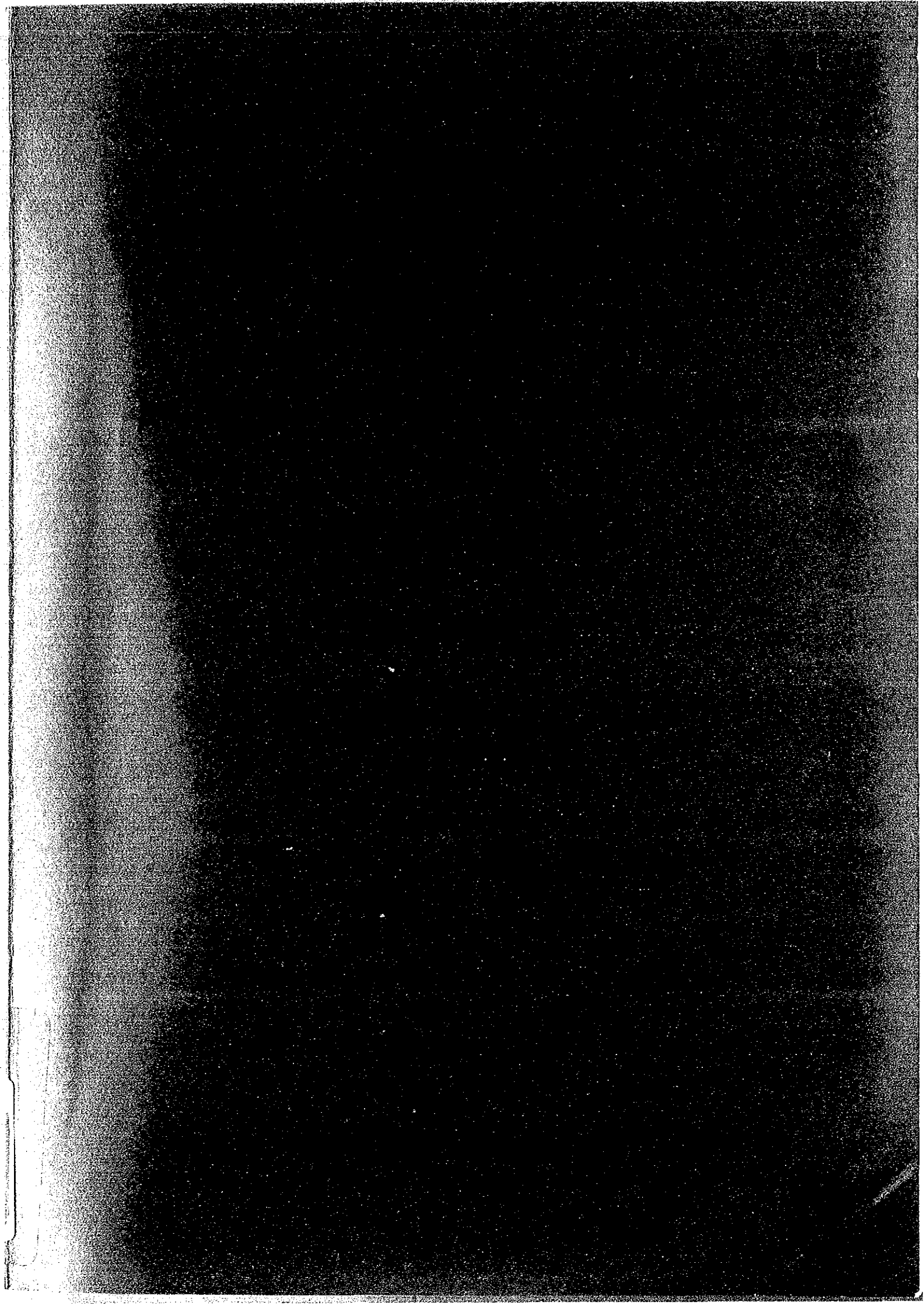

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SULTANATE OF OMAN

THE STUDY
ON
AGRICULTURE DEVELOPMENT PROJECT
IN
THE NEJD REGION

FINAL REPORT

VOLUME I :
MAIN REPORT

OCTOBER 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

国際協力事業団
20296

PREFACE

In response to a response from the Government of Sultanate of Oman, the Japanese Government decided to conduct a study on Agriculture Development Project in the Nejd Region and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Oman a Study Team headed by Mr. Makoto TANAKA, Pacific Consultants International, five times in the period from October, 1987 to September 1989.

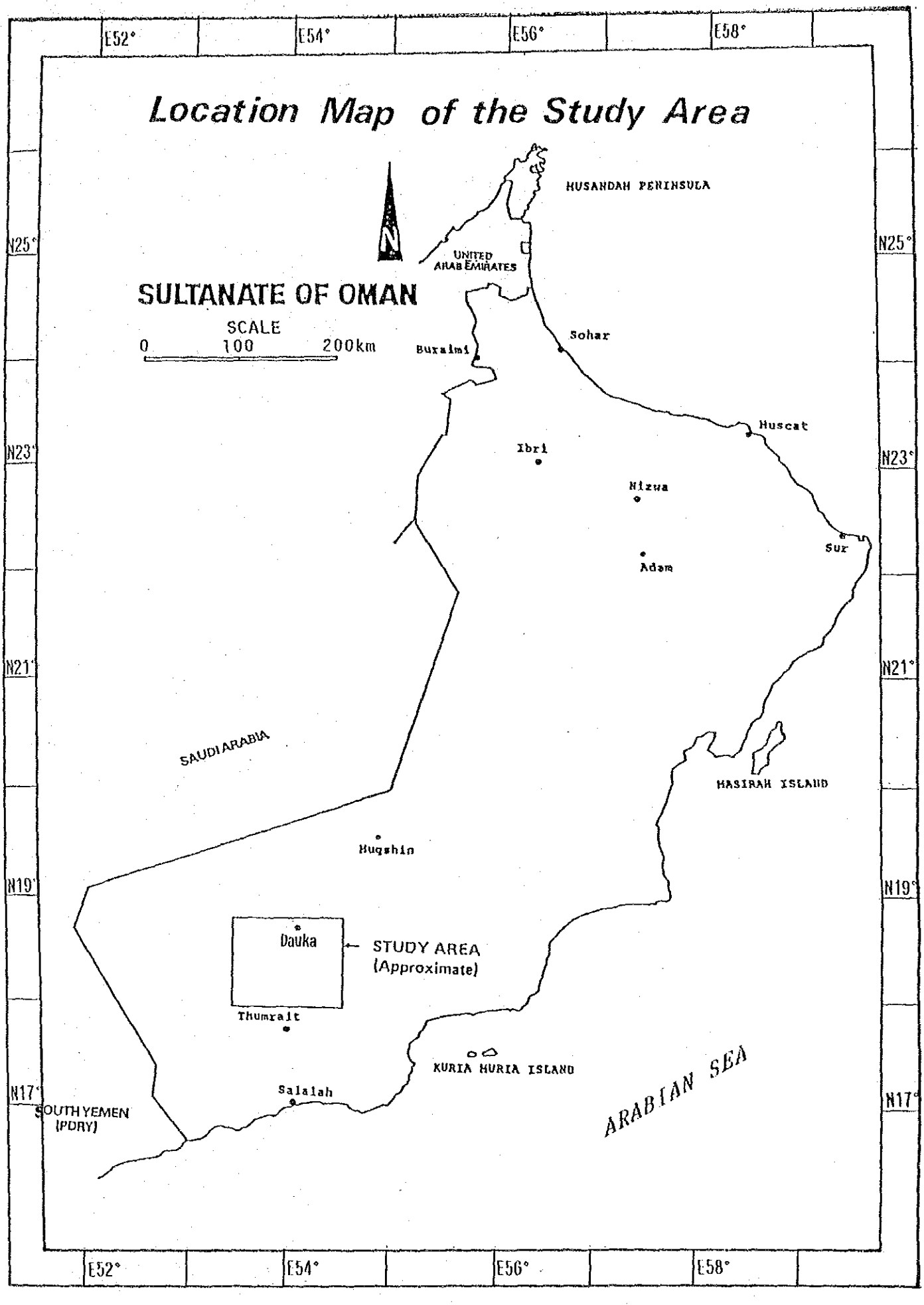
The Study Team held discussions with concerned officials of the Government of Sultanate of Oman and conducted field surveys (Phase I and II) in the Nejd of Southern Region. After the team returned to Japan, further studies were made and the present report was prepared.

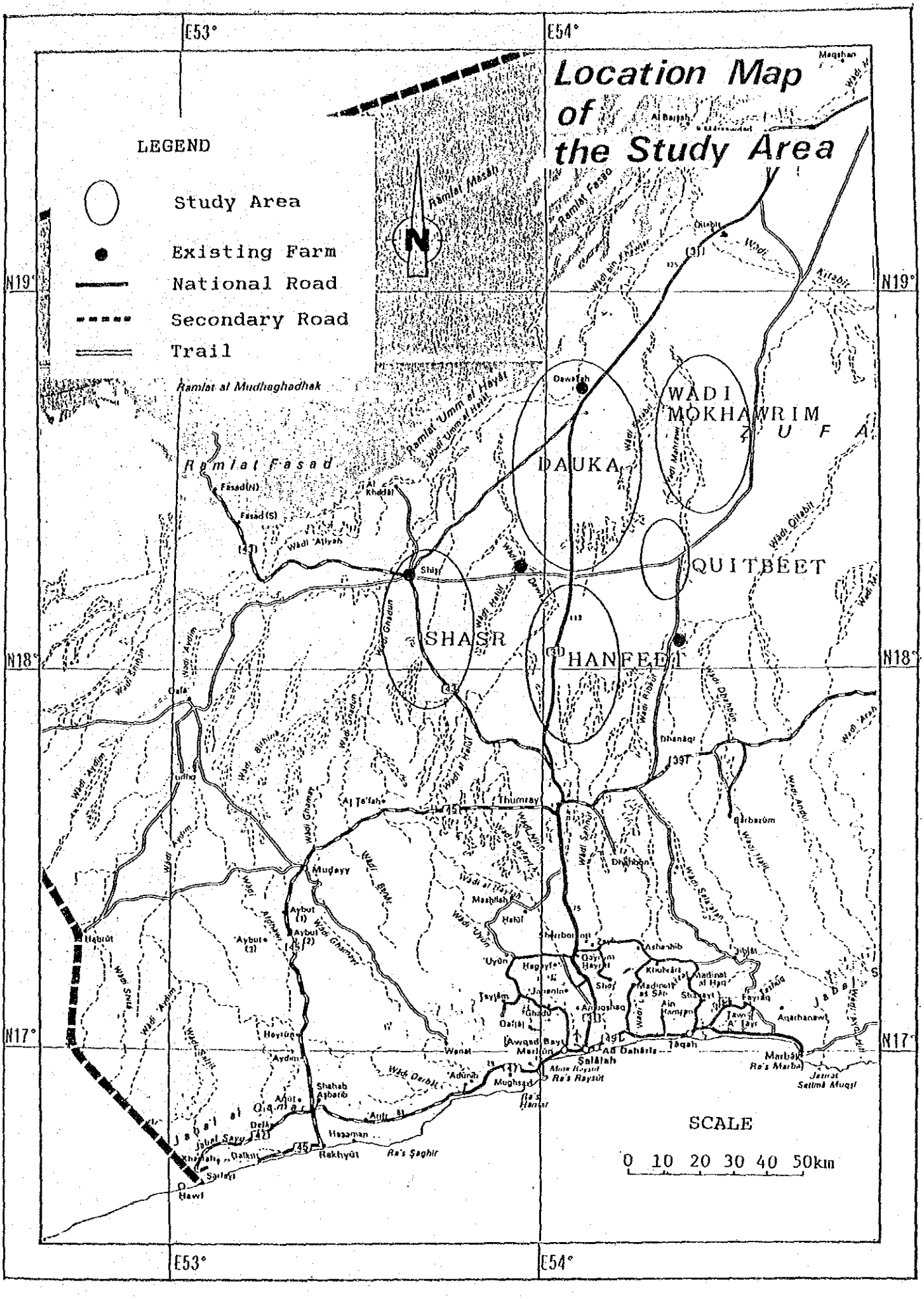
I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Sultanate of Oman for their close cooperation extended to the Study Team.

October, 1989

Kensuke YANAGIYA
President
Japan International Cooperation Agency


Location Map of the Study Area
E52°
E54°
E56°
E58°
N25°
N23°
N21°
N19°
N17°
HUSANDAH PENINSULA
UNITED ARAB EMIRATES
SULTANATE OF OMAN
SCALE
0 100 200km
Buraimi
Sohar
Huscat
Ibri
Nizwa
Sur
Adam
SAUDI ARABIA
HASIRAH ISLAND
Huqshin
Dauka
STUDY AREA
(Approximate)
Thumrait
KURIA MURIA ISLAND
Salalah
SOUTH YEMEN
(PDRY)
ARABIAN SEA


Location Map of the Study Area
LEGEND
Study Area
Existing Farm
National Road
Secondary Road
Trail
E53°
E54°
N19°
N18°
N17°
N
WADI MOKHAWRIM
DAUKA
QUITBEET
SHASR
HANFEET
Ramlat Fasad
Ramlat al Mudhaghadhak
Ramlat Umm al Hayat
Ramlat Masah
Ramlat Fasad
Jabal al Qamar
SCALE
0 10 20 30 40 50km

SUMMARY AND RECOMMENDATIONS

Summary and Recommendations

This is a summary of "The Agriculture Development Project in the Nejd Region". The report of this study consists of the following two volumes:

Volume I : Main Report
Volume II : Appendix

1. Objectives of the Study

In this study, surveys were conducted on the groundwater and soil resources in the five areas of the Nejd from the view point of agriculture development.

Based on the results of the survey, a guideline for agriculture development in a promising area and a plan for a pilot farm, are formulated. Applicable farming system and appropriate utilization of groundwater and soil are elaborated.

2. Background of the Study

2.1 The Sultanate of Oman gives a high priority to the promotion of agriculture development and water resources development, since the Government wishes to achieve economic independence from oil and self sufficiency in the supply of food, a goal since the first five-year plan (1976 - 1980). Furthermore, agriculture is planned to be developed intensively in a 10-year plan.

2.2 Salalah plain is situated on the coast and is the main populated part of the southern region with a major farming area. In this plain, a little room is left for the additional large scale agriculture development, since there has been a rapid utilization of land and water resources caused by the rapid increase of population accompanying with the urbanization.

In this regard, the agriculture development in the Nejd which has a development potential, becomes important for the development of the southern region.

2.3 Critical natural conditions and poor infrastructure facilities had restricted the agriculture development with only some small scale farms doing cultivation in the Nejd. However, the groundwater and soil investigations show the availability these resources and the agricultural development scheme was started in the Nejd.
A PDO desert farm was established as a pioneer to experiment the crops suitable for the desert area.

2.4 However, the condition and the potential of the groundwater resources have not been clarified, since only a partial investigation of the groundwater resources was made in the past. In the above conditions, the effective method is to establish a pilot farm as the first stage of the development and proceed with the appraisal of groundwater resources in order to plan an agriculture development project for the effective conservation of precious groundwater resources.

2.5 For the purpose of carrying out this study on agriculture development in the Nejd, the government of the Sultanate of Oman requested for the technical cooperation of the Government of Japan.
In response to the request, the Government of Japan agreed to carry out the study through the Japan International Cooperation Agency (JICA) which then despatched a preliminary study team to Oman. The team held a series of discussions with the Omani officials concerned and in December 1986 agreed upon the scope of the work.

The survey was carried out from October, 1987 to September, 1989.

3. Current Situation of the Study Area

General Outline of the Area

3.1 Nejd is located in the southern region and has an area of approx. 40,000 km^2.

The study area consists of five target areas; i.e, Dauka, Wadi Mokhawrim, Shasr, Hanfeet and Quitbeet. These target areas extend over 100 km both from east to west and from north to south.

3.2 Infrastructure facilities are undeveloped in the study area, except a National Highway of 1,000 km length which connects Muscat and Salalah.

There are some settlements surrounding the study area, i.e, Thumrait which is the major settlement for both administration and commerce, Shasr which is an oasis from the ancient days, Quitbeet and Hailat Al-Rakah.

3.3 Population density in the Nejd is quite low with approx. 7,300. The population of Thumrait is approx. 2,100 and the other areas is approx. 5,200. Most of the people are nomads who don't have their own permanent residences, and therefore the population varies seasonwise.

Natural Conditions

3.4 The terrain of the Nejd is moderately sloping towards north from mountains at the southern fringe. The mountains at the southern fringe is not only the northern limit of monsoon rain, but also the watershed between the coastal area and the Nejd. The northern margin of the Nejd is bordered by the great sand desert, Rub' Al-Khali at 190 km from the coast.

3.5 In the southern region, southwestern monsoon blows against the southern slope of the 1,000 m high Dhofar Mountains. The monsoon produces rainfall from June to September and for this reason summer is referred as rainy season. However, the rainfall area is limited only to the coastal plains and the southern slope and the summit area of the mountain range. Aridity increases in the inland area, forming parallel climatic zone to the coastline.

According to the meteorological data in Thumrait, diurnal range of atmospheric temperature in the study area is very large and a range of 20°C is common throughout the year. The maximum annual temperature of 43 to 45°C is observed in June. The minimum is 2 to 6°C in January. Annual precipitation is highly variable, ranging from 0 mm to 150 mm. Major rain is caused by cyclone. Large scale cyclones are supposed to occur at the Nejd once in every five years.

Soil Survey

3.6 The Soil Classification Map and the Land Suitability Classification were already prepared by Harza (1985) and GDC (1986). In this study, Soil Classification Map and Land Suitability Classification Map of the same scale (1:60,000) are prepared for an area of 418,100 ha based on the soil information collected around the proposed pilot farm site, in confirmation with the previous data.

3.7 Most of the soils in the study area occur on limestone and marl of Tertiary System. These soils are constitued of the eolian and aqueous sediments of the weathered material of these rocks.

The shallow soil (about 30 cm depth) is dominant in the study area, while the deep soil (more than 100 cm depth) is distributed only in a small area of wadi, alluvial fan and toeslope.

The land unsuitable for cultivation covers an area of 363,125 ha (about 87% of the study area), and the land suitable for cultivation covers an area of 54,975 ha (about 13%). Highly suitable land of 'S1' class and moderately suitable land of 'S2' class cover only an area of 18,905 ha (about 4.5%).

3.8 Some farms were established around the study area without considering the soil conditions. Problems of poor drainage and salt accumulation occur in these farms with shallow soil depth.

At the proposed pilot farm site, an impermeable layer (hard limestone) is located at a depth of 4 - 5 m and therefore the natural drainage potential should be high.

Agriculture

3.9 The agriculture development in the Nejd started at the beginning of 1980's with the development of hand-dug well and flowing well by the local people. Small scale farms are established recently and the agriculture development progressed rapidly.

3.10 There are 54 farms in the study area with a total area of 390 ha, excluding the PDO farm of 100 ha area.
Among these farms only 20 farms of 128 ha area are registered. The total cultivated area is only 95 ha and and other area is in developing stage. At present some of these farms are unsuitable, because of poor soil conditions caused by salinity hazard.
Major crops cultivated are fodder grass, fruits and vegetables with an average planted area of 52.1%, 25.0% and 21.3% respectively.

3.11 There is a high demand of fodder grass for the cattle grazing at the Jabal next to the Nejd. Although there is a plan to reduce the cattle population in Jabal by the livestock destocking program, a stable supply of the fodder grass is indispensable if the rangelands are to be preserved in the Jabal.
Most of the fodder grass cultivated in Nejd is Rhodes grass. Rhodes grass is the most suitable crop to improve the soil structure and is highly tolerant for drought and salinity. Therefore it is widely cultivated at several farms in the Nejd.

Rhodes grass of high quality and high yield was experimented at PDO farm and was found that it can be harvested 10 times a year with the yield of 40 - 45 ton/ha/year as dry matter.

3.12 PDO farm was established in 1985 by the instruction of H.M. Sultan Qaboos with the prime objective of rapidly evaluating the possibility of irrigated agriculture in the Interior desert. Originally the farm size was 40 ha and a 60 ha area was added with a centre pivot irrigation system and at present the total area is 100ha.

Water is pumped with six deep wells of 450 - 590 m depth and the water level is about 60 m depth below the ground level. Forage crop cultivation, mainly Rhodes grass, shares 95% of the total farm land, and vegetables and fruits are also cultivated. Rhodes grass hay is sold to nomads and some amount is sent to market. Other products are mainly consumed by the people who live in Marmul oil camp.

3.13 The agricultural technology such as cropping pattern has not been established in the area. Crop cultivation period of vegetables is much different between each farmer. However, cropping season trials of vegetables, such as tomato and cucumber have been started by the PDO farm and the experimental cultivation is still under progress.

3.14 According to the experimental cultivation results at the PDO farm, the appropriate seeding time of vegetables in the area is from October to November. If the seeding time is delayed, the crop will be damaged by low temperature in the seeding period and yield will be much decreased. Crop cultivation is very difficult in the summer season of July and August and the crops are affected by the high temperature. However, a few crops such as Okra and water melon are cultivated during the summer season.

4. Groundwater Resources

Review of Preceding Groundwater Surveys

4.1 Groundwater survey in the Nejd is still at the preliminary level. Surveys of restricted scale and accuracy were carried out by Sir W.Halcrow and Partners (1976), Sir A.Gibb and Partners (1984) and Harza (1985). These surveys were followed by two significant surveys carried out by PDO (1985) and PAWR (1986).

The survey carried out by PDO was a compilation work of the water resource surveys, which were carried out as an auxiliary part of oil exploration. In this report, eastern portion of the Nejd is covered, but most of the central and all of the western Nejd are excluded.

PAWR drilled groundwater exploration bore holes at 13 points, over an area of 15,000 km^2 of the Nejd in almost the identical area of the present project. Almost in the same period, PAWR had conducted environmental isotope studies on the groundwater in nation wide scale. According to the study, the lower UER aquifer, the target aquifer of the present project, bears groundwater of low level carbon-14 throughout the area and the groundwater ages were computed as more than 10,000 years. Also it was discovered that the oxygen and hydrogen isotope ratios of the lower UER aquifer is different from those of rain and groundwater of the Dhofar Mountains. These facts strongly suggested that the Nejd groundwater is disconnected from the present hydrologic cycle. Eventually the groundwater resources are believed to be finite without any current recharge.

Hydrogeology

4.2 The basement of the Nejd is Pre-Cambrian, but most of the outcropping rocks are sedimentaries of Hadhramaut group from Palaeocene to Eocene in geologic age.

The tertiary formations are divided into the following four formations from the lower to the upper horizon.

1. Umm Er Radhuma (UER) formation
   - Lower UER formation
   - Upper UER formation
2. Rus formation
3. Dammam formation
4. Aydim formation

Remarks : PDO classified UER formation into three subformations in which Shammar Shale of the lower UER of this report is termed as Lower UER and the overlying part as middle UER.

4.3 As the aquifer develops mainly in the carbonate rocks, it is presumed that some fracture structure may be related. Fracture could be caused by faults and/or synclinical structures. These structures may produce lineaments at the ground surface.
In the survey area lineaments of SW-NE trend was recognized to be prevailing.

Groundwater Hydrology

4.4 Four aquifers were discriminated for the project area in the Nejd by PAWR and the present survey.

Zone A: Dammam formation and Rus formations, 0-140 m
Generally good water quality of EC less than 2,000 μS/cm, except for some high salinity water of more than 10,000 μS/cm is available in the Rus formation. However the total resource amount is not appreciable. Some waters are in confined condition.

Zone B: Upper part of upper UER formation 140-270m
Large transmissivity can be encountered. There are some good quality waters but the water quality of the marly part of the formation is degraded, more than 2,000 μS/cm. Mostly in confined condition.

Zone C: Top of lower UER formation, 270-310 (?) m
This aquifer develops extensively in the Nejd. Quality is good with EC around 1,500 μS/cm. The aquifer is confined and produces flowing wells in the north.

Zone D: Lower UER formation, 310 (?) m -
Both quality and quantity is poorer than Zone C. EC exceeds 2,000 μS/cm. and tends to increase with the depth.

4.5 Potentiometric groundwater heads and EC values of Zone C were measured by the observation wells drilled by PAWR and this project. The contour patterns indicate prevailing flow direction of SW-NE in the project area.

By the analysis for Zone C waters, it is anticipated that the groundwater in the Nejd agrees with the flow zone system. These Nejd waters are different from Salalah Plain groundwaters which are currently recharged by the rains on the Dhofar Mountains. Consequently Zone C waters do not seem to contain any recharge waters from the Mountains.

Electric Prospecting

4.6 Two prospecting methods, i.e. ELF-MT and Schlumberger, were applied in stages to cover the widespread area of the Nejd within a limited period.

For the first stage, the ELF-MT method, was selected as the regional mapping method. This method can be easily practiced to determine the general trend of the local ground resistivity.

For the second stage, the Schlumberger method was applied to analyse vertical components of resistivity anomalies which were detected by the first stage.

Exploration Drilling Works

4.7 In order to evaluate groundwater with a view of developing agriculture in the Nejd and secure the water source for the planned Pilot Farm, two observation wells and two test wells were drilled as specified in the following table.

Specification of Exploration Drilling Works

Study Phase	Well No.	Well type	Depth (m)	Borehole Dia. (mm)	Casing Dia. (mm)
Phase I (1987)	NJD-1	Observation Well	400	152-444	178-245
Phase II (1988)	NJD-2	Test Well	350	216-610	245-340
	NJD-3	Observation Well	350	152-444	178-245
	NJD-4	Test Well	350	216-660	245-340

4.8 Based on the result of drilling works, it is found that the groundwaters except for the lower UER formation have low water level with low quality. Lower UER formation has groundwater whose level is merely the same as ground level and it is pressurized under approx. 30 atm with relatively good quality. As per each pumping test, its transmissivity is 4,000 m^2/day and its storage coefficient is 4 x 10^{-5}.

Groundwater Resources Evaluation

4.9 Three models of regional groundwater systems are formulated based on the field results and previously published data, namely,

1. Isolated confined aquifer model
2. Residual gradient model without groundwater recharge
3. Residual gradient model with groundwater recharge

The most suitable groundwater model for the regional groundwater system should be verified by further groundwater observation and survey. However, the "residual gradient model without groundwater recharge" seems to be adequate at this stage.

The drawdown proceeds in two stages. In the first stage it occurs mostly in the piezometric loss. Then in the second stage it involves decline of phreatic level.

Based on the results of the analysis, the following two main points are remarkable.

1. For a development area of 300-500 ha, the life time is generally fairly long, i.e. in the order of thousands years.
2. Initial drawdown puts a limitation to the reclamation scale, i.e. reclamation scale of 1,000 ha is critical.

Development and Conservation of Groundwater Resources

4.10 Lower UER formation is the major water resource for the agriculture development in the Nejd. Based on the characteristics of this formation, the following directions are proposed for the groundwater conservation and development.

1. Optimization of pumping site disposition.
2. Decide the rate of groundwater development based on continuous and systematic groundwater observation.
3. Administrative system for groundwater conservation.
   Under this system, groundwater monitoring, routine groundwater exploration, development and control of the resources shall be executed.

5. Guideline for Agriculture Development in the Nejd

5.1 A guideline is proposed for the agriculture development in the Nejd, based on the potential of groundwater resources and soil conditions in the study area. However there are a lot of constraints to be settled so as to make agriculture in the Nejd as a prime industry of the area.

Particular attention should be paid to the fact that the groundwater in the Nejd is categorized as fossil water and is a limited water resource like oil. Therefore, while utilizing this scarce resource, suitable and appropriate methods should be adopted based on the resource life time and its contribution for the prosperity and development of Oman.

Phased Agriculture Development

5.2 A phased agriculture development plan is proposed in this study, based on the actual conditions and limitations of the Nejd.
Because of high uncertainties of groundwater and other resources, it is not advisable to introduce a large scale development project.

The three phases of phased agriculture development plan are as follows:

1. Phase I
   - Establishment of pilot farm; experimentation at pilot farm and collection of data.
2. Phase II
   - Development of upto 500 ha area based on the results of phase I.
3. Phase III
   - Further development based on the results of phase II.

Tentative Scale and Pace of the Development

5.3 The following two items should be clarified for the successful implementation of the agriculture development project.

1. Project development pace (Suitable development pace)
2. Limitation of the project area (Maximum development area)

In the phase II of the phased development plan, the development area is assumed temporarily as 500 ha and the prosperity of this development scale should be verified at first. If the expected results can not be achieved, the development scale should be revised and the prosperity should be studied once again.

Evaluation Items to Step Up from One Phase to Next Phase

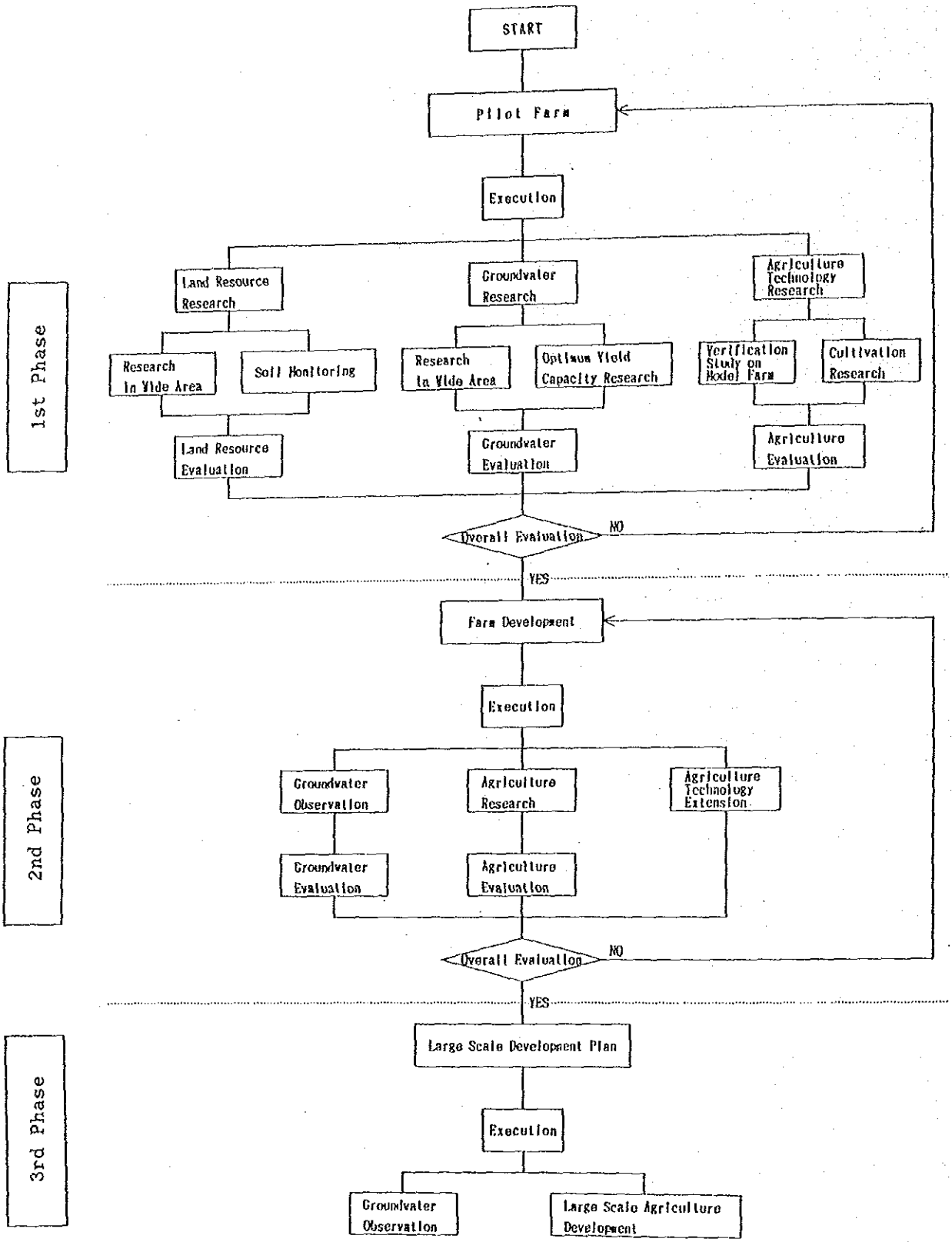
5.4 The phased agriculture development plan in the Nejd is divided into three phases. The problem points of each phase should be clarified properly before shifting from one phase to the next phase.
The following items should be evaluated before shifting from phase I to phase II.

1. Groundwater drawdown accompanying with pumping up should be within the reasonable value.
2. The quality of groundwater should not become worse because of the pumping up operation.
3. There should not be any problems regarding the cultivation technology for fodder grass.
4. Marketability of fodder grass should not be decreased remarkably.
5. Supporting systems to proceed with farm management under commercial base should be clarified.
6. Systematic control system of groundwater should be established.
7. Soil survey for the development area should be carried out in detail.
8. Training and extension system should be established for the farmers.

Items to be evaluated for shifting from phase II to phase III are as follows:

1. Clarification of groundwater condition by the groundwater investigation in the whole area.
2. Confirmation of the suitable project development pace and the limitation of the project area based on the groundwater condition.
3. Confirmation of the cropping pattern, cultivation technology, and marketability for different crops.
4. Establishment of marketing system for the fodder grass and the other crops to be introduced.

Phased Agricultural Development Diagram



Proposed Site for Agriculture Development

5.5 Based on the natural and socioeconomic conditions, the selection is recommended to the following four areas for introducing agriculture development project. The advantage of each area is shown below.

1. Nagha area (Area around the proposed pilot farm site)
   - Adjacent to national highway and located at the centre of the existing development area
2. Dauka area
   - Adjacent to national highway and can expect high pressurized groundwater
3. Shasr area
   - Adjacent to local road and can expect high pressurized groundwater next to Dauka Region
4. Wadi Makhawrim area
   - Adjacent to local road and can expect enough area of 'S2' soil class. At present there is no residence in this area.

Project site selection should be done carefully by considering the conditions mentioned below.

1. Soil condition

   The site selection should be made in the area where the soil class is 'S2' more and the area of this soil class in this study area is 18,900 ha.

2. Static groundwater level

   The pumping area should be selected in a site where the static groundwater level is at a higher level or level equal to the ground surface so that the primary investment, pumping cost and operation and maintenance cost will be cheaper.

3. Socioeconomic Conditions

   The project site selection should be done in an area where it has good access to the national highway and local gravel roads.

Groundwater Development Plan

5.6 Top of the lower UER formation should be developed as a groundwater resources for agricultural development in the Nejd.
It was found that the groundwater with good quality (1,500 μS/cm - 2,000 μS/cm) spreads in the project area from the result of this study.

5.7 The target groundwater resources is a strongly pressured confined one and store stagnant fossil water.
Since any extraction of water causes inevitable decline of water level, it is necessary to envisage the limited availability of groundwater both in terms of volume and span for its agricultural use.

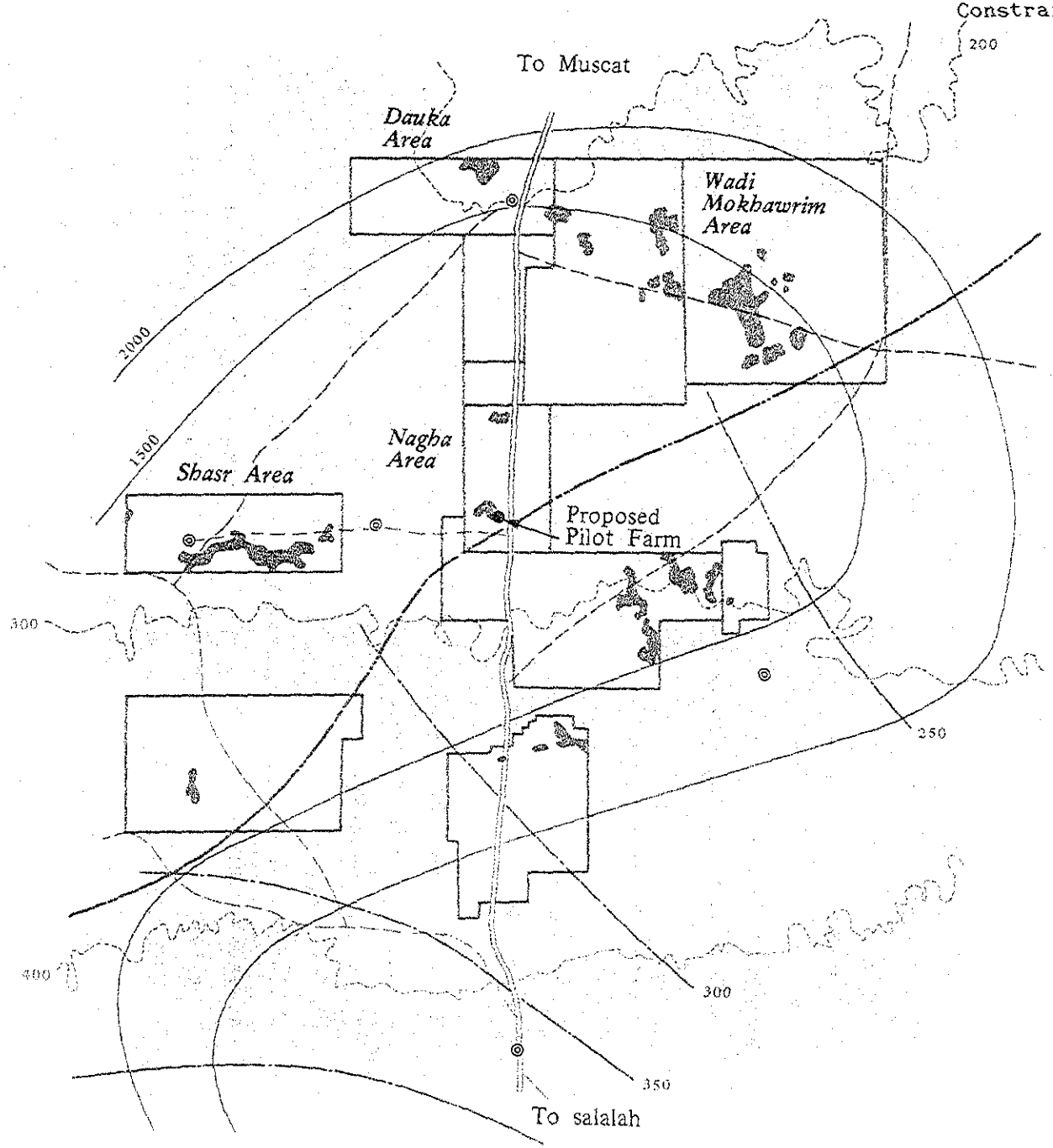
It impractical to pump up the groundwater from 300 meter depth from the view point of farm management. Farming can be done upto a groundwater depth of 100 m, since the pumping head of the ordinary pump for farming is within 100 meters.

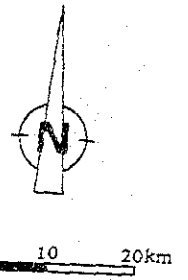
5.8 For the minimum interference of water levels between the production wells, the mutual distance should be kept beyond the radius of influence.
The distance between the production wells should be low enough which will cause low interference in groundwater level and should be close enough to the farms. Hence the distance between the production wells of two 50 ha farms is proposed as 10 km which will cause an acceptable draw down of 100 mm over an area of 50 ha for a discharge of 5,900 m^3/day.

Farm Arrangement Plan

5.9 From the viewpoint of soil and groundwater conditions, two types of farm arrangement are considered.

1. Scattered type
   - In this type, the farms will be located at separate locations close to their production wells





LEGEND

- Muscat-Salalah High Way
- Local road
- E.C. contour (μS/cm)
- Potential Head of Lower UER Top aquifer
- Flowing well southern limit
- Ground Elevation
- [S_2] - area of Land Suitability Classification
- Settlement
- Soil survey area

2. Concentrated type
   - In this type, the farms will be located together at one location although they are separated from their production wells

Among these two types concentrated type is proposed and the reasons are as follows:

1. Concentrated type creates a concept of community which is very much essential for the development project
2. Farm machineries can be purchased and maintained together by farmers' association
3. The infrastructure facilities such as roads, electricity etc. can be developed in common, at one location.

Crop Selection Plan

5.10 At first, it is advisable to grow fodder grass, especially Rhodes grass which is more suitable for the Nejd. Later, in accordance with the progress of the agriculture development, the commercial crops such as vegetables can be added based on the crop selection criteria such as natural conditions, yield benefit, marketing potential etc.

Reasons for selecting fodder grass are as follows:

1. Rhodes grass which has high talerance for drought and salinity can be cultivated as the reclamation crop to improve the soil structure.
2. It is possible to cultivate high quality grass in a whole year in the dry weather of the Nejd.
3. It is possible to minimize the manpower requirement by the introduction of machineries and it doesn't require any extra facilities for marketing.
4. The cultivation and marketing of Rhodes grass are done at the existing farms and PDO farm in the Nejd and hence the cultivation techniques and marketing are already practiced.

5. There is a demand of fodder grass for cattle grazing at the Jabal with a market price of R.O.100/ton.
   In future even if the cattle population of the Jabal is destocked to half by the introduction of the destocking programme, a stable supply of the fodder grass will be indispensable for the conservation of the Jabal grasslands.
6. In the southern region, the farm products are assigned in three areas i.e., Salalah Plain, the Jabal and the Nejd for the effective utilization of available resources in each area. In this regard, the farming in the Nejd is proposed as "fodder grass supply area", to supply grass for the cattle population in the Jabal and Salalah plain.

5.11 Crop selection plan for the commercial crops such as vegetables must be decided based on the experimental cultivation at the pilot farm, considering the following factors:

1. Natural conditions
2. Yield benefit
3. Appropriate cultivation technology
4. Marketing potential

Organizational Set-up for Project Development

5.12 The agriculture development project starting with the establishment of pilot farm necessiates the coordination of different organizations for the effective management of the project.

The various activities to be performed in course of introducing the agriculture development project are as follows:

1. Technical guidance/extension service to the farmers
2. Procurement of production materials and services for storage and marketing of farm products
3. Financing for farming
4. Operation and maintenance of farm roads, electricity, etc.

Hence coordination of different organizations becomes necessary to perform all these activities, "Project appraisal and advisory committee" with the representatives of different organizations is required for this purpose. Besides, a project office which will be responsible for the execution and management of the development project and a pilot farm which will be responsible for the experimental investigation and training will also be established.

Settlement Plan

5.13 The pace of development project mainly depends upon the groundwater condition. The government should decide the number of families/enterprise which will settle at the area to maintain the new developed farms. Policies of land tenure, owning of machineries, facilities, prices etc. should be decided by the government in accordance with government policy.

The main objective of agriculture development project is to introduce agricultural development through the "Omanization" concept. This means that an innovative group of Oman people should take the full responsibility for complete management of the farms and this group will act as the pioneers for the future generation who will shoulder the responsibility of Oman's future agriculture.

Hence a suitable farming group of local people should be selected to take this responsibility. Before the settlement, the farming group should be given enough training at the proposed pilot farm.

6. Pilot Farm Plan

6.1 In the project area, data necessary for planning and implementing of the agriculture development is highly insufficient. Especially data such as groundwater potential, meteorological data, type of crops suitable, appropriate cultivation technology etc. are lacking which restrict the planning of suitable development project. For this purpose a pilot farm project should be executed as the first phase of the phased development plan. The major objectives of the pilot farm are summarized as follows:

1. Experimental cultivation by introducing locally appropriate technology
2. Demonstration of these techniques to the local people and the others through on farm training
3. Extension of these techniques to the Nejd through agricultural extension work
4. Evaluation of groundwater potential and observation of soil and meteorological conditions.

Area of the Pilot Farm

6.2 The farm size is planned as 50 ha, considering the pumping rate of two test-wells which were drilled during this study.
Three types of farm will be operated at the pilot farm, and the following allotment will be made in order to achieve the target.

Experimental farm	5 ha x 1 ea. = 5 ha
Small scale verification farm	6 ha x 1 ea. = 6 ha
	9 ha x 1 ea. = 9 ha
Large scale verification farm	30 ha x 1 ea. = 30 ha

Farm Management Plan

6.3 Based on the objectives of pilot farm, the farm management plan can be divided into the following four categories.

(1) Crop cultivation plan

After establishing the pilot farm, at first it is necessary to improve the soil condition by applying organic matter, fertilizers etc. Fodder grass will be grown for some period till the soil is cultivated enough and become suitable for the other crops. Hence the crop cultivation plan is divided into two stages:

1. Soil reclamation stage
   - At this stage fodder grass will be cultivated in the whole pilot farm area to improve the soil condition.

2. Crop cultivation stage

- After the soil condition is improved and become suitable for the other crops, experimental cultivation should be started using the appropriate technology for the Nejd.

(2) Agriculture Training Plan

To succeed in agriculture in a virgin land, several cultivation techniques and knowledge are required. Continuous technical guidance and education is necessary for the farmers of the existing farms and for the new comers who will be engaged in agriculture in the near future.

Hence it is planned to establish an agriculture training center within the pilot farm, where the farmers and agriculture students can learn and experience the actual farming techniques.

(3) Agricultural Extension Plan

As a primary step towards the agriculture development of the Nejd, the pilot farm is obliged to diffuse the agricultural technology and knowledge to the farmers of the existing farms and to the new comers who will be engaged in agriculture in the future.

The results obtained from these extension activities will be fed back to the pilot farm and will be analyzed by carrying out the consecutive activities at pilot farm.

The main extension works are as follows:

1. Guidance of appropriate farming techniques
2. Publicizing technical informations
3. Investigating and collecting informations

(4) Groundwater, Meteorology and Soil Observation Plan

Continuous observation of groundwater level is necessary to evaluate the hydrogeological features and properties of the Nejd. Therefore after the establishment of pilot farm, the groundwater level at the two observation wells of the pilot farm and the other observation wells around it should be measured continuously and systematically.

Continuous observation of meteorological and soil conditions are necessary since these data can be used in planning the future agriculture development.

Irrigation Plan

6.4 Irrigation methods such as centre pivot sprinkler system in large scale verification farm and rain gun and side wheel sprinkler systems in small scale verification farm and experimental farm will be introduced. Drip irrigation system will be adopted in a part of experimental farm.

The daily water requirements for the 50 ha farm is 7750 cu.m/day as the maximum and 3900 cu.m/day as the minimum. Total annual requirement is 2.16 million cu.m.

The irrigation water requirement for the two pumping cases is summarized as follows:

Pumping Time	MAX	MIN	MEAN
18 hrs	7.1 cu.m/min (118 lit/sec)	3.8 cu.m/min (63 lit/sec)	5.5 cu.m/min (91 lit/sec)
24 hrs	5.3 cu.m/min (89 lit/sec)	2.8 cu.m/min (47 lit/sec)	4.1 cu.m/min (68 lit/sec)

The maximum requirement is 118 lit/sec and the pump capacity required for one production well in case of 18 hrs of pump operation is 59 lit/sec.

Irrigation Facilities Plan

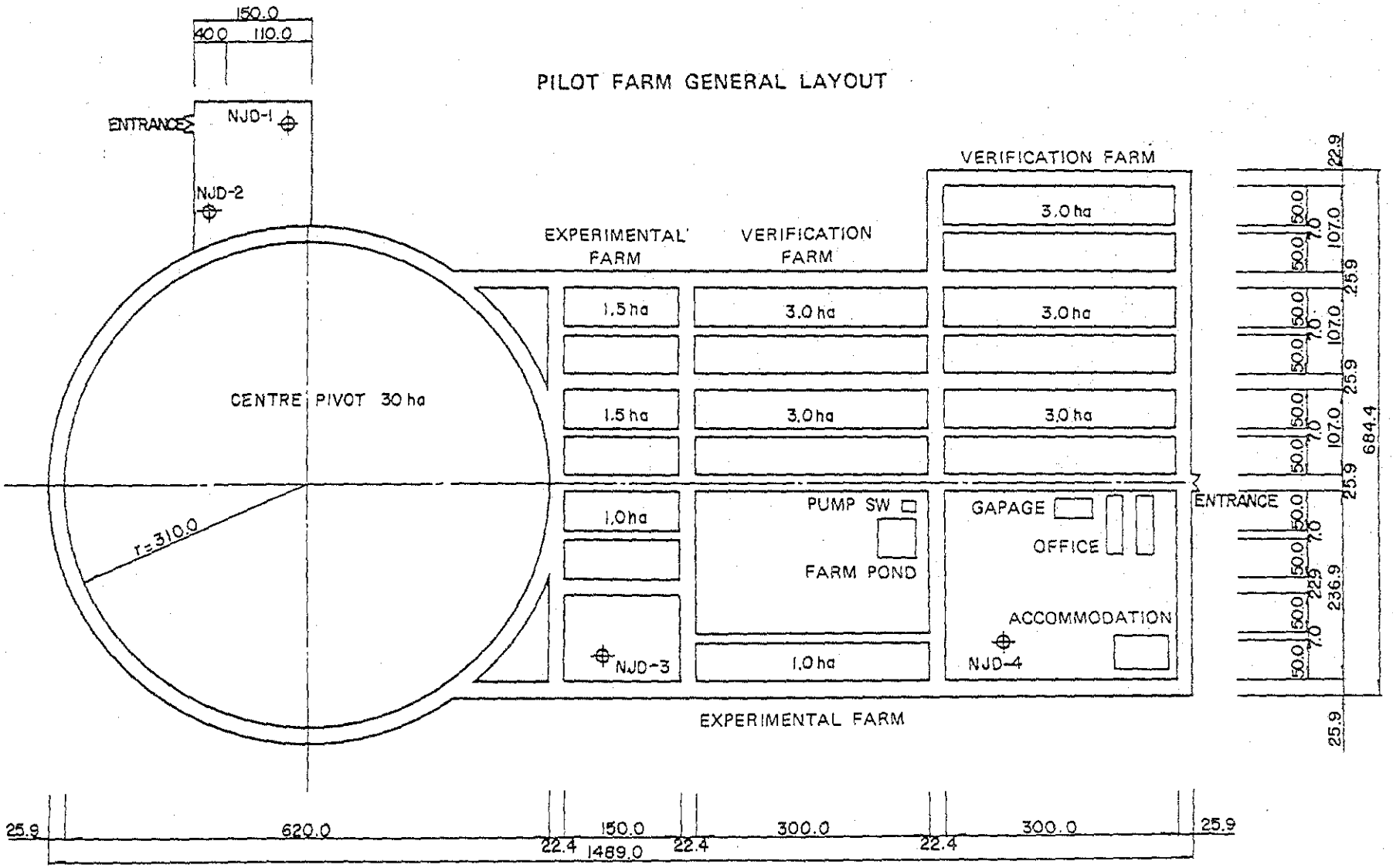
6.5 Irrigation facilities proposed for the pilot farm are summarized as follows:

1. Water supply facilities
   Production well : 2 Nos. (Test well drilled during this study)
2. Water distribution facilities
   Farm pond : 1 No. (2,400 m^2)
   Distribution pump : 1 place (Booster pump: 5 Nos.)
   Distribution line : Pipeline network
3. Drainage facility
   Pipe drainage : 1 ha (Experimental farm)
4. Irrigation facilities

Irrigation Method		Type of Farm
Center pivot sprinkler	:	30 ha (Large scale verification farm)
Side-wheel sprinkler	:	6 ha (Small scale verification farm)
Rain gun irrigation	:	9 ha (Small scale verification farm)
	:	4 ha (Experimental farm)
Drip irrigation	:	1 ha (Experimental farm)

5. Road
   Trunk road : 5.1 km (width 10 m)
   Branch road : 3.3 km (width 7 m)
   Cultivation passway : 2.3 km (width 3 m)
6. Windbreak facilities
   Windbreak trees : 9.7 km
   Windbreak fence : 4.4 km
7. Power facility : 500 kVA (100 KVA x 5 Nos.)
8. Buildings : 1,420 m^2 (Office building, training building, Dormitory, staff quarter, etc.)
9. Agro-meteorological observation station : Temperature, Rainfall, Humidity, Wind, Evaporation, etc.
10. Farm machineries : 16 Nos. (Tractor, Harrow, Truck, etc.)

PILOT FARM GENERAL LAYOUT



Pilot Farm Execution and Maintenance Plan

Project Execution Agency

6.6 The DGAFS (MAF) is recommended as the project execution agency for the pilot farm project. Groundwater monitoring should be technically supported by PAWR which is executed in parallel with operation/maintenance work after its construction.

Project Cost for the Pilot Farm

6.7 The total project cost is estimated as R.O.1,698,500 (US$4,423,200) under prices in January 1989.
The summary of the project cost is shown in the following table.

Summary of the project cost

unit: R.O.

Item	Cost
1. Construction cost	1,193,951
2. Machineries & equipments cost	149,040
Sub Total	1,342,991
3. Project facilities cost	9,400
4. Administration cost	5,700
5. Consultation service cost	186,000
6. Physical Contingency	154,409
Grand Total	1,698,500

Operation and Maintenance Plan

6.8 The pilot farm office takes care of operation/maintenance of several facilities in the pilot farm. This office is composed of 20 staffs including experts of agronomy and irrigation, agricultural extension workers, operators and mechanics. Observation workers should be included for monitoring of groundwater/soil and maintenance of meteorological observation equipments. If the activity of the pilot farm goes well, the experts from outside should also be invited for training.

A Case Study of Agricultural Development in the Nejd

Background and Purpose of the Project Plan

6.9 In order to proceed the agriculture development in the Nejd systematically, the phased development which begins with the pilot farm establishment must be practiced.

In case of proceeding with the development project after the pilot farm construction, the appraisal of the project enlargement pace for farm development and limitation of the project scale is quite important.

A case study of the project proposed from the guideline is discussed in order to understand the problems to be expected at the project execution stage as the second phase of the agriculture development plan.

Main items to be studied are as follows.

1. Rough estimation of the project cost
2. Appraisal of the project
3. Governmental subsidy for the project

Presumptions of the Project Plan

6.10 The presumptions of the project plan of the case study are as follows.

1. Accomplishment scale of the project
   The accomplishment scale for the project is presumed as 500 ha based on the groundwater conditions obtained from the survey results.
2. Phased development
   Development area will be expanded step-by-step, based on the evaluation of the groundwater.
3. Crop selection
   Rhodes grass will be cultivated.
4. Project starting period
   The project will be started after the confirmation of development potential by monitoring/management at the pilot farm for two years.

Development Area

6.11 Among the four areas selected in the guideline, Nagha area and Dauka area are selected as the development areas in this project plan. By selecting these two areas, the mean project cost are estimated, since the project cost is different between these areas.

Construction Plan

6.12 The project plan presumes that the area of farms is 50 ha and the development unit is expanded step-by-step in Nagha area and Dauka area. It presumes that the 50 ha farm is constructed as ten units and the development area reaches to 500 ha in total.

Facilities Plan

6.13 The facilities, materials and machineries required for the 50 ha farm is detailed as follows: Five sets of these items will be required both in Nagha area and Dauka area.

Item		Details
1. Land reclamation	:	50 ha area should be the unit of development and it will be irrigated by a centre pivot irrigation system.
2. Distribution line	:	Same as the pilot farm plan
3. Windbreak facilities	:	-- ditto --
4. Farm road	:	Construct new trunk roads and cultivation pass way.
5. Farm pond	:	One farm pond is designed per 50 ha area.
6. Booster pump	:	Arrange two booster pumps of 65 KW
7. Irrigation facility	:	Introduce a centre pivot irrigation system for 50 ha area
8. Production well	:	Wells are designed assuming their depths as 330 m in Nagha area and 430 m in Dauka area
9. Monitoring well	:	-- ditto --

10. Submersible pump : Submersible pump should be installed at Nagha area only. 45 KW
11. Storage line : Storage line is installed from production well to farm pond to deliver water
12. Power facility : Power facility is designed for both submersible pump and booster pump
13. Connecting road : Connecting road is designed to connect the national highway and development area
14. Operation and Maintenance Road : This road is designed for operation and maintenance of production well and storage line
15. Farm machineries : Necessary farm machineries are introduced
16. Vehicles : Vehicles are provided for operation and maintenance of the farm
17. Residences and accommodations : Residences and accommodations for settlers are provided

Project Cost for the Case Study

6.14 The project cost for 50 ha farm is shown in the following Table. The mean values of the 10 farms of the Nagha and Dauka area are shown in this table. The total project cost for 500 ha farm area is estimated as 10 times of the 50 ha farm.

Item	Mean value of 50 ha unit farm
1. Construction cost	R.O.1,296,500
2. Machinery cost	R.O. 84,500
Sub-total	R.O.1,381,000
3. Construction facilities cost	R.O. 7,400
4. Administration cost	R.O. 5,700
5. Consultation service cost	R.O. 110,700
6. Physical contingency	R.O. 150,500
Total	R.O.1,655,300

Operation and Maintenance Cost

6.15 Operation and maintenance cost includes depreciation, repairing cost and fuel consumption cost.
The mean annual operation/maintenance cost of 50 ha unit farm is R.O.128,500 ($334,600) although it is different for each farm with respect to water resource conditions of the area. The following three costs are the main items of operation maintenance cost.

O/M cost of intake facilities	28%
O/M cost of on farm facilities & housing	48%
O/M cost of farm machineries	23%

7. Appraisal of the Nejd Agriculture Development Plan

7.1 Based on the case study of agricultural development as the phase II of the phased agriculture development scheme, a financial appraisal is prepared in order to examine the policy of governmental subsidy to support the project.

Financial Internal Rate of Return (FIRR)

7.2 Financial Internal Rate of Return (FIRR) of the project is estimated for the following three cases of governmental subsidy for the unit price of Rhodes grass of R.O.100/ton and the unit production rate is set at 40 ton/ha.

CASE	Governmental Subsidy	FIRR (%)
1.	Without any subsidy	+1.1%
2.	Construction of observation well, storage line (with O/M road) and connecting road	+6.9
3.	Construction of production well, observation well, storage line (with O/M road) and connecting road	+11.6%

Presumptions: Project life is set to 30 years
Project price is calculated as of Jan., 1989

FIRR of the project for all the three cases of Governmental subsidy is positive for the unit price of Rhodes grass of R.O.100/ton. In addition to this FIRR of the project is estimated with the unit price of R.O.70/ton for the three cases of Government subsidy and it was found out that FIRR is negative for the unit price of R.O.70/ton. Consequently, it can be concluded that this high cost project will be economical only if the revenue of Rhodes grass will be equal to or above 4,000/ha (= R.O.100/ton x 40 ton/ha).

Debt Service Schedule, Financial Statement and Government Expenditure

7.3 The financial statements tell us that, with generous doses of government subsidies, which is set to cover the interest cost of investment to the farm facilities, to bear the investment and operation/maintenance cost to the rest of the facilities except to installing the production wells with its pumps which is to be charged to the farm operators, the annual sale of fodder grass with the unit price of R.O.100/ton will not only cover the direct production cost including water cost, the O/M cost, depreciation cost and repayment of the long term loan but also be able to allow the farmers to retain the remuneration of R.O.720 per year per hectare.

With the level of remuneration mentioned above, the periodical replacement cost of machinery can be paid without raising any extra short term loan.

The following items of the government expenditure are required for obtaining the remuneration.

1. Interest

   The government is supposed to bear the interest (1.5%) of the long term loan for the project provided by the OBAF.

2. Monitoring Well with Observation Equipment

   It is supposed to bear the cost of installation of the facilities and its maintenance and operation. The latter cost may be borne by the PAWR, as the operation may appropriately fall within its jurisdiction .

3. Storage line with O/M Roads
   Construction costs and O/M cost are supposed to be borne by the government. The latter may be maintained by the MAF.

4. Connecting Roads
   Construction costs and O/M cost are supposed to be borne by the government. The latter may be borne by either the MOC or the Wali of Dhofar.

Project Impacts

7.4 In addition to the project benefit that can be quantified and valued in monetary terms, every project entails cost and benefit that are intangible and do not lend themselves to evaluation. Because these cost and benefit are a factor for project selection, it is important that these are identified.
Probable impacts are as follows:

1. Agriculture development in the Nejd facilitate the development of southern region as a whole.
2. Development of basic industries creates new employment opportunities in the area.
3. Pilot farm project contributes for the development of human resources through its training and extension program.
4. The project will supply fodder grass for the cattle population in the nearby Jabal.
5. The project will facilitate to improve the social infrastructure of the area.

However spares they may be, people have been living in the frontier desert of the Nejd. It is important for the government to provide them with infrastructures not only for living but also for production and transport, because they give the local people self-esteem. But beyond the level of purely financial appraisal, ranking of the project in the priority schedule would be left entrusted to the perspective of the policy makers.

Recommendations

At present, the socioeconomic conditions of Oman highly depend on the petroleum industry and the agriculture development is highly essential for stabilizing post-oil economy. However, the informations regarding the Nejd such as natural environment, soil, groundwater and socioeconomic conditions are not sufficient enough. Hence the scale and details of the agriculture development project in the Nejd should be decided carefully.

Based on the study of groundwater and soil, and agricultural conditions the following recommendations are made for the agriculture development in the Nejd.

(1) The agriculture development project should be established in confirmation with the groundwater and soil conditions of the area. The groundwater and soil conditions in the Nejd can not be clarified until the detailed investigation is carried out further in the whole area. Hence the accumulation of the informations regarding all the relevant parameters should be carried out under a suitable investigation system.

(2) The development project should proceed with a systematic development plan in order to obtain good results fitting with proper investment. It is hoped that the establishment of the project appraisal and advisory committee with the coordination of concerned governmental offices will be helpful in order to manage and control groundwater, land and manpower resources and for the planning and promotion of suitable agriculture development project.

(3) The phased agriculture development project plan should be established based on the guideline for the agriculture development proposed in this report.

(4) The pilot farm project which will be carried out as the first phase of the phased agriculture development project is the most important phase to confirm the development potential of the Nejd. In this regard, the early execution of the pilot farm project is strongly recommended.

It is necessary to collect the following data which are indispensable for developing the agricultural project in the Nejd.

1. Continuous observation of groundwater conditions
   - Groundwater level
   - Groundwater quality
2. Continuous observation of soil conditions
   - Physical and chemical properties of the cultivated soil
   - Tests of fertility status and salt concentration
3. Continuous observation of meteorological data
4. Crop cultivation experiments which include type of crops to be introduced, cropping pattern and cultivation techniques.
5. Irrigation tests which include the selection of irrigation method and analysis of water requirement for each crop.

(5) The groundwater resource is the most important factor which influences the promotion of the agriculture development project in the Nejd. For the further development and conservation of the groundwater resource, the investigation of groundwater condition in the whole area should be carried out systematically and in detail in parallel with the phased agriculture development project. The following investigations should be carried out.

1. Exploration of groundwater
   - Drilling of new exploration wells and new observation wells
   - Exploration of aquifer distribution by the electro-magnetic prospecting

2. Groundwater monitoring
   - Continuation of groundwater observation and improvement of its observation network.
   - Establishment of groundwater observation system and securing of staffs for its observation.

3. Administrative system for groundwater resource conservation
   - Establishment of administrative system for groundwater development and conservation
   - Desirable drilling procedure and well structure
   - Optimization of well arrangement
   - Determination of suitable development speed and limitation of project area based on the groundwater appraisal.

(6) Although a detailed soil survey was carried out in the pilot farm site, only a preliminary soil survey was done in the other areas and the information of soil condition is not sufficient enough. In case of selection of further development area the following detailed soil survey is required in the target area proposed in this report.

   - Air photo survey
   - Topographical survey
   - Definition of land suitability and description of soils

(7) The results of the financial appraisal make it clear that the large scale governmental subsidy is required to implement the project with proper remuneration under the assumption of the unit price of Rhodes grass as R.O.100/ton and the yield as 40 ton/ha. The high cost of groundwater irrigation project will be economical only of the high yielding crops, which can make the revenue of R.O.4,000/ha/year should be grown in the newly developed area.

(8) It is hoped that the concerned governmental offices should review the project plan periodically during the promotion of the project and revise its contents if necessary, so as to reflect the socioeconomical conditions of Oman.

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GLOSSARY AND ABBREVIATIONS

Arabic Glossary

Ain	Spring
Falaj	Water distribution system under or above ground
Jabal	Mountain
Sabkha	Salt-flat
Wadi	Valley or drainage channel in an arid region (normally dry)
Wali	Local Governor

Abbreviation for Units and Terms

Measurements

Length

mm	Millimetre
cm	Centimetre
m	Metre
km	Kilometre

Area

sq.cm	Square Centimetre
sq.m	Square Metre(s)
sq.km	Square Kilometre
ha	Hectare
fd	Feddan = 0.42 ha
MSM	Million Square Metre

Volume

l	Litre
cu.m	Cubic Metre
MCM	Million Cubic Metre
bal	1 barrel = 36 U.K. gallon
gal	1 U.K. gallon = 4.546 litre

Weight

mg	Milligram
g	Gram
kg	Kilogram
ton	Metric Ton

Others

μS/cm	Micro siemens per centimetre
mS/cm	Milli siemens per centimetre
pH	Potential Hydrogen
EC	Electric Conductivity
El	Elevation above the mean sea level
sec	Second
min	Minute
hr	Hour
Min	Minimum
Max	Maximum
^{o}C	Degree Centigrade
^{o}F	Degree Fahrenheit
%	Percent
FY	Fiscal Year
a.	Annum = Year
mon	Month
G.D.P.	Gross Domestic Product
ELF-MT	Extremely Low Frequency Magneto-Telluric
VES	Vertical Electric Sounding
UER	Umm Er Radhuma

Currency Conversion

R.O. (Rial Omani)	1 R.O. = 2.60 U.S.$
U.S.$ (U.S. Dollar)	1 U.S. $ = 0.384 R.O.

Abbreviation of Organization Names

CCEWR	Council for Conservation of Environment and Water Resources, Oman
DC	Development Council, Oman
MAF	Ministry of Agriculture and Fisheries, Oman
DGIA	Directorate General of Irrigation Affairs
DGA	Directorate General of Agriculture
DGF	Directorate General of Fisheries
DGAFS	Directorate General of Agriculture and Fisheries in Salalah
MCI	Ministry of Commerce and Industry, Oman
MC	Ministry of Communications, Oman
DGCAM	Directorate General of Civil Aviation and Meteorology
DGM	Directorate General of Meteorology

MD	Ministry of Defense, Oman
GSA	Government Survey Agency
MDA	Ministry of Diwan Affair, Oman
MEWR	Ministry of Environment and Water Resources, Oman
DWRR	Directorate of Water Resources Research
MEY	Ministry of Education and Youth Affairs, Oman
MEW	Ministry of Electricity and Water, Oman
DGW	Directorate General of Water
DRW	Directorate of Rural Water Supply
MFA	Ministry of Foreign Affairs, Oman
MI	Ministry of Interior, Oman
DTA	Directorate of Tribal Affairs
MOH	Ministry of Housing
MPM	Ministry of Petroleum and Minerals, Oman
MSWD	Ministry of State and Wali of Dhofar, Oman
PCDESR	Planning Committee for Development and Environment in the Southern Region, Oman
PDO	Petroleum Development, Oman
PAWR	Public Authority for Water Resources, Oman
PAMAP	Public Authority for Marketing Agricultural Produce, Oman
WRC	Water Resources Council, Oman
JICA	Japan International Cooperation Agency
FAO	Food and Agriculture Organization, United Nations
WMO	World Meteorological Organization, United Nations
WHO	World Health Organization, United Nations
UAE	The United Arab Emirates
GCC	The Gulf Cooperation Council
HALCROW	Sir William Halcrow & Partners
TAYLOR	John Taylor and Sons
GIBB	Sir Alexander Gibb & Partners
HARZA	The Harza Engineering Company Limited
GDC	Groundwater Development Consultants
HYDRO	Hydroconsultants

CHAPTER – 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The Government of Sultanate of Oman requested the Government of Japan for the technical cooperation of the study on Agriculture Development Project in the Nejd Region.

In response to the request, the Government of Japan agreed to carry out the study through the Japan International Cooperation Agency (JICA) which then despatched a Preliminary Study Team to Oman. The Team held a series of discussions with the Omani Government officials concerned and in December, 1987, agreed upon the scope of work.

The Government of Oman established a Technical Permanent Committee for this study consisting of eleven representatives from the following Government bodies:

The Ministry of Agriculture and Fisheries (MAF), The Council for conservation of Environment and Water Resources (CCEWR), The Ministry of Petroleum and Mining (MPM), and the Planning Committee for Development and Environment in the Southern Region (PCDESR).

The Technical Permanent Committee's Chairman is Mr. Abdulla bin Hamdan Al-Wahaibi, the Director General of Irrigation Affairs, MAF.

The Committee's vice Chairman is H.H. Barghash bin Ghalib Al-Said, the Director General of Water Resources Research, CCEWR.

1.2 Objectives of the Study

Surveys will be conducted on groundwater and soil resources in the five areas of the Nejd from the viewpoint of agricultural development. Based on the results of these surveys, a guideline for agriculture development in a promising area and a plan for a pilot farm will be formulated. Applicable farming system and appropriate utilization of groundwater will be elaborated.

1.3 Study Area

The study area consists of Dauka, Wadi Mokhawrim, Shasr, Hanfeet, and Quitbeet. These five areas are located in the north of Dhofar Mountains.

1.4 Scope of the Study

The study work is performed in two stages, i.e. Stage I and Stage II and the scope of each stage is as follows (TABLE 1.4.1):

(1) Stage I

1) Phase I

The first field survey of groundwater, electrical resistivity of ground, and soil and agricultural conditions was carried out during the period of October to December, 1987. Based on this survey a promising agriculture development area, a pilot farm site, and observation and test well drilling locations were selected.

During the second field survey period (from January to March 1988), a well drilling contract was made with a local drilling contractor, and the first observation well was drilled. Pumping tests, bore hole loggings, and water sampling of the well were carried out. A meteorological observation point was set up and automatic water level recorders were installed in the wells existing in the study area.

2) Phase II

During the third field survey period (from June to October 1988), one observation well and two test wells were drilled. Bore hole loggings, pumping tests, and water sampling were carried out and aquifers' hydraulic coefficients were measured. Further, by geochemical groundwater surveys, dissolved ions, radioisotopes, and stable-isotopes were analyzed.

(2) Stage II

1) Phase I

Based on the results of the analysis of observation and test wells, the groundwater potential was estimated. Based on the estimation, a pilot farm plan and the agriculture development guideline were studied and appropriate farming systems were investigated during the fourth field survey period (from December 1988 to March 1989).

2) Phase II

After the analysis (performed in Japan) of the fourth field survey, a pilot farm plan and the agriculture development guideline have been formulated during the Phase II period.

TABLE 1.4.1 Overall Work Items of the Study

Japanese Fiscal Year	Study Stage	Study Phase	Work Stage	Work Item
1987	Stage I	Phase I	Field Study I	• Field surveys (meteorology, groundwater, electrical prospecting, soil, agriculture) • Preparation of well drilling work • Selection of promising agriculture development area and pilot farm site • Selection of observation and test well drilling sites
			Home Office Study I	• Data analysis of field study I • Selection of a drilling contractor
			Field Study II	• Drilling of observation well • Water-gauge installation in existing wells
1988		Phase II	Field Study III	• Observation and test well drilling • Pumping tests of observation and test wells • Geo-chemical groundwater survey • Existing well surveys
			Home Office Study II	• Analyses of groundwater surveys • Formulation of subsequent study work
	Stage II	Phase I	Home Office Study III	• Estimation of development potentiality of groundwater • Preparation of study scope for agriculture development
			Field Study IV	• Surveys necessary for agriculture development guideline • Surveys necessary for pilot farm plan • Problem-screening and clarification • Outlining of pilot farm plan
1989		Phase II	Home Office Study IV	• Formulation of agriculture development guideline • Formulation of pilot farm plan • Project evaluation
			Field Study V	• Submission of draft final report
			Home Office Work Completion	• Final report preparation

FIG. 1.4.1 Overall Work Schedule of the Study

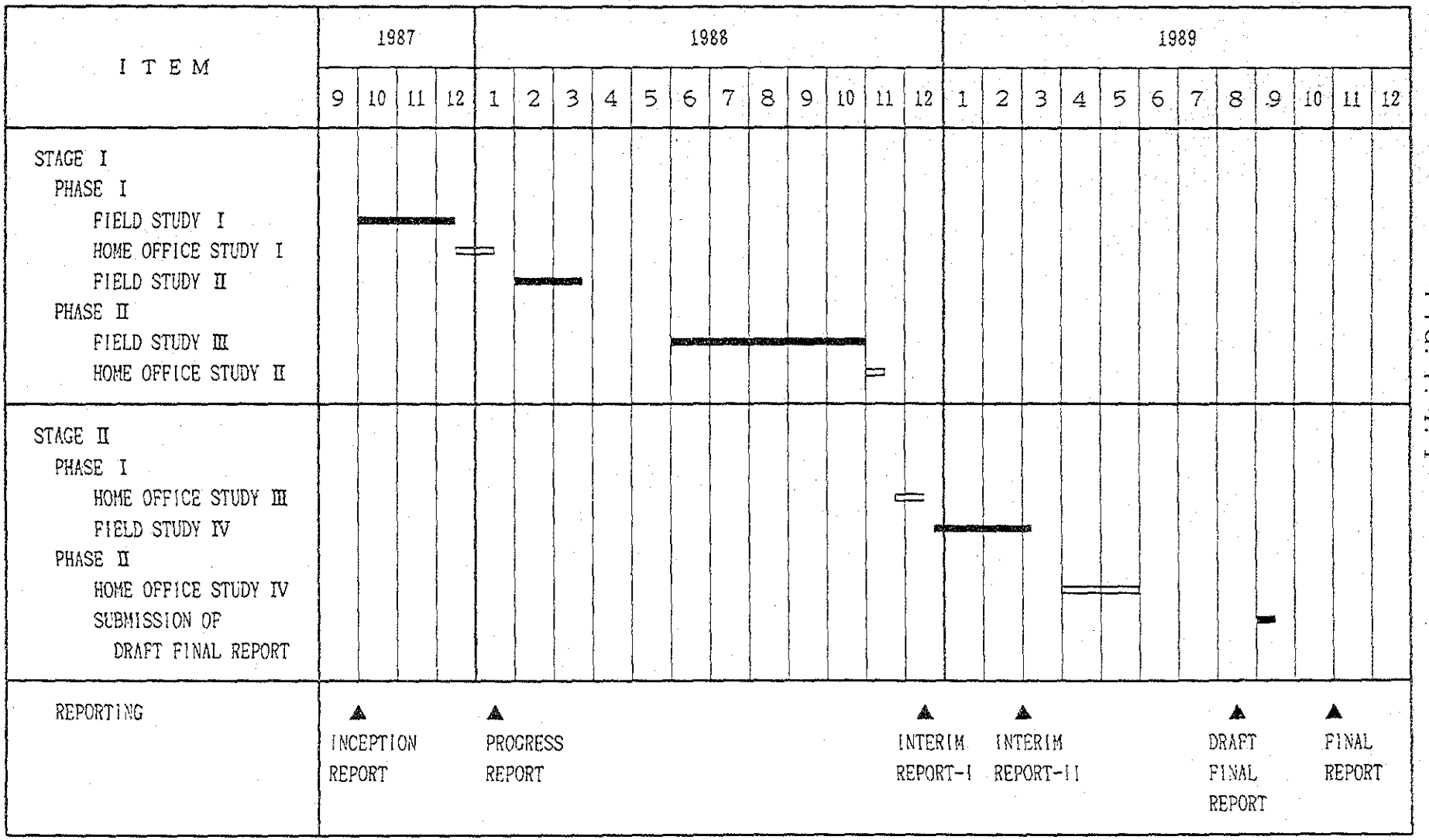

FIG. 1.4.1

CHAPTER – 2

BACKGROUND

CHAPTER 2 BACKGROUND

2.1 General Background

2.1.1 Geography

Oman is situated at the southeastern corner of the Arabian Peninsula and is bounded by the People's Democratic Republic of Yemen in the south, and by the Kingdom of Saudi Arabia and the United Arab Emirates in the west. Gulf of Oman and Arabian Sea wash the north and east coast respectively.

Its territory extends from 16°37'N to 26°30'N and from 51°50'E to 59°40'E, with a coastline of 1,600 km and territorial area of 300,000 km^2 approximately.

The geography of Oman varies greatly from area to area. Two extensive mountainous regions are the major remarkable geographical features; one is Hajar Mountains along the northern coast and the other is Dhofar Mountains along the southern coast. They are separated by a great desertic flat land, Rub' Al-Khali or the Empty Quarter and its marginal barren areas.

The mountains scrape the altitude levels in excess of 2,000 m in the north and 1,000 m in the south. Due to the orographic effects there are appreciable amounts of rainfall which provide amicable environment in and around the mountainous regions.

2.1.2 Climate

The climate of Oman is classified as a tropical arid, but it varies from place to place influenced by various factors such as oceanic geomorphological, etc. The climatic contrast of the northern region to the southern regions and of coastal to inland are especially noticeable. The northern and southern regions are 1,000km away from each other and their climatic conditions are considerably different.

In the northern region, westerlies cause rainfall during the winter. In the southern region, the southwestern monsoons bring rainfall during the summer.

Southwestern monsoons blow against the southern slope of the 1,000 m high Dhofar Mountains and cause rainfall due to its ascending air currents. However, the rainfall area is limited only to the coastal plains, the southern slopes and the summit areas of the mountain range.

2.1.3 Social Aspect

In 1970 H. M. the Sultan Qaboos bin Said undertook a reformation of his country by opening it again to the outside world and promoted its reconstruction, and the efforts has been continued till the present time.

The sequence of the country's modernization after 1970 is as follows:

a) 1970 - 1975:
Construction of various infrastructures such as sea-ports, airports, roads, schools, power stations, etc.

b) 1976 - 1980:
Improvement of infrastructure and promotion of industries, in line with the First Five-year plan.

c) 1981 - 1985:
In the Second Five-year Plan, further improvement of infrastructure, promotion of agriculture, fisheries and mining industry, expansion of education, public health and public welfare facilities were achieved.

d) 1986 - 1990:
Improvement of infrastructure in rural places and investment for the development of agriculture, fisheries and medium-small scale industries were tangible. However, because of the effects of the sudden and sharp fall of oil price since the beginning of 1986,

some new development projects have been frozen, while the others have been revised.

Oman has a variety of communities created by the long tradition of maritime state and by the consistant national unity. Stable communities based on the tribal groups have been maintained and these groups operated agriculture, fisheries, animal husbandry, manufacturing and urban commerce. Under the modernization policy these communities are being progressively united with each other by the extension of infra-structures such as road, communication and electric supply. National administration services which accompany modern education system has been also strengthened in the country side.

In 1987, the Sultan Qaboos University was established as the first national university. It culminated the education campaign, completing the construction of national educational frame. The National Consultative Council, which is the consulting body of the Sultan, can be regarded as manifesting the social maturity explained above.

2.1.4 Economy

Major industry of Oman is the production of oil which shares about 46% of GDP and 91% of Gross export value in 1987. Agriculture and fishery production against GDP was about 30% before the commencement of oil production, while this value fell into a mere 3% in 1987, in spite that it occupied about 44% of employed population.

In itemise, import of machines and transport equipment shares 36% of the total. Manufactured goods and food products/livestock shares 17% and 19% respectively. These three items corresponds to 72% of the total import.

2.1.5 Population

According to the World Bank, the population of Oman is estimated as 1.38 million (1987). However, the Government of Oman estimated the population as two million and uses this figure for the various national development plans (Statistical Year Book, 1988). It is estimated that one-third of the population is concentrated in the capital and Batinah Coast areas.

One of the characteristics of the population structure is the large contribution from expatriates to the working force. The number of expatriates at the end of 1985 was estimated as 400,000. However, since the beginning of 1986, 100,000 expatriates, mainly Indians, left Oman due to the decline of oil economy.

Major expatriates in Oman are Indians (about 170,000), Pakistanis (about 40,000), Bangladeshis (about 40,000), Egyptians (about 15,000), Philipinos (about 20,000), Srilankans (about 10,000), Europeans, and Americans.

As new farms are reclaimed increasingly, foreigners came to supplement the local work force. This phenomenon is same even in the southern part of the country. In this area, both large and small farms hire foreign laborers.

2.1.6 Agriculture

(1) Role of Agriculture in National Economy

It is assumed that 60% of the Oman's work force is engaged in agriculture. However, the contribution of agriculture to the country's economy is very small (about 3% of the GDP). The total farmland area of Oman is 83,000 ha (0.28% of the territorial area) of which the cultivated land occupies 41,000 ha.

(2) Farming Areas in Oman

There are two major farming areas in Oman. One is in the northern part of the country on both sides of the 2,000 m high Hajar Mountain range, and the other in the southern part around Salalah City. In the desert areas, which occupy more than one half of the country, only a limited parts are used by nomads and oil bases.

The northern areas can be divided into four zones:

1) the Batinah coast zones (along the coastline north of Muscat) stretches 300 km in north-south direction having a width of 10 - 30 km.
2) the inland area spreads out at the western out-skirt of the Oman mountains.
3) the northwestern oases of Al-Dhahirah Region border on the United Arab Emirates.
4) the Sharqiyah Region fringes the northern flank of the Wahiba Sands.

The southern farming areas can be divided into three areas; the Salalah Plain, the mountainous area in the north of the Salalah Plain, and the Nejd beyond the mountains. However, the coastal plain is the only cultivated area and the mountainous area is used as grazing land.

(3) Crops

Orchard crops occupy more than 28,000 ha in Oman, which amounts to 68.6% of the total cultivated area. Grains and forage crops are planted on 4,800 ha (11.7% of the total area) and vegetables are planted on 2,140 ha (5.2% of the total area).

Main forage crops cultivated in the country are Rhodes grass and alfalfa. They are widely cultivated in Oman and used as feed crops for cattles, goats and sheep. These crops are important in order to promote livestock farming. Recently Rhodes grass is widely cultivated but the areal data is not availabile in the official

reports. Alfalfa farms occupy an area of 3,700 ha and is placed at the second after date farms.

Date palms are planted on more than 20,000 ha which occupies 49% of the total cultivated area, and is the major crop in Oman.

Other subsequent orchard crops include mango (2,960 ha), lime (2,030 ha), and banana (1,990 ha).

Major vegetables cultivated in the country are onion, water melon, tomato, chilli, etc. However, these vegetable supply can only meet a small percentage of the country's need and their consumption is expected to increase with increase of urban population. Wheat is planted only on 300 ha and barley is planted on 150 ha. The areas used for growing wheat and barley are limited to the inland plateau area. Only a small amount of wheat and barley is produced.

2.2 Background in the Southern Region

2.2.1 Geographical, Social and Economical Conditions

The Southern Region of Oman spreads over an area of approximately 117,000 km^2 (about 40% of the entire country) and is bounded by Saudi Arabia in the north, People's Democratic Republic of Yemen in the west and Arabian Sea in the south with the coastal line of about 500 km.

According to the country's sampling census, the population of the Southern Region in 1985 was estimated as about 110,000 with about 81,000 Omanis and 29,000 foreigners. In Salalah city, about 64,000 people (more than 50% of the region's population) 38,000 Omani and 26,000 foreigners are living.

The southern region which includes the Nejd comprises a single Wilayah (administrative province), Dhofar, which executes the local government administration. The Dhofar Wilayah is administrated by a Wali who is also the Minister of State and is responsible for local administration, policy and implementation of civil law in the region.

75% of the employed male omanis are civil servants including the military men. It is assumed that 12% of Omanis are employed in agricultural sector. 45% of non-omani are engaged in the construction works, 12% in retail and catering works, and only 3% in agricultural sector.

As shown in TABLE 2.2.1 the southern region shares 14% of GDP excluding oil production and 40 - 45% of oil production, playing an important role in national economy. Major industry other than the oil production is fishery which shares 30 - 35% of total amount of fishery production in Oman. Other industries include Fish Processing, Soft Drinks, Cement, Cattle Feed and small scale constructive industries.

Following table shows main socio-economic index:

TABLE 2.2.1 Comparison of Socio-Economic Index
(National-Southern Region)

Item	National	Share of South
I Economic Index	(1987)	(1975-85 *)
GDP (Excluding oil)	1674.4 Mill.R.O	14%
Oil	1362.0 Mill.R.O	40-45%
Manufacturing (Excluding oil refinery)	101.4 Mill.R.O	5-8%
Fishing	34.8 Mill.R.O	15%
Exports (Excluding oil, Mostly Fish)	39.0 Mill.R.O	20%
Development Expenditure	328.8 Mill.R.O	12%
II Social Index	(1987)	(1987)
Land Area	300000 km²	100000 km² (33%)
Population	1200000	120000 (10%)
Towns and villages	1898	60 (3%)
Hospitals	47	5 (11%)
Beds	3450	384 (11%)
Government Schools		
Primary	367	73 (20%)
Preparatory	249	29 (12%)
Secondary	62	7 (7%)

Source : Statistical Year Book, 1988
* Economic Development Prospects for the Southern Region, Vol.1

2.2.2 Agriculture

(1) Agricultural Land Use

Agricultural land use in the southern region can be divided into three distinct subregions:

1) The Salalah Plain
2) The Jabal or Dhofar Mountains
3) The Nejd, Inland plains

The agricultural land use patterns differ vastly between the subregions. These differences are due to the difference in soil and water resources and climatic patterns.

In the Salalah Plain and south zone of the Jabal, summer monsoon brings rainfall with cool weather, which results in the ecology of plants and animals having a distinct features among the Arabian Peninsula.

(2) Crops

a) The Salalah Plain

Salalah Plain is bounded by the Jabal and the coast, extending 10 km from south to north and 50 km from east to west. The water resources originated from the rainfall in the mountains are utilized by local agriculture from spring and falaj. Cultivations in the Southern Region are concentrated mostly in this area.

There is a rainy season from June to September in the Salalah Plain and the Jabal due to southwestern monsoon. Local conditions are favorable for cropping in these areas. Because of the monsoon, crops in these areas are different from those in the other parts of the country: coconut, banana, and papaya are popular grown here. The total cultivated land in the southern region is about 3,000 ha. An areal breakdown of cultivated land in 1987 is as follows:

Orchard:	970 ha
Vegetables:	380 ha
Field crops:	340 ha
Forage crops:	1,310 ha

The main agriculture pattern in this area can be characterized by small scale traditional agriculture which occupies more than half of that area and large scale organized agriculture.

Traditional agriculture is represented by small scale farms of about 2 ha and produce fruits and vegetables for local consumption and for the north Oman market. Main crops are coconut and banana, and others are lime, melon, tomato, but grown only in a small area.

Large scale farms of Dhofar Cattle Feed Company have areas of 350 ha and 150 ha. These farms are specialized in dairy products and feed crops, Rhodes grass. Most of the products are consumed locally and some of them are transported to the north Oman market. The farm keeps 3,000 cattles including dairy and beef cattles which consumes 40% of the forage products. The rest, 60%, is sold to the local people.

b) The Jabal

The main local agriculture is livestock grazing. Southwest monsoon from June to September brings rain to the mountains, which grow natural pasture there. The mountain tribe Jibbali are grazing cows and goats this pasture.

The livestock population in this area is estimated to share 90% of the Southern Region, forming the most important livestock region in Oman.

In recent years, the rapid increase of livestock disturbed the natural ecology and caused shortage of natural pasture and increased the need for the supplementary feeds.

In 1978/79 agricultural census, the cultivation area is reported as only 3 ha, but in the latest report it was estimated that 100 - 200 ha cultivated area was developed in stone wall enclosures.

c) The Nejd

In 1978/79 agricultural census, the total cultivated area was estimated as only 65 ha.

Agriculture development was hindered by severe climatic conditions, moratorium of well drilling and undeveloped infrastructure.

Recently some farms were developed by local people, using artesian well and/or potable water well.

Main crop in the area is Rhodes grass; vegetables and orchard crops are also cultivated in a small area. The farmers have a poor experience. Hence agriculture extension activities are urgently required.

PDO desert farm was established in 1985 with initial 40 ha cultivation, and tested cropping technology in the area. The farm was expanded in 1987, constructing a 60 ha centre pivot irrigator.

2.2.3 Regional Development Plan

The development of the Southern Region is one of the major issues of the long term government policy to construct a geopolitically well-balanced nation. The local advantages of the Southern Region, i.e. its monsoonal climate along the coast and relatively massive communities have been exploited for many centuries, especially over the last twenty years, there has been very rapid development there.

The Planning Committee for Development and Environment in the Southern Region (PCDESR) was established in 1984 in order to formulate a comprehenseve plan for land use and coordinate all the related fields of development in the South.

PCDESR is comprised of the following members:
The Minister of State and Wali of Dhofar (the chairman), the Minister of Agriculture and Fisheries, and six other Ministers related to the national development plan, the Undersecretary for Financial Affairs, and a Representative from the Council for Conservation of Environment and Prevention of Pollution.

At present, PCDESR is preparing the regional development plan and setting up an appropriate future land use plan in the Southern Region.

In line with the Third Five-year Plan (1986 - 1990), the Ministry of State and Wali of Dhofar nominated a study of agricultural development plan (maximum 1,000ha) in its jurisdiction. The Ministry of Agriculture and Fisheries will carry out the detailed investigations on groundwater, soil and other agricultural items which are necessary for positioning development sites of up to 1,000 ha for cultivation in the Nejd.

CHAPTER – 3

CURRENT SITUATION OF THE STUDY AREA

CHAPTER 3 CURRENT SITUATION OF THE STUDY AREA

3.1 General Outline of the Area

3.1.1 Location

The Nejd stretches from north of the Dhofar Mountains to the Rub' Al-Khali Sands. The total areal extent is 40,000 km^2 consisting of sandy desert and hammadah plain.

The Study Area belongs to the Nejd and is enclosed from 17°55'N to 18°45'N and 53°35'E to 54°35'E, and is located north of the Salalah city.

There are five target areas, i.e. Dauka, Wadi Mokhawrim, Shasr, Hanfeet and Quitbeet.

These target areas extend 100 km both from south to north and from east to west. They overlap the previous preliminary survey area for soil and water resource. (HARZA 1985 and GDC 1987)

Salalah - Muscat National Highway of 1,000 km length is the only route which provides access to the study area. From this national highway there are some gravel roads connecting Thumrait to Shasr, Marmul and Mudayy. However, local guides are indispensable to reach each target area due to poor road conditions.

3.1.2 Social Condition

(1) Administrative Structure

The Nejd is administrated by a Naib Wali, a deputy governor of the Southern Region, who stations at Thumrait.
Thumrait is a major settlement near the study area located at 80 km north of Salalah. The town developed rather recently when a air-base was constructed. Nowadays it has become the center of administration and commerce in the Nejd.

(2) Population

The population density in the Nejd is quite low. According to sample population survey in 1985, the population of Thumrait is approximately 2,100 with 1,400 Omanis and 700 foreigners. Population of the Nejd excluding Thumrait is estimated approximately 5,100 Omanis and 100 foreigners.

Most of the people are nomads who don't have their own permanent residences. Therefore population distribution varies from time to time.

(3) Settlement

Settlements adjacent to the study area except for Thumrait are summarized as follows:

(a) Shasr

Shasr is an oasis settlement from ancient times, located at about 70 km northwest of Thumrait and about 80 km southwest of Dauka. Most of the inhabitants are nomads, forming a small settlement composed of about 10 houses and a mosque. Sixty grazing families are said to live around there with 1,000 camels and 2,000 goats. The nomads come to Shasr in order to pray at the mosque and to get water for their livestock. Housing corporation, MOH, is now constructing ten new residences at Shasr for the settlement of the nomads.

In 1970s, date palms were planted with oasis water. Now they have grown up with abundant leaves. There is a 6 ha farm owned by six families and vegetables, citrus fruits and grasses are cultivated by some Pakistani employees.

On the other hand, recently some new farms are reclaimed with new shallow wells and this development proceeded rapidly.

(b) Hailat Al-Rakah

Hailat Al-Rakah is located along the branch road to Shasr from Al-Nagha and is 17 km west of the National Highway and 20 km southwest of the pilot farm site.

In 1980s a sub-tribe of Bait Kathir established a group-reclaimed farm. In 1983, a first shallow well was dug and five farms are constructed. The land registration was completed for 15 farms in 1986, 25 farms in 1988 and 42 farms in 1989. All these farms are cultivated with shallow wells. In future, about 80 farms are scheduled to be established in the region.

However, the farm owners do not live in Hailat Al-Rakah, instead they live in Salalah or Thumrit. The infrastructure facilities such as Wali-office, mosque, school, clinic or water service facilities does not exist. Only the foreign employees live and work in the farms.

(c) Quitbeet

Quitbeet is a small settlement of nomads located at about 30 km east of the pilot farm site. Few years ago, there were about 20 houses but houses rapidly increased to 40 in 1988 and 60 in 1989. There are a Wali-office, a mosque, a school and water supply and it forms the principal place for the nomads around there. However, the cultivated area is very little.

(d) Dauka

Dauka is located along the National Highway to Muscat at about 110 km north of Thumrait. There is nothing but only several households running farms there. The owners are living in Thumrait and/or Salalah. Those farms depend on leaking water from abandoned flowing well. The well was drilled as oil exploration well originally.

3.2 Natural Environment

3.2.1 Geomorphology

The geomorphological maps of 1/100,000 (1986) and 1/250,000 (1982) scale, published by the Ministry of Defence of U.K. are the available reference.

The Ministry of Agriculture and Fisheries of the Sultanate made composite satellite imageries and interpretational charts over its own territory in 1982. In 1983, the defence Ministry of Oman carried out aerial photographing of 1/60,000 scale in the Southern Region.

In addition to these, in 1988 the ministry of Agriculture and Fisheries took aerial phtographing of 1/20,000 scale over the parts of the project area which cover about 350 km^2.

The terrain of the Nejd is moderately sloping towards north from mountains at the sourthern fringe. The mountains at the sourthern fringe is not only the northern limit of monsoon rain, but also the watershed between the coastal area and the Nejd. The northern margin of the Nejd is bordered by the great sand desert, Rub' Al-Khali at 190 km from the coast.

The terrains of the Nejd from seashore to inland can be divided into the following zones.

(a) Zone from the southern watershed to the northern fringe of the alluvial fans deeply dissected by wadis in places. Surface gradient is 1/100 approximately.

(b) Zone from the fringe of alluvial fans to the central area of the Nejd. There are terrains of three levels, i.e. high, medium and low. Surface gradient is 1/300 approximately.

(c) Zone from the central area to the southern fringe of Rub' Al-Khali. Flat plains extend widely. Surface gradient is 1/500 approximately.

The areal extent of the three zones are of the ratio, a:b:c: = 1:2:4 approximately. Generally surface materials become finer and rounder from the mountain to inland. There are weathered angular detritus on the old terrains and exposed rock surfaces. They are frequently observed objects in arid region.

Terrains can be distinguished by their relative heights. The color grade of desert varnish, formed on cherty gravel, may indicate the age of the terrains.

3.2.2 Meteorology and Hydrology

(1) Climate

In the southern region, southwestern monsoon blows against the southern slope of the 1,000 m high Dhofar Mountains. The monsoon produces rainfall from June to September and for this reason summer is referred as rainy season. However, the rainfall area is limited only to the coastal plains and the southern slope and the summit area of the mountain range. Aridity increases inland, forming parallel climatic zone to the coastal line.

According to the meteorological data in Thumrait, diurnal range of atmospheric temperature in the study area is very large and a range of 20°C is common throughout the year.

The maximum annual temperature of 43 to 45°C is observed in June and the minimum temperature of 2 to 6°C is observed in January.

Annual precipitation is highly variable, ranging from 0 mm to 150 mm. The average precipitation in 1980s is 32 mm.

Major rain is caused by cyclone. Large scale cyclones are supposed to occur at the Nejd once in every five years and there is no definite wet season.

There was no meteorological observation station within the study area. However, three meteorological observation stations are maintained by the Ministry of Communication in adjacent south. Informations are given in TABLE 3.2.1. Each location is shown in FIG.3.2.1.

The data from Qairoon Hairitti were not adopted for observation period, was short. In this study, two new meteorological observation stations were established at Dauka and at the pilot farm site.

Continuous observations at these locations will clarify the meteorological condition in the study area. The equipments installed at each site and the observation parameters adopted are as follows:

a) Dauka Station (Observation started at 13:00 Oman Standard Time, on 19th of November, 1987)

* Robinson type wind-run anemometer (Weekly mean wind speed)
* Rutherford type maximum and minimum thermometers (Weekly maximum and minimum atmospheric temperature)
* Dry and wet bulb thermometer (Relative humidity)
* Automatic hygro-thermo-recorder (Relative humidity and temperature on a weekly chart
* 20 cm diameter rain gauge (Rain precipitation)

b) NJD-3 Station (Observation Started at 16:00 Oman Standard Time, on 21st of October, 1988)

* Vane type automatic wind recorder, model KDD-300, (Wind speed and direction record on a 3 month recording chart)
* Solar radiometer, model MS-42, (Solar radiation on a 3 month recording chart)
* Automatic rain recorder (Rain precipitation on a 3 month recording chart)

(2) Precipitation

The highest annual rainfall recorded were 359.8 mm and 144.6 mm at Salalah and Thumrait respectively and both were recorded in 1983. And the lowest was 53.4 mm at Salalah in 1981 and 7.0 mm at Thumrait in 1982. Precipitation is quite variable from year to year.
The average annual rainfall at Salalah and Thumrait is calculated as 120.7 mm and 36.3 mm respectively. Salalah is located in the coastal area and Thumrait is beyond Qara Mountains and the precipitation data clearly demonstrate the orographic effect of Qara against the monsoon.

(3) Atmospheric Temperature

Annual mean temperature at Salalah is around 26°C. The annual and diurnal ranges of maximum, mean and minimum temperatures are about 5°C and 10°C respectively.

For Thumrait, the annual mean temperature is about 26°C which is almost similar to Salalah. But the annual and the diurnal ranges are 15°C and 20°C respectively. The diurnal range is almost same throughout the year.

(4) Relative Humidity

Relative humidity at Salalah reaches the maximum of 90% in July and August and gradually attains the minimum of 50% in December and January.

In Thumrait, the peak humidity is found twice in a year, i.e. in December/January and July/August with 55% and 60% respectively. During the other months the relative humidity is about 40%.

(5) Wind

In Salalah, average wind blows at a speed of around 3.5 m/sec throughout the year, and annual variation is small. Southern wind prevails throughout the year with some minor northern wind in January/February and western wind in July.

In Thumrait annual average wind speed is 5 m/sec, but the annual range is large, i.e. a maximum of 9 m/sec in August and a minimum of 3.5 m/sec in winter. The average wind speed at the first half of the year is 6.0 m/sec and southern wind prevails throughout the year with occasional north and northwestern gale in winter. The northwestern gale is called 'Shimal'. Shimal causes large scale sand storms.

(6) Evaporation

Evaporation is measured by Piche atmometer at both Salalah and Thumrait.

Evaporation rate at Salalah in monsoon and winter seasons are 2.0 ml/day and 10ml/day respectively, and the annual average is 6.4 ml/day. The annual range is comparatively small and is about 4.0 ml/day.

In Thumrait the annual average is 15.5 ml/day with maximum in summer and minimum in winter, and this trend is opposite to Salalah.

(7) Sunshine duration

Sunshine duration is observed only at Salalah. It is only 2 hours per day in monsoon season of July and August. In the other seasons 9 to 10 hours of sunshine per day are common.

TABLE 3.2.1 Available Climatological Data

Item \ Station Name	Salalah Airport	Salalah QAIROON HAIRITI	Thumrait	JICA station Dauka	JICA station Nagha (Pilot Farm)
location (N) or (LAT) (E) or (LON) Altitude (m-ASL)	17° 02' N 54° 05' E 21.78m a.s.l	17° 15' 17.6" N 54° 05' 06.7" E 878.30m a.s.l	17° 40' 22.8" N 54° 01' 35.7" E 466.86m a.s.l	18° 40' N 54° 04' E 213.70m a.s.l	18° 19' N 54° 03' E 283.10m a.s.l
Operation Agency	MOC	MOC	MOC	JICA	JICA
Data Collection term	Jan.'80 - Oct.'87	Jan.'85 - Dec.'86	Jan.'85 - Oct.'87	Nov.'87 - Now	Oct.'88 - Now
Pressure	Daily & Monthly (Daily Mean) ,hPa	nil	Daily-Mean,max,min hpa	nil	nil
Air Temperature (℃)	Daily & Monthly Daily,Max,Min,Mean	Daily & Monthly Daily,Max,Min,Mean	Daily & Monthly Daily,Max,Min,Mean	Weekly,Max,Min Hoarly	nil
Vapour Pressure (hPa)	nil	nil	Daily & Monthly Daily,Max,Min,Mean	nil	nil
Relative Humidity	Daily & Monthly (Daily Mean) %	nil	Daily & Monthly Daily,Max,Min,Mean	Hourly	nil
Wind PREV-D	Daily & Monthly (Daily Mean) deg	nil	Daily & Monthly (Daily Mean) deg	Weekly	Daily & Hourly
M-SPEED	Monthly Mean kt	nil	Daily & Monthly (Daily Mean) kt	nil	Daily & Hourly
Max-Gust	Daily & Monthly Daily Mean, Kt	nil	Daily & Monthly Daily Mean, Kt	nil	Daily & Monthly
Evaporation	Daily & Monthly PICHE,ml	nil	Daily & Monthly PICHE,mm	nil	nil
Duration of Bright Sunshine	Daily & Monthly (hours)	nil	Monthly (hr) Mean,Max,Min	nil	nil
Radiation per Day	Monthly (mWh/cm²) Mean,Max,Min	nil	Monthly (mWh/cm²) Mean,Max,Min	nil	Monthly (mWh/cm²) Mean,Max,Min
Precipitation	Daily & Monthly (mm)	Daily & Monthly (mm)	Daily total,10min, 1hr-max Monthly	Accumulate	Hourly,Daily, Monthly

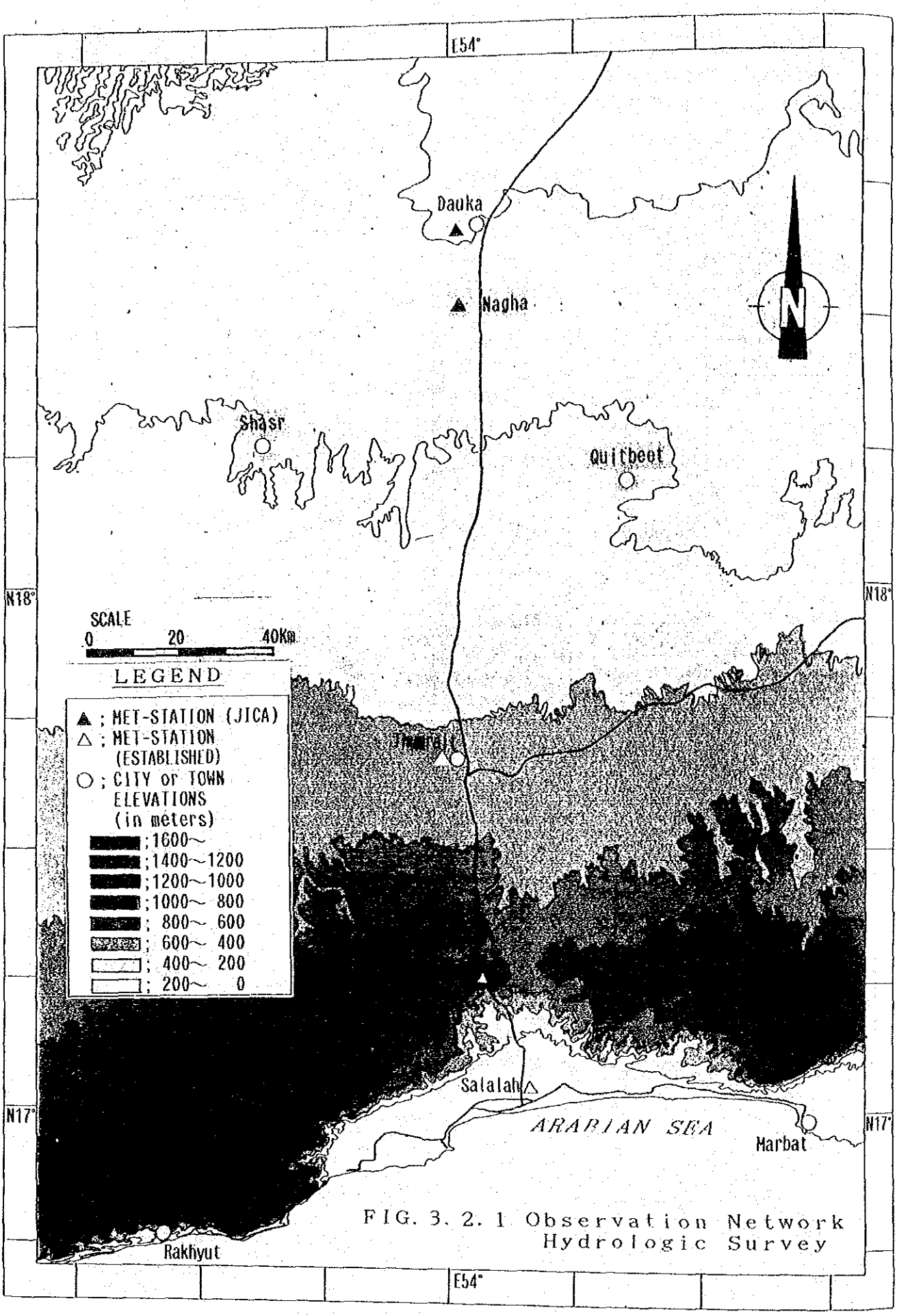

FIG. 3. 2. 1 Observation Network
Hydrologic Survey

TABLE 3.2.2 Mean Monthly Climatological Data

Salalah Airport (24.38 m-A.S.L.)

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Dec	TOTAL	Mean
1. Precipitation (mm)	3.5	17.3	3.9	18.9	5.7	5.6	24.9	26.0	4.8	2.5	0.5	0.0	120.7	10.1
2. Max temparature(℃)	27.6	27.9	30.0	32.0	32.4	32.2	29.0	27.5	29.2	30.7	30.8	28.7	-	29.9
3. Min temparature(℃)	17.7	18.2	21.3	23.5	25.7	26.8	24.3	22.8	23.3	21.6	20.4	18.6	-	22.0
4. Mean temparature (℃)	22.9	23.7	25.9	27.5	29.2	29.3	26.3	24.8	26.4	26.6	25.8	23.9	-	26.1
5. Relative humidity(%)	50.7	56.6	62.6	69.3	75.6	80.4	88.3	89.6	80.3	66.8	55.9	50.6	-	69.9
6. Mean wind speed(m/sec)	3.5	3.5	3.2	3.5	3.8	4.7	3.5	3.3	3.6	3.2	2.6	3.4	-	3.5
7. Bright sunshine(hr)	9.2	10.2	9.1	9.7	9.1	6.9	1.9	1.4	6.7	9.6	10.1	9.7	93.6	7.7
8. Evaporation(ml/day)	10.9	9.4	7.7	6.6	6.1	4.6	2.4	1.8	4.0	6.2	8.4	10.9	2397.5	6.3

Source : Climate Summary / National Meteorological Service / Sultanate of Oman

Mean Monthly Climatological Data

Thumrait (466.9m a.s.l)

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Dec	TOTAL	MEAN
1. Precipitation (mm)	0.6	13.4	6.9	8.5	0.0	0.5	0.0	6.7	0.0	0.0	0.0	0.2	36.3	3.0
2. Max temparature(℃)	25.4	27.5	32.3	35.7	38.9	40.6	37.4	38.0	35.9	34.6	30.0	26.0	-	33.9
3. Min temparature(℃)	10.4	13.3	17.8	19.3	22.5	23.5	23.7	22.9	21.5	18.4	14.6	11.5	-	18.6
4. Mean temparature (℃)	18.5	20.5	24.8	28.0	31.0	32.6	29.5	29.3	28.8	26.6	23.1	19.3	-	26.2
5. Relative humidity(%)	54.0	53.3	47.1	41.9	44.1	45.1	62.3	58.3	51.1	40.4	48.8	55.5	-	50.1
6. Mean wind speed(m/sec)	3.7	5.2	6.6	6.0	6.7	7.0	10.8	9.0	6.3	4.5	3.2	4.0	-	5.8
7. Bright sunshine(hr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Evaporation(ml/day)	9.2	11.0	15.7	18.2	20.6	20.0	16.6	17.0	16.4	16.9	11.9	9.2	5564.2	15.5

Source : Climate Summary / National Meteorological Service / Sultanate of Oman

FIG. 3.2.2 Mean Monthly Climatological Data

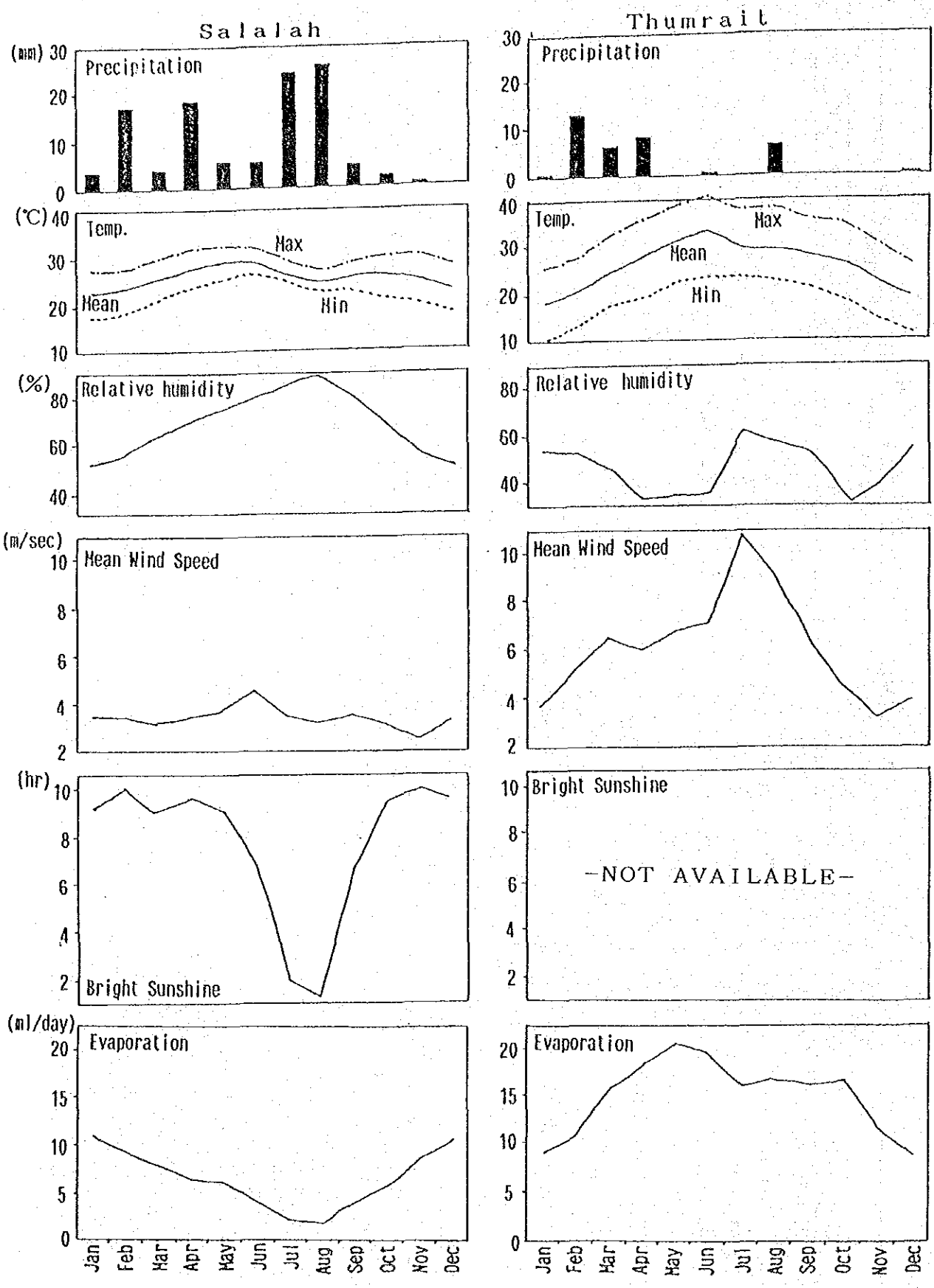

FIG. 3.2.3 Summary of Wind at Thumrait