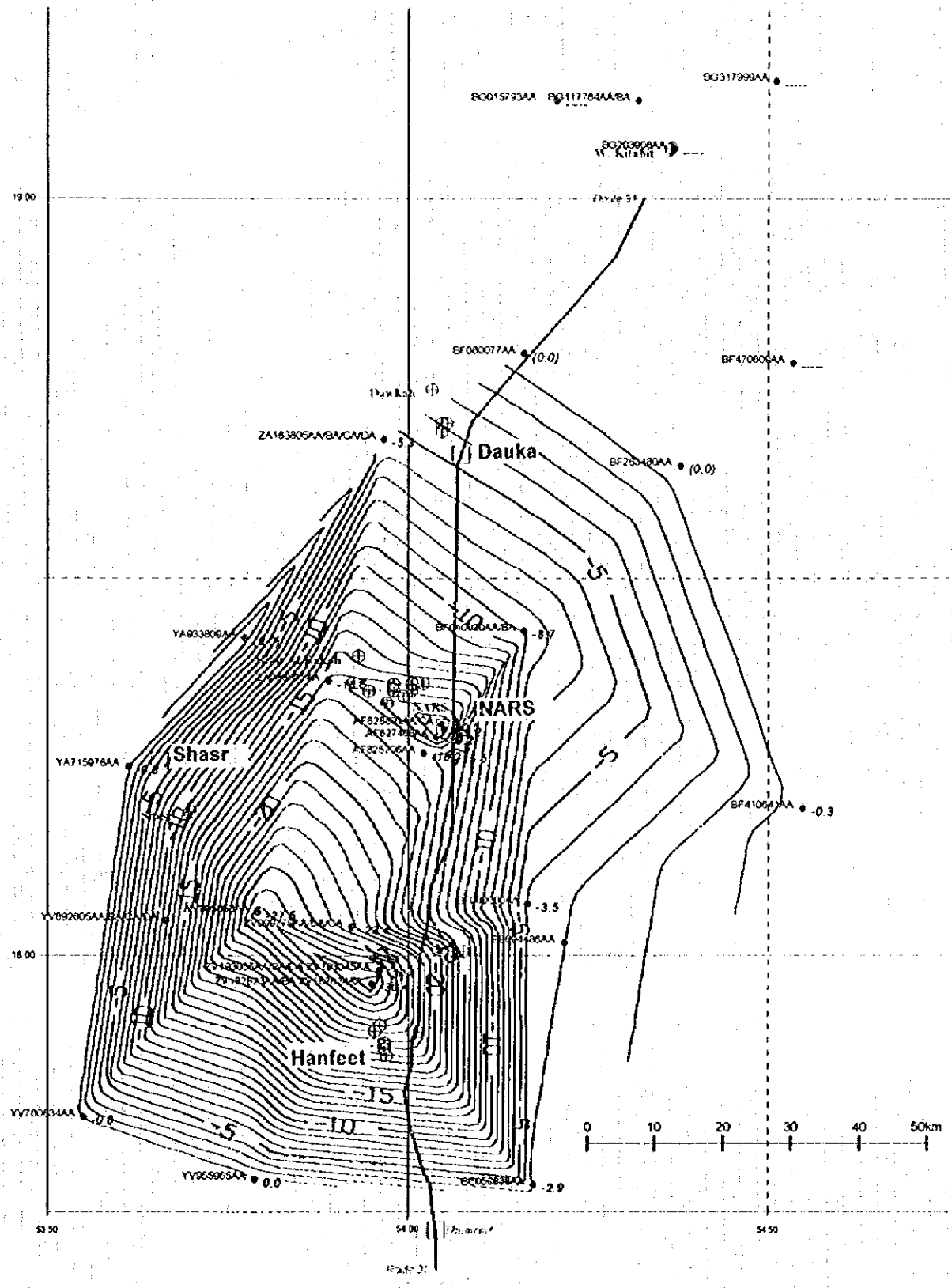


Fig.4.2.7 Drawdown Contour Map (Before '94 - '96)

CHAPTER 5

AGRICULTURAL DEVELOPMENT PLAN

CHAPTER 5

AGRICULTURAL DEVELOPMENT PLAN

5.1 Development Strategies

5.1.1 Agricultural Development Policy

The main development policies of the Government in the agricultural sector are summarized as follows:

1. to develop sustainable agriculture
2. to increase domestic production
3. to achieve self-sufficiency in food for import substitution
4. to create employment opportunities
5. to conserve natural resources and the environment

The specific development objectives of the Agricultural Development Project in the Nejd Region are recognized in the governmental development policy, as well as with the physical and socio-economic conditions of the Study Area, as shown below:

1. Expansion of agricultural production area through optimum exploitation of water resources to make a contribution to self-sufficiency.
2. Creation of new employment source for local Omanis and improvement of agricultural labour force.
3. Strengthening and modernisation of institutional services for agricultural experimentation and extension activities.

5.1.2 Present Situation on Agricultural Development in the Nejd Region

(1) Nejd Agricultural Research Station (NARS)

The Nejd Agriculture Research Station (NARS) was constructed by the proposal of the Phase-I Study as a Pilot Farm, where agricultural experimental trials can be carried out to find out an optimum and sustainable agronomic conditions for the Nejd region and prospecting the groundwater development potential by continuous monitoring survey. NARS was originally planned as a pilot farm but later the name was changed to the present name, and there was some modification in the objective of the original pilot farm concept, as much importance is given to scientific research than experimentation in the pilot farm. Presently, it seems that the role of NARS is expected as a centre of investigation and research for the desert agriculture.

(2) Agricultural Development

As mentioned in the previous chapters, number of centre pivots and cultivated area with irrigation in the Study Area has been increasing very fast during the past two or three years. Already the groundwater development area for agricultural production of more than 800 ha has been executed and adding constructing and planning areas, the total developed area can be estimated as more than 1,000 ha. Besides, drastic drawdowns of the groundwater level have been observed and there are some production wells which were already abandoned. According to the existing development studies concerning possibility for agricultural development, it seems that already there is not much more possibility for development than present situation, and a large scale development concept might be unrealistic from the view point of sustainable development.

On the other hand, according to the response of MWR to the question from JICA Study Team concerning the agricultural development in the Nejd region, recent monitoring data and modelling indicates that large drawdowns of the groundwater can be expected if pumping is concentrated in a few areas. A decentralised development strategy with sites across the Nejd region would decrease drawdown and give an indication of where water resources could be developed further. An area of 30 to 50 ha would allow an economically sized centre pivot at each site which could be supported by one or two wells sited 500 to 1,000 meters apart. A reasonable development speed would be two or three sites per year (MWR, June 1996).

(3) Water Resource Conditions

According to the conclusions of the Nejd Groundwater Modelling Brief Report (Draft, MWR, February 1996), the simple analytical modelling indicates that to obtain the maximum amount of groundwater from the aquifer it is better to spread pumping wellfields across the Nejd region and not have concentrated pumping centres. On the other hand, according to the comments of MWR concerning the Nejd Aquifer C monitoring (June 1996), significant groundwater drawdown has occurred over the past two years. Most drawdown is occurring at Hanfeet where irrigation using centre pivots has recently expanded dramatically. Once more, it was said that over 85% of drawdown established in the first year of operation, only minor reductions in drawdown if farm development is staged over 1 - 3 years (MMI, 1994). However, actual phenomena of wells in the Nejd region seems to be very different.

5.1.3 Restrictive Factors and Potentiality of Development

Generally, to formulate an agriculture development plan, natural factors such as land resources, water resources, meteorological conditions, biological adaptations, etc., social

factors such as economy, human resources, impacts to the environment, national profit, etc. should be considered as the important elements of the plan. Soon, for the Agricultural Development Project in the Nejd Region, it is clear in the results of the Phase-I Study and the field survey of the Phase-II Study that the water resources is the largest restrictive factor against agricultural development and development pace and scale will be decided by the development potential of the groundwater conditions.

According to the opinion of MWR for the "Policy for Water Resources Development" (August 1996), it is clear that the hydrogeology of the Nejd region is not well understood and more assessment work is required for the better understanding of the aquifer characteristics and to evaluate the sustainable yield. To fulfil this objective, the policy of MWR will be cautious and limit the use of water resources at the beginning. Therefore, MWR suggests that at the beginning there will be a small scale agricultural development and during the first three to five years there will be a continuous assessment of the aquifer behaviour. The results of the assessment will help to understand the aquifer characteristics and to propose the long term development strategy in the Nejd region.

5.1.4 Basic Concept for Development

As the overall evaluation in the end of the First Phase of the development plan, land resource research and agricultural research have been able to achieve their purposes almost all except some items, through the activities of monitoring survey during two years at NARS. However, significant groundwater drawdown is occurring in the Study Area and it seems that this phenomenon is not within the reasonable value which was considered as evaluation item to step up of development stage. Also, many uncertainties regarding groundwater research exist still now.

Consequently, before shifting to the Second Phase of the development plan intending a development of 500 ha which was proposed in the Phase-I Study, it is judged that feedback concerning the basic concept for development should be necessary. Still more, considering the actual situation of agricultural development during these years, reconsideration of the basic development concept of the further agricultural development plan in the Nejd region which was proposed in the Phase-I Study should be necessary. Principally, following three articles are proposed as a basic concept for the Agricultural Development Project in the Nejd Region for the next agricultural development phase.

(1) Agricultural Development Concept and Sustainable Development

At the Phase-I Study, the Phased Agricultural Development was proposed as agricultural development concept, and though development pace and development scale were considered. However, the actual agricultural development situations during this two or three years became a phenomenon exceeding these considerations. Especially, development pace was drastic. Also, from the view point of water resource development, it seems that this phenomenon is going toward the total possible area for development. Still more, there are characteristics that development is unevenly distributed and concentrated, and there has been

a progress of unlimited development.

These present situations are evaluated as a over development. Considering the tendency of recent development, it is judged that reconsideration of the agricultural development concept is necessary. Especially, prudent correspondence for this concept is necessary from a view point of sustainable development depending on effective utilisation of the limited water resources. Once more, at present it can be judged that reconsideration for a future large scale agricultural development should be necessary. For an effective utilisation of limited resources for a long term, the agricultural development concept should be considered once again. Without this care, the prospects for the coming generations in the Nejd and of the Sultanate will be limited.

(2) Establishment of New Pilot Farm

The pilot farm plan was developed based on the Phased Agricultural Development concept. And some parts of the original purpose of the pilot farm concept wasn't achieved and is remaining now also. For example, 1) establishment of systematic control system of groundwater, 2) establishment of training and extension systems and 3) clarification of supporting systems for farm management under commercial base of the overall evaluation on the First Phase have not been able to achieve their purposes. Further, there are many uncertainties concerning groundwater. Consequently, the main objective of establishing the New Pilot Farm(s) is considered as achieving these purposes. Principal roles of the New Pilot Farm are as follows:

1. Evaluation of the groundwater potential in the Nejd region for the next development phase.
2. Achievement of the desert farm management of the Nejd region for the next development phase.

The most important factor for the agricultural development in the Nejd region is groundwater conditions. Sustainable development is necessary, to avoid coming generation to suffer because of over exploitation of the limited resources and to ensure future sustainable resource exploitation in the Nejd region. This is a plan including a part of purposes of the Second Phase of the development plan in the Phased Agricultural Development concept such as settlement, farm management, technical extension, etc., and the New Pilot Farm concept is made as the 1.5^{th} Phase of the development plan.

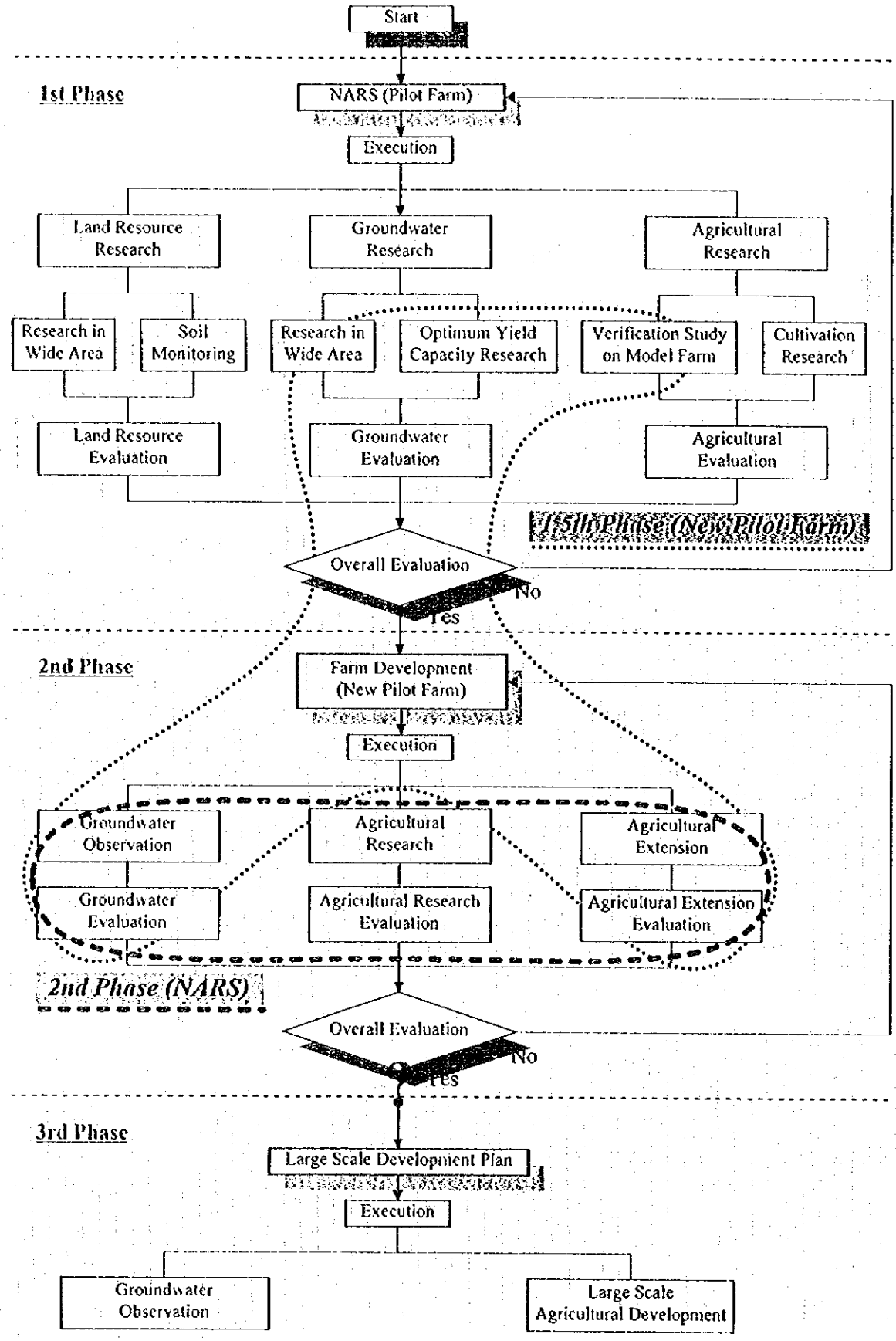
(3) Farming Technology and Technical Transfer

In order to advance the future agriculture development in the Nejd region, fundamental scientific principles such as research and investigation regarding the desert agriculture should become more important. Therefore, it is necessary that NARS should enforce more fundamental, special and scientific activities concerning the desert agriculture not only in the Nejd region but also the whole Sultanate. Also, NARS should take the responsibility of execution and operation of the New Pilot Farm plan as an administrative centre. In this context, the role of NARS as an experimental station would be progressed to a research centre and a management centre of the New Pilot Farm. Future main roles of NARS will be

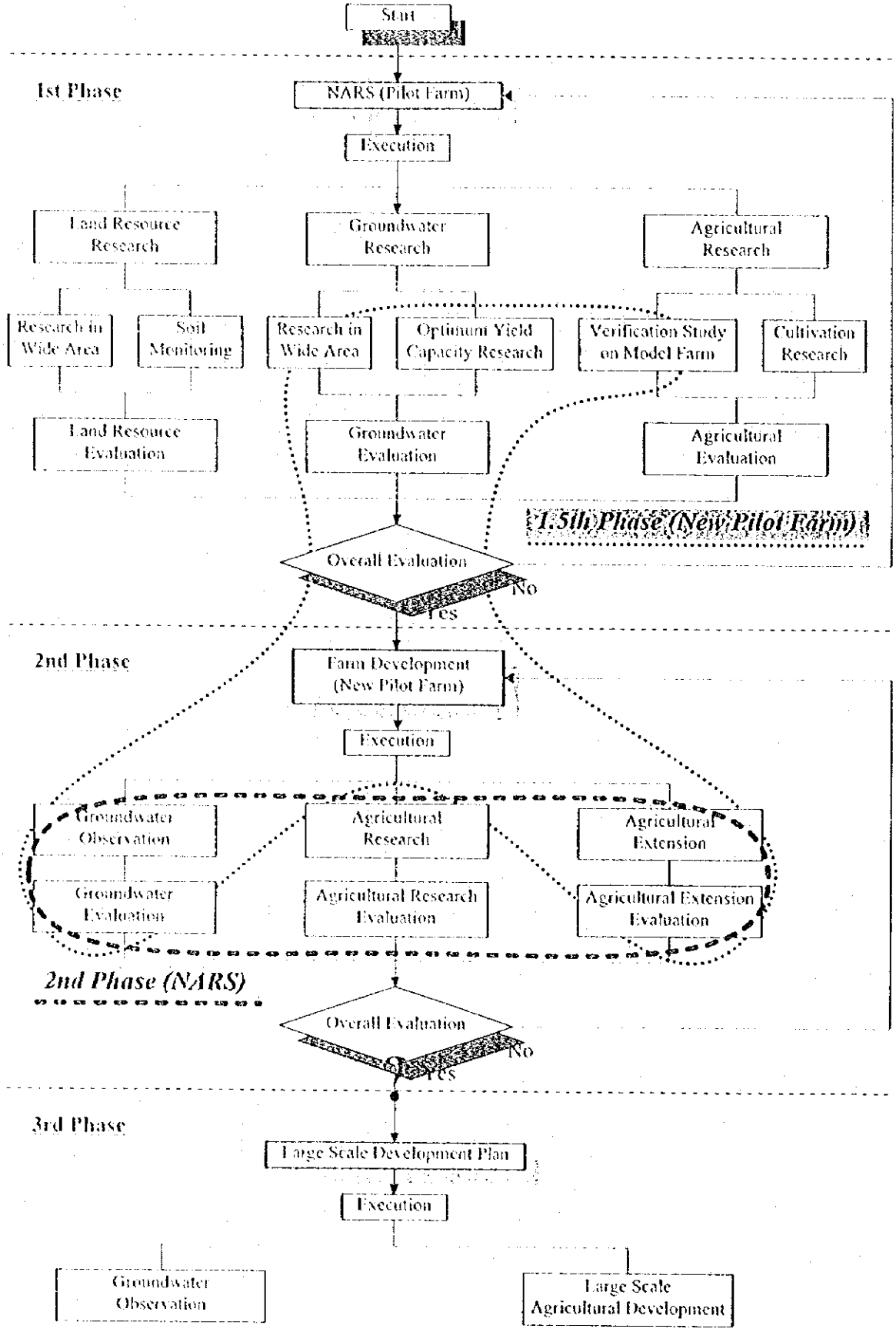
considered as three systems of research, monitoring and training and extension as mentioned below:

1. Centre of research and investigation and of laboratory analysis of soil, water, crop element, etc. for the desert agriculture.
2. Experimental cultivation of the newly introducing crops and generation of appropriate cultivation technology for the Nejd region.
3. Demonstration of the new crops and technology to the local farmers and the function of training and technical transfer centre using own farm and the New Pilot Farm sites.
4. Administration office of the New Pilot Farm(s).
5. Collecting and publicising technical information of the desert agriculture.

Future NARS plan is considered as the Second Phase of the development plan in the Phased Agricultural Development concept, but it will be executed with the New Pilot Farm plan parallely.



Concept of Phased Agricultural Development and New Concept



Concept of Phased Agricultural Development and New Concept

5.2 New Pilot Farm Plan

5.2.1 Objective

In the Nejd region, many data necessary for planning and implementing of the further agricultural development is insufficient still now. Especially, data such as groundwater potential, meteorological variation, appropriate cultivation technology, farming management, etc. are lacking which restrict planning and implementing of sustainable agricultural development. For this purpose, the New Pilot Farm plan is proposed to be executed. The major objectives of the New Pilot Farm are summarised as follows:

1. Continuous and systematic observation of groundwater and meteorological conditions and evaluation of groundwater potential in the Nejd region.
2. Sub-centre of technical transfer of appropriate farming techniques from NARS to the Nejd region through extension services.
3. Training field where the farmers and agricultural students who will be engaged in agriculture in the future could learn and experience the actual farming techniques by guidance of NARS.
4. Farm management trial as a model farm of the Nejd region.

5.2.2 Scale

The farm size is considered with irrigation plan, production plan, cropping pattern plan, etc. Irrigated crop area of the New Pilot Farm would be proposed as approximately 30 ha, consisting of one centre pivot, one production well and one monitoring well. It is considered that the short term development period is the first four years and the long term development period is from fifth year. The number of farms proposed would be about three considering the objectives of the Farm,

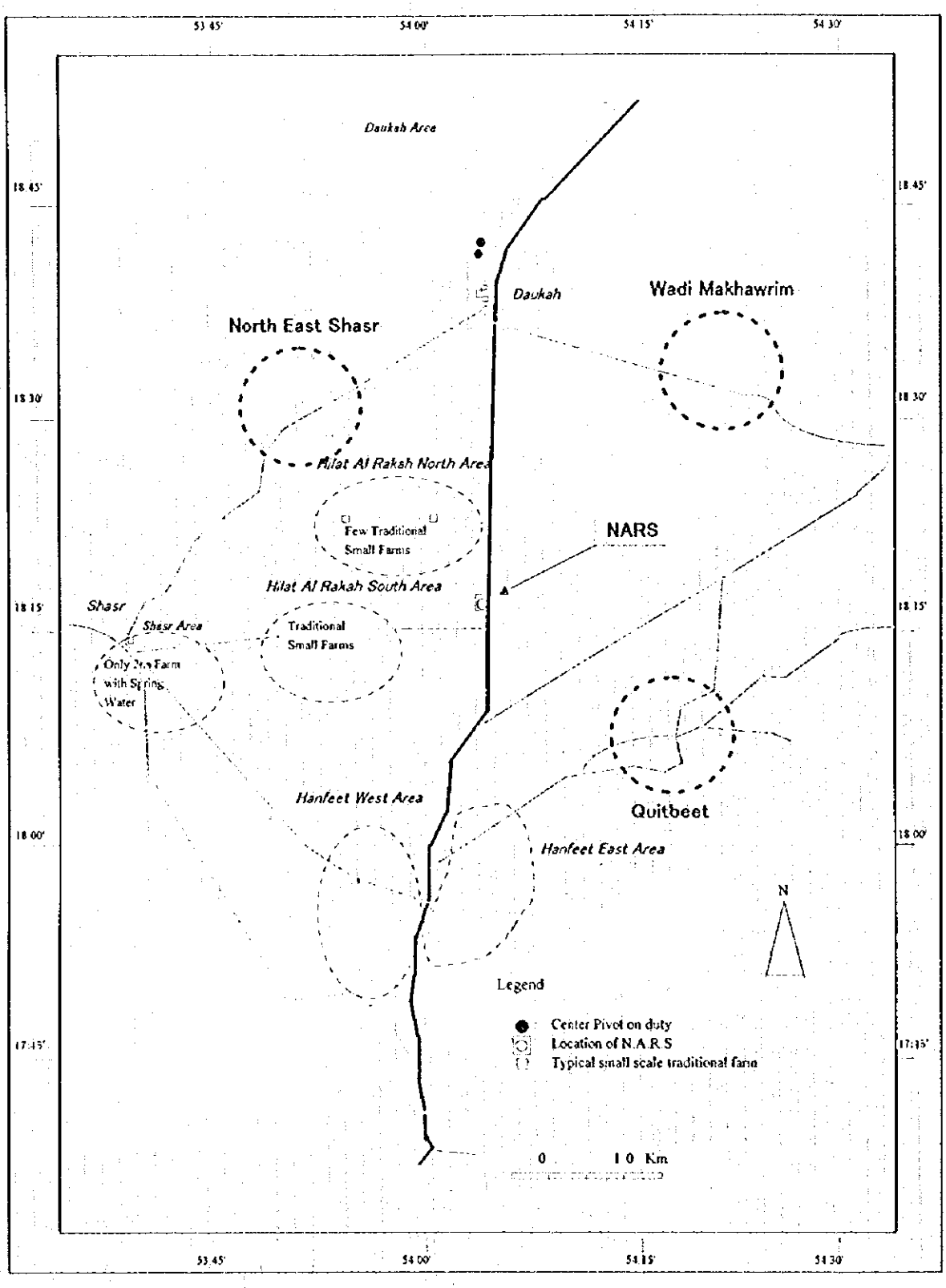
5.2.3 Selection of Locations

Three sites which are located along the existing roads would be proposed for the New Pilot Farms as follows:

1. North of Quitbeet village
2. North-east of Shasr village
3. Wadi Mokhawrim

5.2.4 Farmers

One of the main objectives of the agricultural development in the Nejd region is to create employment opportunities through the "Omanization" concept. This means that an innovative group of Oman people should take the full responsibility for complete management of the farm and this group would act as the pioneers for the future generation who will shoulder the responsibility of further agriculture in the Nejd region.



Location of New Pilot Farms

Hence, local people who are living in the settlements around the New Pilot Farms such as Shasr village, Quitbeet village, Dauka village and Thumrait Town, should be selected to take this responsibility. Before the farming, the new farmers group should be given enough training at NARS and after the commencement of the New Pilot Farm, they should be given technical transfer from NARS as on-the-job training. Farmers would not live permanently inside of the Farm and each Farm would accept 15 farmers.

5.2.5 Farming

(1) Farming Character

It will enable economically efficient physical development to take place in harmony with the social and environmental needs in the Nejd region. Therefore, the self-sufficiency agriculture would be engaged for the purpose of the technical transfer to the new farmers and if some surplus would be produced it will be supplied for the rural and regional markets. Farm management practice would be investigated in more detail than the original pilot farm concept as a model farm of the Nejd region. After completion of the technical transfer at first stage, the New Pilot Farms would be transferred to the farmers and managed by themselves with the technical supports from NARS as smallholders.

(2) Crop Selection

It is advisable to cultivate fodder grass, especially Rhodes grass which is agronomically more suitable for the Nejd region. The advantages of Rhodes grass are that it produces good returns and at the same time improves the soil structure for a wide range of crops to be grown successfully at the end of the reclamation period. Actually, most of the farms in the Nejd region are cultivating it although the farm sizes are different.

Concerning with the agricultural diversification, other crops such as vegetables which can be used for self-consumption should be considered. Later, after becoming self-supporting farm, in accordance with the progress of the agricultural development, the commercial crops such as more vegetables and fruits crops could be introduced based on the experimental cultivation at NARS.

(3) Crop Rotation and Cropping Pattern

Cultivation with water saving system especially during summer season should be considered on the cropping pattern. Therefore, cropping patterns proposed are based on a reclamation period of four years; perennial cropping of Rhodes grass would be carried out over the whole cropped area of 30 hectares, followed by some limited post-reclamation diversification into winter vegetables such as onions, carrots and cabbage which would be introduced in a half of the cropped area. Considering the economical renewal of grass, it is suggested that the cultivation areas of Rhodes grass and the vegetables should be inter changed in every five years. In addition, the cropping area of each vegetable should also be changed each year by changing the area of one vegetable crop to the other vegetable crop, in order to prevent the problem of replanting failures caused by cultivating the same crop successively.

After the New Pilot Farm would be transferred to the farmers, each farmer should manage two hectares of cropped area covering one hectare of Rhodes grass cultivation area and one hectare of vegetable cultivation independently. However, Rhodes grass cultivation of total 15 hectares would be cultivated in a collaborative farm works by the farmer's association, and melons could be introduced as the summer crops in the future.

5.3 Proposed Facilities of the New Pilot Farm

5.3.1 Farm Layout

A general layout of a New Pilot Farm is shown as Fig. 5.3.1, which is provided through the considerations of following aspects;

- The farm will be a part of agricultural development in the region; hence the farm development should be planned to save initial and operation cost
- The farm will have a function of groundwater monitoring
- Field training and extension services will be conducted in the farm in the initial stage

Major dimensions of the farm is planned as shown below :

Farm compound		*Windbreaks/ North boundary*	
Width	730.0 m	Width	25.0 m
Length	730.0 m	Length	1000.0 m
Area	53.3 ha	Area	2.5 ha
Center pivot		*Windbreaks/ South boundary*	
Radius	317.0 m	Width	25.0 m
Total coverage area	31.6 ha	Length	1000.0 m
Working space at pivot point	0.8 ha	Area	2.5 ha
Cultivation area	30.0 ha		
Inner farm roads & allowance	0.8 ha		

5.3.2 Water use plan

(1) Water requirement for grass

Crop water requirement for the planning is summarized in the table shown below. The conditions for the estimation are already discussed in Chapter 3. The maximum requirement for the irrigation facility will be in a case of pre-harvesting stage (available condition to harvest) and the water requirement for Rhodes grass at that stage is 13.0 mm/day (3900m^3/day). It is assumed the soil reclamation stage will take 4 years and after the stage crop diversification with vegetables will be introduced to the half area of the center pivot field.

Net Water Requirement at New Pilot Farms

Unit : mm/day

Descriptions		Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	
ETo		4.9	5.4	7.6	8.1	10.3	10.1	10.1	10.4	8.7	7.1	5.1	4.2	2794.0	100%
ETcrop	Kc														
Initial*	0.50	2.5	2.7	3.8	4.1	5.2	5.1	5.1	5.2	4.4	3.6	2.6	2.1		
Middle*	0.80	3.9	4.3	6.1	6.5	8.2	8.1	8.1	8.3	7.0	5.7	4.1	3.4		
Final*	1.00	4.9	5.4	7.6	8.1	10.3	10.1	10.1	10.4	8.7	7.1	5.1	4.2		
Mean*	0.85	4.2	4.6	6.5	6.9	8.8	8.6	8.6	8.8	7.4	6.0	4.3	3.6	2383.2	85%
Net water requirement (Irrigattion efficiency 0.80)															
Initial		3.1	3.4	4.8	5.1	6.4	6.3	6.3	6.5	5.4	4.4	3.2	2.6		
Middle		4.9	5.4	7.6	8.1	10.3	10.1	10.1	10.4	8.7	7.1	5.1	4.2		
Final		6.1	6.8	9.5	10.1	12.9	12.6	12.6	13.0	10.9	8.9	6.4	5.3		
Mean		5.2	5.7	8.1	8.6	10.9	10.7	10.7	11.1	9.2	7.5	5.4	4.5	2979.0	107%

*Note : * Initial, Middle and Final indicate crop growing stages. Hence it is available to know the value of a certain growing stage of each month. Irrigation coefficient is adopted as 0.80*

(2) Water Requirement for Tree Irrigation

Trees are to be planted as windbreak belts with 25 m width at both of north and south borders. Total area will be 5 ha and the total number of the trees will be approx. 1750. Amenity trees will be planted on both east and west boundary. Total required number of the trees are approx. 85. Hence grand total of the trees are 1835. Unit water requirement for one tree is defined as 60 liters per tree per day. So the daily water requirement for trees is 110 m3/day.

(3) Other water demands and total water requirement

Besides the previous two water demands, both of potable water and veterinary water are estimated as 4.00 cum./day for potable water and 1.50 cum./day for farm animals. The maximum total daily water demand is estimated as follows.

a	Net water requirement for grass (Maximum)	:	3,900.0 m3/day
b	Water requirement for trees	:	110.0 m3/day
c	Potable water requirement	:	4.0 m3/day
d	Water requirement for animals	:	1.5 m3/day
	Total water requirement	:	4,015.5 m3/day

5.3.3 Facility Plan

(1) Wells

The targeted water resource of the wells is C-aquifer and all of the wells to be constructed in the region should follow the specifications defined by MWR. Both of production well and monitoring well might be constructed in the farm compound.

Production well will have sufficient inner casing diameter for pump installation at depth of

100 meters below the ground level with proper well head assembling. The well might be provided at the location of Center pivot irrigation.

Monitoring well should be provided to know the groundwater fluctuations of C-aquifer with water level monitoring system.

(2) Production Pump

The required pump capacity for water abstraction is 62.0 lit./sec (4,015 cum./18 hrs=61.95lit./sec., say 62.0 lit./sec.), which is installed at 50m b.g.l. with 100 m total head to obtain sufficient water pressure for irrigators.

(3) Irrigation facility

Center pivot system is introduced as main irrigation system for cultivation of grass which should have sufficient travel speed control system, chemigation system.

Bubbler irrigation system is provided at both of north and south borders of the compound with chemigation and relay switching system to alternate irrigation block.

(4) Housings

Several housings will be provided as farm office, workshop and accommodations to match with number of farm population. Some superstructures such as farm office (unit space - 50 m^2, fertilizer stock space (144 m^2), accommodation for farmers (3 nos, each 50 m^2) operators (5 m^2) & drivers (5 m^2) and laborers (5 m^2), roof cover for generator sets (8 m^2 & 4 m^2) and roof cover for RO plant (12 m^2) will also be designed and constructed to keep proper conditions for farm materials and implements.

(5) Electric power plant

Two electric generator system are introduced, one is for production pump and irrigators and the another for housing and office which will have a smaller demand. Each output capacities are as follows ;

No.1 Electric power plant : 215 KVA (for production pump & irrigators)
No.2 Electric power plant : 25 KVA (for housing and farm office)
No.2 Electric power plant consists of two 25KVA generator sets, which are utilized alternately.

(6) Water Services

Reverse Osmosis plant will be installed to produce drinkable water with raw groundwater, with a productivity of 4 cum. per day.

(7) Ancillaries

Soak pit as sewage treatment will be provided at locations of accommodations and farm office.

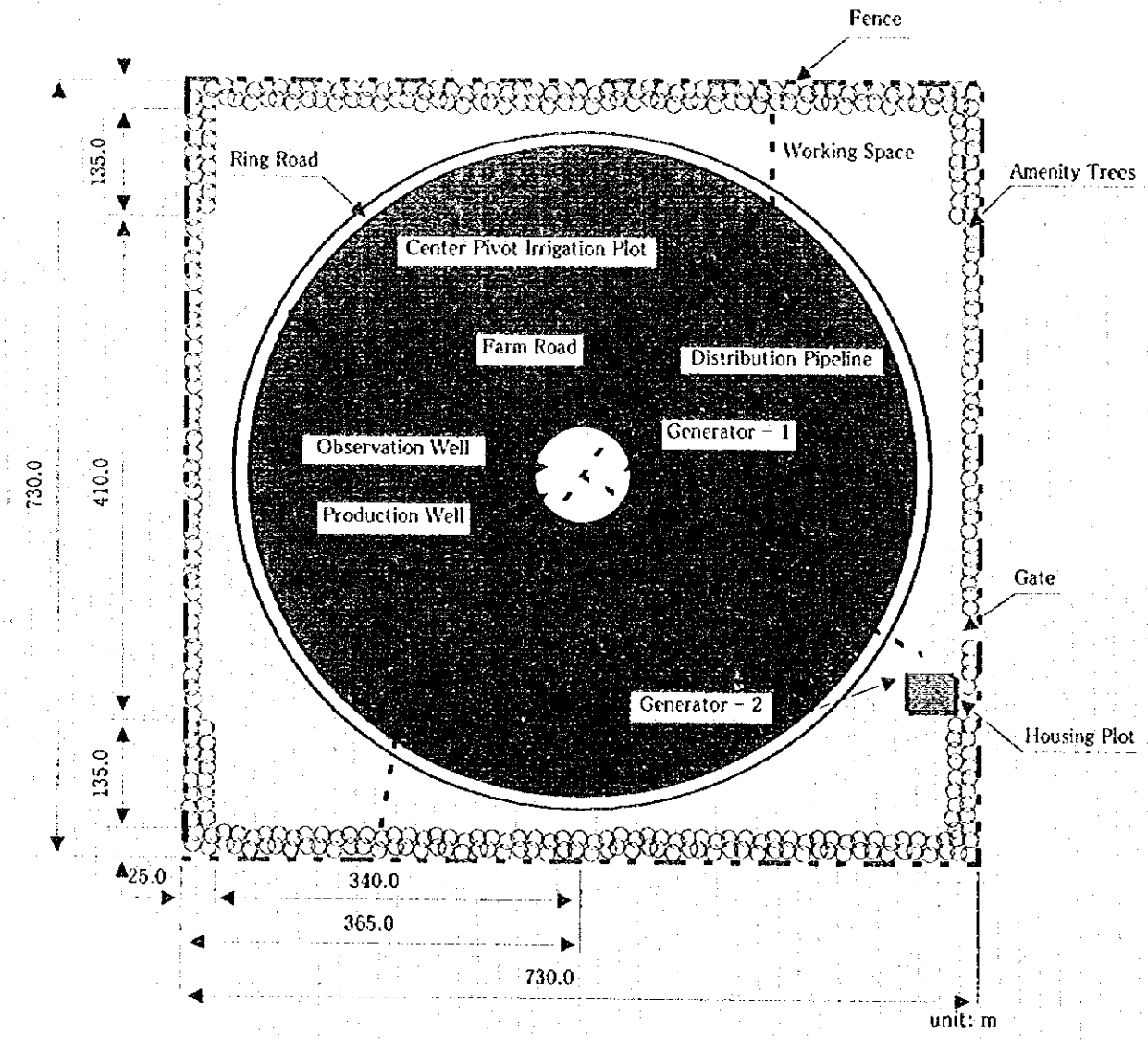
Street lights will be introduced for being convenient the night work

5.3.4 Farm Machinery

Some farm machinery are selected to rationalize farm activities as shown below :

Descriptions	Quantity	Remarks
Vehicle		
Pick-up, 4WD	1 No.	For transportation of staffs and goods
Truck, 2ton	1 No.	For transportation of goods
Farm Machinery		
Tractor, 80pc, 40WD	1 No.	For traction
Chisel cultivator	1 No.	
Leveling harrow	1 No.	
Fertilizer spreader	1 No.	For fertilization
Mower	1 No.	For reaping
Side rake / cylinder	1 No.	For grass gathering
Finger wheel rake	1 No.	For sub-soiling
Tight baler	1 No.	For baling
Auto bale carrier	1 No.	For loading balers
Weighing scale	1 No.	For measuing produced hay

Fig. 5.3.1 General Layout of a New Pilot Farm



Legend:

- Center Pivot Irrigation Plot
- Windbreaks
- Amenity Trees
- Fence
- Central Working Space
- Ring Road
- Farm Road
- Distribution Pipeline
- Housing Plot

N

5.4 Cost Estimation

5.4.1 Prerequisite for Cost Estimate

(1) Components of the Project Cost

Components of the project cost are as follows:

a. Construction cost of facility
b. Procurement cost of machinery and equipment
c. Consulting services cost
d. Physical contingency

(2) Conditions for Cost estimation

Project cost is estimated based on the following conditions;

Basic cost of laborer, materials and construction machinery are determined taking into account of the costs used for similar projects undertaken recently in the Sultanate.

Basic price of machinery and equipment prices of supply and provision to be used for this estimation are determined based on the data collected in Salalah and Muscat in October 1996.

5.4.2 Project Cost

(1) Construction cost

Components of the construction cost are as follows:

Site preparation includes land preparation of 53.3 ha farm compound, constructing outer ring road and inner farm roads of the center pivot, installing fence and gate.

Monitoring well includes construction of a monitoring well with provision of proper well head which is sufficient to mount groundwater level monitoring equipment in the farm compound. Procurement and installation cost of the equipment is also included in the cost.

Intake facility presents costs of construction of a production well to obtain groundwater from C-aquifer under the MWR's specifications of well structure for the Nejd. Costs of proper well head assembling, geological logging and pump test after the well provision is included. A production pump system with control panel, provision and installation of water level sensor system is also included.

Irrigation facility consists of four components as follows;

- Supply and installation of a complete center pivot irrigation system.
- Supply and installation of a complete bubbler irrigation system.
- Supply and installation of required distribution pipe lines to water demands

- Provision and planting to complete windbreaks

Costs of the center pivot irrigation system for grass cultivation includes supply, installation, testing with whole of necessary appurtenances following required specifications for the system. Major aspects of the requirements are as follows;

a) Supply and installation of the center pivot irrigation system for 30 ha,
b) Construction of concrete foundation for center pivot,
c) Installation of control panel to adjust travelling speed properly
d) Supply and installation of buried pressure pipeline, buried cable line, with
e) necessary chemigation system and control panel for the system.

The bubbler irrigation system consists of two parts, one is for north boundary and another is for south. The costs includes the following items;

a) Supply and installation of sufficient bubbler irrigation system for windbreaks with,
b) A control panel to alternate irrigation blocks, and
c) necessary chemigation system.

Costs of distribution pipelines are made up of supplying and installation of required length of buried pressure pipelines with necessary appurtenances to the center pivot system, bubbler irrigation system and potable water system.

Windbreaks brings in whole of necessary works and materials to provide windbreak tree belts on both of north and south boundaries of the farm compound.

Electric power facility will consist of 215KVA capacity generator system, which supplies electricity to a production pump and irrigators and 25KVA capacity generator system for power supplying to housings. Costs of necessary appurtenances are included, which are as follows;

- Supply and install required number of diesel generating plant
- Supply and install power transmission system, and
- Construction of bulk fuel storage tank.

Potable water facility includes all of costs of procurement, transportation and installation of reverse osmosis plant with 6 cum. productivity per day. Costs of following items are also included.

- Supply and construction of a storage tank which receives raw water from the production well
- Supply and construction of water tower and tank for potable water including pumping plant and electricity supply, and
- Supply and installation of pipeline from elevated tank to distribution line of each demand

Housing includes all costs to construction and complete a farm office, sufficient accommodations for Omani farmers, operator and driver and laborers. And also a roofed

space for fertilizer storage is included.

Ancillary includes soak pits as sewage treatment facility and street lights to keep safety of farm works in night.

The construction cost, including those above aspects for one farm is estimated as RO. 203,615.

(2) Procurement Cost of Machinery and Equipment

There are three items for cost estimate, which are farm machinery, vehicles and furniture for the farm. Details of the requirement were already presented previously and the estimated cost for those items is120,416 RO.

(3) Physical contingency

Ten (10) percent of the construction and procurement cost is calculated as physical contingency, which will cover costs to allow for minor modification in work quantities, unforeseeable difficulties in construction, possible changes in the plan because of site conditions or facilities. The cost is estimated as 32,404 RO as defined above.

(4) Consulting services

There are two items with regard to this cost, one is a detailed design services and another is construction supervision. The cost of detailed design is 5,900 RO and 10,000 RO for supervision works.

(5) Project cost

The project cost of one farm will come to RO. 372,333, and this cost will be the initial cost for the construction of the farm.

5.4.3 Operation and Maintenance Cost

(1) Annual operation and maintenance cost

Annual expenditure for operation and maintenance cost are originated from the following five aspects.

Salary for operator, driver and laborers is estimated, including all necessary allowances and basic salaries for the staffs planned in the previous section.

Maintenance for facility include all of the maintenance costs related with maintenance works of irrigators, generators, and housing to keep them in good condition.

Maintenance for machinery and equipment covers the costs to maintain and operate properly for farm machinery, vehicles and equipment. Expenditure for fuels is also included in the cost.

Fuel for Generator Sets is estimated 18,679 RO/year for running all generator systems of the farm. Oil and lubricants are also included in the cost. This cost shares about 50% of the whole operation and maintenance cost of the farm. Administrative expenditure is the cost of communication with NARS mainly.

The summary of those costs per year for one farm is as follows.

Salary for operator, driver & laborers	10,258	RO/year
Maintenance for Housings	4,150	RO/year
Maintenance for Machinery and equipment	3,831	RO/year
Fuel for Gen.sets	18,679	RO/year
Administrative expenditure	500	RO/year
Total	37,418	RO/year

(2) Replacement of Goods

All of the goods introduced to the farm might have certain life time and they are required to be replaced after expiring their durability. Durable period of facility and equipment can be referred in the list of project cost.

Estimation of Project Cost

A.	**Construction and Procurement** **********			**356,433 RO**	
	1. Civil & Housing Works ----------			**203,615 RO**	Life Time
	1-1 Connecting Road				
	Connecting Roads (from trunk road, 3 km)		1 L.S.	9,000 RO	30 year
	1-2 Site Preparation (Roads, Fences & Gates)			14,144 RO	
	Site Cleaning		1 L.S	500 RO	
	Farm Roads (C.P. interior)		1 L.S.	3,804 RO	30 year
	Farm Roads (C.P. Outer ring)		1 L.S.	5,970 RO	30 year
	Fences		1 L.S	3,650 RO	15 year
	Gates		1 L.S	220 RO	15 year
	1-3 Monitoring well			27,074 RO	
	a) Observation well construction		1 No.	22,674 RO	30 year
	b) Monitoring equipment		1 set	4,400 RO	30 year
	1-4 Intake Facility			51,520 RO	
	a) Production well construction		1 No.	34,170 RO	30 year
	b) Production pump system		1 set	17,350 RO	10 year
	1-5 Irrigation Facility			50,059 RO	
	Center Pivot System (30 ha)		1 set	16,372 RO	10 year
	Bubbler Irrigation System for Windbreaks		1 set	16,575 RO	10 year
	Distribution lines (150 mm for Windbreaks)		1 set	8,580 RO	30 year
	Distribution lines (for Drinks)		1 set	3,721 RO	30 year
	Windbreaks planting (including trees)		1 L.S.	4,811 RO	30 year
	1-6 Electrical			18,370 RO	
	Gen. Set & control panel		1 set	10,000 RO	10 year
	Fuel tank		1 set	1,500 RO	10 year
	Gen. Set & control panel		1 set	6,000 RO	10 year
	Fuel tank		1 set	870 RO	10 year
	1-7 Potable water			3,598 RO	
	RO-Plant		1 set	1,800 RO	10 year
	Elevated tank		1 set	1,298 RO	30 year
	Reservoir		1 set	500 RO	30 year
	1-8 Ancillary			750 RO	
	Sewage soak pit		2 set	150 RO	30 year
	Street lights		5 set	600 RO	10 year
	1-9 Housing & Superstructure			29,100 RO	
	Farm office	48 sm.	1 set	3,780 RO	10 year
	Fertilizer stock space	144 sm.	1 set	2,160 RO	15 year
	Gen. Set-1 superstructure	8 sm.	1 set	120 RO	15 year
	Gen. Set-2 superstructure	12 sm.	1 set	180 RO	15 year
	For Omani farmers	48 sm.	3 set	11,340 RO	10 year
	For Laborers	144 sm.	1 set	11,340 RO	10 year
	RO plant space	12 sm.	1 set	180 RO	15 year
	2. Supply of Machinery & Equipment >>>>>>>>>>>>>>>>			**120,415 RO**	
	2-1 Vehicles			13,900 RO	By item
	2-2 Farm Machinery			103,200 RO	By item
	2-3 Furniture			3,315 RO	7 year
	3. Total of Item 1 & 2			**324,030 RO**	
	4. Physical Contingency			**32,403 RO**	
B.	**Project Administration**			**0 RO**	
C.	**Consulting Services**			**15,900 RO**	
D.	**Project Total Cost**			**372,333 RO**	

5.5 Project Evaluation of the New Pilot Farm Plan

5.5.1 Basis of Evaluation

(1) Approach

The project evaluation method to assess an agricultural development plan for validity of its implementation includes economic evaluation, financial evaluation and socio-economic evaluation (effect). Usually, in case of the agricultural development emphasis is placed on the economic evaluation and public profitability is also emphasised. The main objective of the New Pilot Farm plan is not economic activity, for that reason, it could say that general project evaluation such as economic evaluation and financial evaluation is not to adopted for this kind of the Plan.

However, for a case study as a future agricultural development scheme, the financial evaluation is elaborated in order to examine the proportion of the governmental subsidy to support the agricultural development. Still more, as it is stated in the Phase-I Study report, it is quite obvious that an agricultural development investing a large amount of capital for desert area with disadvantageous natural conditions to produce agricultural products of low international price, is not really economically viable. Therefore, economic evaluation is not carried out, nor the sensitivity analysis of the financial evaluation, as the latter relies on many indefinite factors.

(2) Conditions of Evaluation

The criteria used in the estimation of evaluation are as follows:

1. The project life is set as 30 years from the commencement of the Plan including detailed design and construction works periods, considering the useful life period of the main facilities.
2. The currency used for the estimation is the money of Oman (RO).
3. The foreign exchange rate used set as US$ 1.00 = RO 0.385 (RO 1.000 = US$ 2.60) as monthly average rate of the foreign exchange rate of the National Bank of Oman as of October 1996.
4. The prices of agricultural products are farm-gate prices and the prices of agricultural production input materials and construction materials are prices on delivery at the production and construction sites.
5. The discount rate as the opportunity cost of capital in the agricultural sector applied in the evaluation is 6.5%, as the current deposit interest rate of commercial bank.
6. Principal benefit and cost are only estimated.

5.5.2 Benefit and Cost of the Plan

The project evaluation is applied for one New Pilot Farm as an example.

(1) Estimation of Benefit

The benefit of the Plan refers to a difference of net profit expected between With Project and Without Project conditions through the whole project life. In this Plan the without project condition means before development, consequently, no profit would be produced and the profit of the with project condition becomes a benefit from the implementation of the Plan. The project benefit consists of tangible benefit as an increase in agricultural production, and intangible benefit such as a creation of employment opportunities, an improvement of living standard of inhabitants, a stabilised food supply, etc. Tangible benefit is directly subjected to financial evaluations, while intangible benefit is analysed for the socio-economic effects.

(2) Agricultural Production Benefit

Agricultural production of the New Pilot Farm is likely to be based on fodder crop and winter crops of vegetables with or without livestock enterprises attached to the farm. Cropping pattern of 100% Rhodes grass grown for hay for the first 4 years of the project life, followed by diversification into the winter crop such as vegetables which will be cultivated half of total cropped area. In the first year, harvest would start after the detailed design and construction work period of 6 months and the first seeding and growing period of Rhodes grass of 4 months. Therefore, the production volume of the first year could be decreased to 2/12 comparing with the years from second year.

Rhodes grass is partly dried and then tied into bales of 12 - 16 kg, average is 14 kg. The price of a bale is typically RO 0.7 - 1.3, an average is RO 1.0 at farm gate of the Nejd region depending on season and monsoon condition, equivalent to about RO 71 per ton. One hectare of farm land produces approximately 40 tons/year with a gross production value on the order of RO 2,857/ha. The production cost of Rhodes grass excluding O/M cost is about RO 587 and the net production value from Rhodes grass is RO 2,270/ha.

The prices of vegetables are based on PAMAP purchase prices at Salalah, averaged over the years from 1991 to 1995, for the months in which it is anticipated that vegetable production would be sold by the farm in the Nejd region. The net production values of the vegetables such as onion, carrot and cabbage from fifth year of the project life, ranges from RO 1,983 to 2,525/ha. An average value of RO 2,258 is assumed for the winter crop. Livestock enterprises such as goat grazing is not included in the evaluation.

Benefit of Crop Production

Crop	Price [a)] (RO/t)	Yield [b)] (t/ha/year)	Gross Production Value (RO/ha)	Production Cost [c)] (RO/ha)	Net Production Value (RO/ha)
Rhodes grass	71	40	2,857	587	2,270
Onion	73	35	2,538	555	1,983
Carrot	99	30	2,955	430	2,525
Cabbage	53	55	2,901	635	2,266
Vegetable average			2,798	540	2,258

Source: *a) Vegetable prices are average farm gate prices in the Najd region.*
b) MMI, 1994.
c) MMI, 1994. Production cost dose not include O/M cost.

Annual net production value of one New Pilot Farm with 30 ha is estimated as RO 68,100 from second year to fourth year and RO 67,920 from fifth year.

(3) Project Cost

The cost of the Plan which is the subject of the evaluation consists of initial (capital) cost, operation and maintenance (O/M) cost and replacement cost of main facilities. Initial cost includes detail design (D/D) cost, construction cost with physical contingency and procurement cost of machinery and equipment. Operation and maintenance (O/M) cost includes for irrigation system and agricultural machinery, power cost, and fixed farming labourer cost. Initial cost totals RO 372,333, through six months of detailed design and construction works periods. The construction cost covers the costs of road, monitoring well, intake facility, irrigation facility, electrical facility, etc. The value of the farm land is estimated as zero, since it is a national property and has no market value without irrigation facilities.

Annual operation and maintenance (O/M) cost after the completion of the construction works is estimated as RO 37,418 on all facilities. The principal facilities and equipment should be replaced at times when its useful life period is expired. Replacement cost of facilities and equipment is estimated with RO 100,915 every 8 years, RO 113,927 every 10 years, RO 2,500 every 12 years and RO 6,510 every 15 years. Residual values of facilities and equipment at the end of the evaluation period as the project life are excluded.

5.5.3 Financial Evaluation

(1) Evaluation Criteria

The evaluation uses three relevant indexes: financial net present value (FNPV), financial benefit-cost ratio (F.B/C) and financial internal rate of return (FIRR). The benefit and cost of the Plan which are estimated based on the implementation schedule of the Plan are discounted by the opportunity cost of capital through the project life. The term FNPV is a difference

between accumulated benefit and accumulated cost and F.B/C is the ratio of the former to the latter. The term FIRR means a discount rate by which accumulated benefit is equalised to accumulated cost.

The criteria to financially validate the implementation of the Plan are that FNPV is positive, F.B/C is more than 1 and FIRR exceeds the opportunity cost of capital. The opportunity cost of capital (discount rate) is financial marginal productivity of capital input in the Plan, and the discount rate is considered to be 6.5%.

(2) FIRR, FNPV and F.B/C

Table A-9.6.1 shows the flow of initial cost, replacement cost, O/M cost and the all project benefit of the whole project life. Where FIRR is -0.70% and at discount rate of 6.5%, FNPV is RO -190,492 at price for October 1996, F.B/C is 0.81 at the same discount rate (Table A-9.6.2). Project evaluation has proven that FIRR is drastically below the opportunity cost of capital as the discount rate 6.5%, FNPV is negative and F.B/C is under 1. It is judged that the implementation of the Plan is not financially sound.

(3) Governmental Subsidy

As mentioned above, FIRR of the Plan is less than the opportunity cost of capital, and it can be judged that this Plan is not validated from financial view point only. The governmental subsidy for the Plan is considered as income of the Plan. Accordingly, it is possible to examine validity of the implementation of the Plan depends upon proportion of the governmental subsidy as a case study (Table A-9.6.3 ~ A-9.6.5).

FIRR for Different Cases of Governmental Subsidy

Case of Governmental Subsidy	Ratio of Subsidy (%)	FIRR (%)
1. Without any Subsidy	0.0	-0.70
2. D/D, Consulting Services and Construction supervision, Road Construction and Monitoring Well Construction	14.9	0.41
3. D/D, Consulting Services and Construction supervision, Road Construction and Monitoring Well Construction, and 50% of Intake Facility Construction, Irrigation Facility Construction and Electrical Facility Construction	32.6	2.26
4. D/D, Consulting Services and Construction supervision, Road Construction and Monitoring Well Construction, and 50% of Intake Facility Construction, Irrigation Facility Construction, Electrical Facility Construction, all remaining Civil and Housing Works and supply of Farm Machinery	54.9	6.63

In the fourth case study of governmental subsidy with about 55% for the total initial cost, FIRR exceeds the discount rate of 6.5%. According to the results of the FIRR estimation, the

Omani Government should provide a range of subsidies to implement the New Pilot Farm plan from the financial point of view.

5.5.4 Socio-economic Evaluation

As stated before, the Plan brings about direct, tangible benefit as well as the secondary or indirect, intangible benefit, which is important in reviewing validity of the implementation of the Plan.

(1) Sustainable Development Concept

The New Pilot Farm plan should be put into effect to confirm the groundwater and farm management conditions and to reconsider the basic development concept of future agricultural development plan which was proposed in the Phase-I Study. Consequently, it would be possible to emphasise a sustainable agricultural development depending on rational utilisation of the limited water resources in the Nejd region.

(2) Human Resources Development

The local people do not have much background of agriculture. The training and extension activities at NARS and the New Pilot Farms could develop their mind to improve the agricultural labour force in desert agriculture. This development would create a new valuable resource "farmer" for the Nejd region.

(3) Creation of New Employment Opportunities

Implementation of the New Pilot Farm plan would create new employment opportunities for the local people and reduces unemployed laborers in the Nejd region. This is to make the "Omanization" concept come true. The new employment opportunities will be helpful for nomads to settle at one location.

(4) Improvement of Living Standard

Implementation of the Plan would produce agricultural product and the living standard of the local farmers could improve, thus contribute to stabilisation of living in the Nejd region. Improved income further increases purchase power of the local people and vitalises local commercial activities. In this way, the implementation of the Plan would bring valid effect to the Nejd region.

(5) Strengthening and Modernisation of Institutional Services

Agricultural research, experimentation and extension services would be improved by the Plans of NARS and the New Pilot Farm using both sites. The future main roles of NARS would consider three systems of research, monitoring and training and extension. And the New Pilot Farm can be established as a model farm of the Nejd region. Implementation of the Plans could be help strengthening and modernisation of these institutional services.

5.5.5 Comprehensive Evaluation

As a result of the financial evaluation as computed from tangible benefit, it is considered that a large amount of the governmental subsidy is required for the implementation of the present Agricultural Development Plan in the Nejd region. On the other hand, it is also judged that there would be significant positive socio-economic impact as evaluated from intangible benefit. In addition, large negative impact from the implementation of the Plan would be not confirmed and the Plan is evaluated as a sustainable development concept considering rational utilisation of the limited water resources. Moreover, the implementation of the Plan is justified to be feasible from technical and operation of organisation view points. Accordingly, it is recommended that a high priority should be given to the present Plan be implemented.

CHAPTER 6

FUTURE PLAN OF NARS

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FUTURE PLAN OF NARS

6.1 Prerequisites of the Planning

Constraints for the agricultural development in the region were already discussed in the previous chapters on both of natural and socio-economical aspects and the direction for the future development was proposed. NARS should be in line with the development direction and it should be a forerunner in the region, mainly for the technical subjects.

The prerequisites for the planning of future NARS activities are as follows :

(1) Legal control against the reckless development by large scale farms is required to avoid free abstractions and to understand the present situations of water use in the region. There might be no way to develop the region without an effective legal control.

(2) Coordination among different ministries to exchange related data & information is indispensable to let the NARS to move in the line of direction of proper development, such as Dhofar Governorate for the information on regional development, Ministry of Water Resources for groundwater information and Ministry of Housing for the information on land acquisition.

6.2 Objectives and Role of NARS

The objectives of NARS are to clarify the scientific principles of farming practices to keep the sustainable agriculture by means of monitoring and experiments, to establish the suitable farming practices, and to transfer the technology to farmers in Nejd.

To accomplish the objectives, NARS might have the three systems, that is, research system, monitoring system and training and extension system.

(1) Research System

The researches in NARS as described later should be in-charge to solve the problems of the pilot farms and farmers in Nejd in close cooperation with the other organizations such as MAF research stations and the Sultan Qaboos University.

(2) Monitoring system

NARS collects and evaluates the results of monitoring on groundwater level, soil and water quality, meteorology, diseases and insects, crop production and amount of water use in NARS and the pilot farms in Nejd, in which monitoring activities are carried out continuously after transfer of pilot farm to farmers.

(3) Governmental services system

NARS shall also be in-charge of governmental services such as training and extension services. The extension services should be provided to the farmers in Nejd, as it is done now in the other regions of the country.

6.3 Plan of Organization and Function

6.3.1 Organization and function

(1) Sections and duties

Considering the required daily activities of NARS, some categorizations of the organizational functions are made as shown below.

Function 1 : Decision making for daily activities of NARS and coordination among its sections and with outside organizations
Function 2 : Administrative supporting for decision making and daily activities
Function 3 : Backing up the researches with specialized experience and knowledge
Function 4 : Carrying out continuous monitoring works
Function 5 : Supporting for agricultural machinery and equipment
Function 6 : Taking care of farm works and facility maintenance

These are the fundamental functions to let NARS pursue its tasks and objectives. Each function can be a section for formulating NARS organization as shown below.

Organization of NARS

Sections	Duties by section
Director of NARS	Responsible for activities of NARS, management of personnel, property and administration, and liaison and coordination to superstructure
Administration Section	Assisting Director on administration works of general affairs, personnel, welfare and management of facilities, and accounting on budget, revenue and paying, procurement, cashier and auditing
Research and development Section	Planning and implementing agronomic practices and experimental researches
Monitoring Section	Planning and implementing monitoring works at NARS and pilot farms in Nejd
Operation and maintenance Section	Operation and maintenance of farm machinery and farm facilities
Training and extension Section	Training for farmers, governmental staffs and students and extension services for farmers in Nejd

(2) Staffing and manpower development plan

DGAAF already provided a staffing plan to adapt for the reclamation phase and they are trying to satisfy the plan. The specific tasks of each staff are described below, referring to a plan which was updated through discussions in 1996 with counterparts. Table A-9.7.1 shows a details of the staffing.

1) ***Agronomist, soil and water engineer engineer and researcher of pesticides in the research and development section*** are also responsible for growth and yield of grass, monitoring of soil and water quality, groundwater level and meteorology, and pests besides being the researchers of experiments in NARS

2) ***Agronomist*** is in charge of the research on field crop cultivation including grasses.

3) ***Researchers of pest and disease control*** should be appointed as a staff of NARS with introduction of vegetables and fruits to the research activities.

4) ***Chemical analyst and his assistants*** carry out the chemical analysis of soil, water and plant tissues in NARS and the pilot farms in Nejd rapidly and cheaply.

5) ***Animal husbandry specialist, assistant and veterinarian*** should be appointed with introduction of livestock farming to the research activities, and they also attend to extension activities for herders of goats and camels in Nejd.

6) ***Technician (irrigation) of the monitoring section*** collects and compiles the meteorological data in NARS and the pilot farms, and transfers the data to the soil and water engineer in the research and development section. He also carries out the sampling of soil and water in NARS and the pilot farms in every season, and transfer the samples to the engineer in the research and development section.

8) ***Technician (Agronomy) of the monitoring section*** also collects and compiles the daily data on growth, yield of crops and disease and insect damage in the pilot farms, and transfers the data to the agronomist and the researchers of pest and disease control in the research and development section.

9) ***Assistant agronomists,*** who are in charge for the each pilot farm, is responsible for ;

a. assistance for management and supervision of each pilot farm,
b. observation, record of growth, yield of crops and other daily farming data,
c. monitoring on groundwater, weather and crop cultivation, and report to NARS,
d. assistance for management of machinery at pilot farm

To perform each staff's duty, it is necessary to train all the staffs of NARS in various ways, such as training in the Rumais Agricultural Research Center and the Sultan Qaboos University, periodical training in NARS, visiting the advanced farmers in Oman, etc.

6.3.2 Organization and Functions for the Activities Outside of NARS

(1) Monitoring Activities Outside of NARS

Technicians in the monitoring section of the NARS will also be in charge for the monitoring works outside of NARS, with assistant agronomist of NARS. They will visit the pilot farm and private farms to collect specified data and transfer them to the engineers in the research

and development section. The engineers in charge in NARS summarize and evaluate the results of monitoring.

(2) Training and Extension Services to Outside of NARS

Training for governmental staffs, farmers and students and extension services for farmers are carried out by the training and extension section. They will provide the extension services to the local farmers and to the new pilot farm.

6.3.3 External Organizations for Supporting NARS

(1) NARS Committee

NARS should mainly focus on the research, extension and development of the region and therefore most of the administrative burden should be removed. For this purpose, a NARS Committee shall be formed ; this committee can provide the administrative supports to NARS, such as budgeting, procurements, arrangements of required implements and so on. The committee is to be chaired by the Director General of DGAAF and shall include the directors under the DGAAF.

(2) Coordination Committee

With regard to agricultural development of the region, the scope of the NARS is mainly to research, develop and provide the scientific and technical outputs for the development as the main agricultural research institution of the region. And NARS alone can not be in charge for all the subjects related to agricultural development in the region, and the development should be coordinated with the higher decision makers of the other ministries.

Even though NARS can play a role in exchanging the information related to the development, it is obvious that a coordination committee should be established outside NARS, to present information and to build up inter-ministry consensus on this matter. Participants of the committee might be Dhofar Governorate Office, Ministry of water resources, Ministry of development, Ministry of housing, and others.

6.4 Activities Plan

6.4.1 Field Use Plan

(1) Center Pivot field

The Center pivot field of 30 ha is used for the field trials of irrigation, cultivation of Rhodes grass and other crops, mechanization, crop rotation, soil management and fertilization, open yard feeding of goats, monitoring, training, etc.

(2) Linear Movement field

NARS is already strengthened in terms of its work force including engineers, technicians, and labors who can take care of all the facilities and research works in NARS. Therefore, once the machinery will be available, the cultivation trials can be restarted in the linear movement field.

In future, there might be a higher scope for introducing fruits and vegetables and a bigger field area similar to the center pivot field might be necessary for carrying out the research of many types of vegetables and fruit crops. In such case, some part of the linear movement area shall be changed to the field of Bubbler Irrigation System.

(3) Lysimeter

Lysimeter with 8 plots of 3m x 3m is used for the investigation on the water requirement of various crops by seasons and growing stages, the experiments of irrigation, soil management and fertilization.

6.4.2 Plan of Experimental Crop Cultivation

The future research subjects at NARS are mentioned below, which are to contribute to solve the technical constraints in Nejd region (Appendix A-7-5).

(1) Irrigation

-1. Water saving methods of Rhodes grass cultivation
-2. Comparison of irrigation by Center pivot or Linear Movement system with drip irrigation system in vegetables cultivation
-3. Prevention against salt accumulation in surface soils by irrigation and drainage
-4. Appropriate water use in cultivation of various crops

(2) Crop cultivation

-1. Selection of suitable varieties of vegetables
-2. Selection of suitable fodder crops in winter
-3. Suitable cropping season of various crops
-4. Reasonable methods of fertilization and irrigation in crop cultivation
-5. Pot culture of vegetables
-6. Control methods of weeds and pests
-7. Diagnoses of macro- and micro-elements deficiency and excess and fertilization

(3) Mechanization

-1. Method of subsoiling to improve the soil compaction induced by mechanization
-2. Methods of tillage, leveling and sowing in cultivation of crops following Rhodes grass
-3. Effective farm work methods in mechanized crop cultivation

(4) Crop rotation : Cropping patterns suitable to the Nejd area by farming size

6.4.3 Experimental plan of livestock farming

Open yard feeding of goats is carried out in summer and winter in the Center pivot field to clarify the feeding method of goats on basis of results of the trial, such as quantities of feed intake, chemical components of feeds including microelements, gains in weight and animal hygiene.

6.4.4 Monitoring plan

The monitoring data of groundwater level should be presented to the periodical meeting with MWR,SLL and should be discussed to evaluate and plan the next phased development of Nejd. The Monitoring items are as follows;

(1) Groundwater level in NARS and Pilot Farms

(2) Organic matter and macro- and micro-elements of soils in NARS and pilot farm in every season

(3) Quality of irrigation water in NARS and pilot farms in every season

(4) Meteorological monitoring in NARS and pilot farms by daily observation

(5) Diseases, insects and weeds in NARS and pilot farms every time whenever they are observed in the field.

(6) Crop production and analysis of nutrients and minerals in NARS and pilot farms in Nejd

1) Crop production at every harvest :
2) Analysis of nutrients and minerals in every season :

(8) Amount of irrigation water use by daily observation

6.4.5 Training and extension service plan

(1) Training

Main objectives of training activities in NARS are the technical transfer to farmers, government engineers, agriculture extension officers, farm machinery operators and mechanics and agricultural students.

Main training items are appropriate crop cultivation and soil management techniques, farm practices, crop protection techniques, irrigation techniques, operation and maintenance techniques of farm machinery, etc.

The training and extension section plans the annual training programs and arranges the affairs related to the training, such as trainers, training materials, transport, etc.

(2) Extension

Main extension activities are as follows;

1) Technical extension advisory and visiting service.
2) Supply of farm materials at the subsidized prices, such as seeds, inorganic fertilizers, pesticides, etc.
3) Land preparation service and a crop spraying service based on the hourly rental of machinery provided by the government at a subsidized cost.

These activities are carried out by the training and extension section and by the substations in each pilot farm under supervision of the training and extension section in NARS, as it is applied now in other regions of Oman.

Training and extension program

Items	Programs	Description of programs
Guidance	Circulation guidance	Periodical circulation in the region and direct guidance at the farm
	Exhibition guidance	Exhibition and guidance at the demonstration fields.
	Practical guidance	Practical guidance of cultivation, farmworks with machinery, etc. at the fields.
	Transmission	Lectures and discussion
	Observation guidance	Guiding by visiting advanced farmers, market, etc.
Publicity	Technical information	Publication of periodicals regarding technical information
	Preparing of technical manuals	Preparing of technical manuals for each subject
	Films	Producing of films explaining the appropriate farming
	Panels and drawing	Photographic panels and drawing as lecture-aid
Exhibition		Opening exhibition of machinery, equipment, new technology, etc.
Investigation and collecting information	Investigation on present problems	Investigating the farming problems caused by soil, water, fertilization, insects and diseases, marketing, etc.
	Arrangement and analysis of data	Collecting, arranging and analyzing various statistical data on actual conditions in Nejd, such as agricultural production, population, manpower, machinery, production costs, etc.
	Collecting information	Collecting relating documents and guidance books

6.5 Facility, Farm Machinery and Equipment Augmentation

6.5.1 Facilities, equipment and implements

(1) Laboratory arrangement

Office building, extension center, laboratory building and animal husbandry building should be provided with necessary facilities, such as supply of water including distilled water, electricity, gases, washing place, ventilator, draft for decomposition of soil and plant tissues, etc. according to the purpose of each room use.

With regard to the laboratory building, the rooms at present should be defined according to purpose of use as follows;

a. Crop laboratory
b. Physiology laboratory
c. Soil and water laboratory
d. Chemical analysis laboratory
e. Water requirement laboratory
f. Pathology laboratory
g. Entomology laboratory
h. Preparation room
I. Equipment room
j. Laboratory store

On the other hand, the rooms of the animal husbandry building should be defined as veterinary laboratory, consulting room, surgery, animal husbandry laboratory, etc.

(3) Laboratory equipment

Laboratories in the laboratory building should be provided with suitable equipment according to the activities of each room. Main activities in each laboratory are shown as below.

Main activities in each laboratory

NO	Laboratory (room)	Main Activities in each Laboratory
1	Crop Laboratory	Seed storage system (simple seed bank unit), field trial facilities, nursery materials, observation of growth environmental conditions, observation of plant growth and yield
2	Physiological Laboratory	Basic biotechnology analysis, observation of growth environmental conditions, pre-treatment of samples for nutrients analysis, observation of plant transpiration
3	Soil and Water Laboratory	Soil survey and soil sampling, pre-treatment for samples for soil chemical analysis, soil physical analysis (mechanical and soil moisture analysis)
4	Chemical Analysis Laboratory	Chemical analysis of soil, water and plant tissues including organic matter, macro- and micro-elements and nutrients of fodder crops
5	Water Requirement Laboratory	Water intake analysis, soil moisture and temperature analysis, long term and short term observation of meteorology
6	Pathology Laboratory	Identification of diseases, incubation of samples and sample storage
7	Entomology Laboratory	Field sampling, identification of insects and sample storage
8	Preparation Room	Preparation of samples for analysis
9	Equipment Room	Store of spare implements, chemical reagents and others
10	Laboratory Store	Store of samples and others

6.5.2 Farm machinery

Introduction of farm machinery is indispensable for the success of the activities of NARS. Required farm machinery to NARS and the new pilot farms is shown as below.

Introduction Plan of Farm Machinery in NARS

NO.	Description	NARS	Extension Center in NARS
		Qty	Qty
1	Tractor 4WD, 80 PS	3	2
2	Chisel Cultivator	1	1
3	Subsoiler (Shakerator)	1	-
4	Plough	1	-
5	Leveling Harrow	1	-
6	Fertilizer Spreader	1	1
7	Rotary Cultivator	1	1
8	Mower	1	-
9	Side Rake	1	-
10	Finger Wheel Rake	1	-
11	Tight baler	2	-
12	Auto Bale Carrier / Tipping Trailer	1	-
13	Weighing Scale Kit (portable/0~13.6 tons)	1	-
14	Crop Sprayer	1	1
15	Seed Drill	1	1
16	Rear Blade	1	-
	(For small size experiments)		
17	Power Tiller with Rotary (12 HP)	1	-
18	Reversible Plough for Power Tiller	1	-
19	Ridger for Power Tiller	1	-
20	Power Sprayer (5 HP, with barrow type)	1	-
21	Reaper (5 HP)	1	-
22	Trailer for Power Tiller (Loading capacity 500kg)	1	-

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

7.1.1 Conclusions on Monitoring Activities at Nejd Agricultural Research Station

The following main conclusions are arrived at from the results of the monitoring surveys held at NARS.

(1) Production of Rhodes Grass

The yearly hay production during one year from May, 1995 to April, 1996 was 33.7 tones/ha and this yield was obtained with a nitrogen application of 613 kg N/ha/year. In summer season, the relationship between the average daily increase of dry matter per ha (growth rate) of Rhodes grass and the total amount of nitrogen applied during cutting interval between each harvest is linear upto the upper limit of an yearly amount of nitrogen application of one ton per ha.

(2) Soil Improvement

Generally, increment of organic matter contributes to improve the soil physical properties and influence its chemical and biological characteristics. When the soil monitoring survey was started, the organic matter content was at a very low level and only traces of organic matter have been measured. However after two years of continuous cultivation, the organic matter content of the soil has been increased to approx.1%, which can be considered as a significant improvement in this two years of cultivation. Generally, most of the cultivated soils contain 1-5% organic matter in the root zone, which has a significant influence on the physical properties of the soil and strongly influence its chemical and biological characteristics.

However, in terms of soil development, the soils in the NARS are immature and have a weak development of the soil horizon and soil structure and the soils are expected to develop by continuous cultivation. Chemical Analyses of the soil reveal that Cation Exchange Capacity and the fertility status of the soil is low. Presence of macronutrients such as N,P and micronutrients are also low. In spite of these problems, with good irrigation practices and proper fertilizer management, the soils do not constrain for a range of crops including Rhodes grass, dates, vegetables, water melon etc.

(3) Linear Drawdown of Groundwater Level in NARS

A general hydrogeological theory indicates that a 50-70% drawdown due to a long term pumping occurs in the first year after starting the abstraction. Although two years have already passed since NARS started to operate, the water level seems to continue declining so

far. The decrease in water level in NARS indicates probably that this is a complex phenomenon in the area. It is necessary to clarify the behavior of groundwater in the area, which includes Dauka, Shasr, Hanfeet, Quitbeet and Wadi Mokhawrim for further agriculture development. Not only the continuous monitoring in NARS, but also further monitoring work in the above areas including the continuous measurement of water use is strongly recommended for further agricultural development of the Nejd region.

(4) Meteorological Observation and Water Use at NARS

Potential evapotranspiration at NARS calculated by Penman method indicates that the ETo is approx. 3/4th of the evaporation value. These results reveal two possibilities ; one is that potential evapotranspiration can be referred to as 75% of daily evaporation value and it can be an easy reference to use at the site. And the other is the present reference of water application at NARS can be reduced based on the observed climatological data at NARS, because the present ETcrop was provided using Thumrait climatological data.

(5) Irrigation Water Requirement and Possibility of Intermittent Irrigation

It was found out that there is a good possibility to modify the existing practices of daily irrigation to intermittent irrigation, based on the available water holding capacity of the soil and the soil moisture measurements. The average AWC of NARS soil is 112 mm. If the readily available soil moisture is considered as 2/3rd of the AWC, approx. 75mm can be considered as readily available soil water. If the maximum daily water requirement of the crop is considered as 15mm, the crop can obtain its full water requirement for 5 days, even without any irrigation. However, it should be reiterated that intermittent irrigation is possible only if soil contains enough soil moisture through sufficient irrigation.

7.1.2 Conclusions on Agricultural Development Plan

The main development policies of the Government in the agricultural sector are summarised as 1) to develop sustainable agriculture, 2) to increase domestic production, 3) to achieve self-sufficiency in food for import substitution, 4) to create employment opportunities and 5) to conserve natural resources and the environment. The specific development objectives of the Agricultural Development Project in the Nejd Region are recognised in those governmental development policies, as well as with the physical and socio-economic conditions of the Study Area, as shown below:

1. Expansion of agricultural production area through optimum exploitation of water resources to attain food to self-sufficiency.
2. Creation of new employment source for local Omanis and improvement of agricultural labour force.
3. Strengthening and modernisation of institutional services for agricultural experimentation and extension activities.

A Pilot Farm Plan was proposed as an actual approach on the same line of the Phased Agricultural Development Concept which was developed at the end of the Phase I Study,

whose objectives were to clarify the technical constraints through agricultural experiments and to predict the development potentiality of the groundwater resources. The name of the Pilot Farm was later changed as Nejd Agricultural Research Station (NARS) and there were some modifications in the objectives of the original pilot farm concept, as much importance is given to scientific research rather than experimentation.

As the overall evaluation in the end of the First Phase of the development plan, land resource and agricultural research have been able to achieve their purposes almost all except some aspects, through the activities of two years monitoring survey at NARS.

Besides, number of centre pivots and cultivated area with irrigation in the Study Area has been increased rapidly during the last two or three years. Presently more than 800ha has been under irrigation and adding constructing and planning areas, the total developed area can be estimated as more than 1,000ha.

Significant groundwater drawdowns have been occurred over the past two years. Most drawdown is noticed at Hanfeet where irrigation using center pivots has recently expanded drastically. It was said usually that usually over 85% of drawdown occurs in the first year of operation and only minor reductions in drawdown in the following years. However, actual phenomena of wells in the Nejd region seems to be clearly different from this trend.

It is clear from the results of the Phase-I Study and the field survey of the Phase-II Study that the water resources is the largest restrictive factor against agricultural development and development pace and scale will be decided by the development potential of the groundwater conditions.

It is clear that the hydrogeology of the region is not well understood and more assessment work is required for the better understanding of the aquifer characteristics and to evaluate the sustainable yield. Consequently, before shifting to the Second Phase of the development plan intending a development of 500 ha which was proposed in the Phase-I Study, still more, considering the actual situation of agricultural development during these years, reconsideration of the basic development concept of the further agricultural development plan in the Nejd Region which was proposed in the Phase-I Study should be necessary. Principally, following three articles are proposed s a basic concept for the agricultural development project in the Nejd Region for the next agricultural development phase.

1) Agricultural Development Concept and Sustainable Development
2) Establishment of New Pilot Farm
3) Farming Technology and Technical Transfer

The pilot farm plan was developed based on the Phased Agricultural Development concept. And some parts of the original purpose of the pilot farm concept wasn't achieved and is remaining now also. For example, 1) establishment of systematic control system of groundwater, 2) establishment of training and extension systems and 3) clarification of supporting systems for farm management under commercial base of the overall evaluation on the First Phase have not been able to achieve their purposes. Further, there are many

uncertainties concerning groundwater. Consequently, the main objective of establishing the New Pilot Farm(s) is considered as achieving these purposes. Principal roles of the New Pilot Farm are as follows:

1. Evaluation of the groundwater potential in the Nejd region for the next development phase.
2. Achievement of the desert farm management of the Nejd region for the next development phase.

The new farmers' group, who might participate in the proposed plan, should be given enough training at NARS and after the commencement of the New Pilot Farm, they should be given technical transfer from NARS as on-the-job training.

The farm size is proposed as approximately 30 ha, consisting of one centre pivot, one production well and one monitoring well. It is considered that the short term development period is the first four years and the long term development period is from the fifth year. The number of farms proposed would be about three considering the objectives of the Farm, as North of Quitbeet village, North-east of Shasr village and Wadi Mokhawrim.

The cropping pattern to be proposed are based on a reclamation period of four years; perennial cropping of Rhodes grass would be carried out over the whole cropped area of 30 ha, followed by some limited post-reclamation diversification into winter vegetables which would be introduced in a half of the cropped area. The cultivation areas of the grass and the vegetables should be inter changed once in every five years. In addition, the cropping area of each vegetable should also be changed each year by changing the area of one vegetable crop to the other vegetable crop, in order to prevent the problem of replanting failures caused by cultivating the same crop successively.

As it is stated in the Phase-I Study report, it is quite obvious that an agricultural development investing a large amount of capital for desert area with disadvantageous natural conditions to produce agricultural products of low international price, is not really economically viable.

Financial internal rate of return (FIRR) exceeds the discount rate of 6.5% in a case study of governmental subsidy with about 55% for the total initial cost. According to the results of the FIRR estimation, the Omani Government should provide a range of subsidies to implement the New Pilot Farm plan from the financial point of view.

The Plan brings about direct, tangible benefit as well as the secondary or indirect, intangible benefit, which is important in reviewing validity of the implementation of the Plan such as 1) Sustainable Development Concept, 2) Human Resources Development, 3) Creation of New Employment Opportunities, 4) Improvement of Living Standard and 5) Strengthening and Modernisation of Institutional Services.

7.2 Recommendations

7.2.1 Recommendations on NARS Activities

Based on this Study, following recommendations are made for capacity building and strengthening of NARS activities.

1) Human resources development should be kept in coordination with Rumais agricultural research station and Sultan Qaboos University
2) The principle issues of NARS are to examine and find appropriate water saving methods and proper crop diversification for establishing sound agricultural development. And NARS is expected to carry out the related experiments and extension continuously.
3) To clarify in more detail and to understand the regional characteristics, NARS should continue the climatelogical observation as one of its activities.
4) It is required to introduce experimental facilities at NARS to analyze soil and crops by themselves.
5) NARS should keep efforts to up-date information of agricultural policies to synchronize its tasks and activities with directions of national and regional development.
6) NARS should be kept involved in three systems roles of research, monitoring and training and extension.

7.2.2 Recommendations on Agricultural Development Plan

Considering many developmental constraints, the following recommendations are made as guidelines for future agricultural development in the Nejd Region.

1) New developments of private sectors need to be regulated because their free abstractions are doubted to cause recent draw-downs.
2) A monitoring system should be established for further development and an evaluation of groundwater resources system should be enforced while challenging to reveal the present development conditions.
3) New pilot farms shall be developed with all required facilities, as units of wide range monitoring network and as a part of systematic development by the Government, which shall be managed by NARS.
4) NARS should involve on issues such as research and development of appropriate agricultural techniques, monitoring works and extension activities
5) A coordination committee which includes all the relevant organizations such as the Dhofar Governorate, Ministry of Water Resources, Ministry of Housing and others should be established so that all the relevant information for further development can be exchanged and an inter-ministry consensus can be built up on this matter.
6) The agricultural supporting system need to be strengthened including technical supporting services, training of farmers, extension of appropriate cultivation techniques and crop marketing services.

ANNEX

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