THE UNITED ARAB EMIRATES
THE MINISTRY OF AGRICULTURE AND FISHERIES
WATER AND SOIL DIRECTORATE

WADI AL BASSIERAH BASIN WATER RESOURCES DEVELOPMENT PROJECT

REPORT ON FEASIBILITY STUDY

VOL. II

MAIN REPORT

JAPAN INTERNATIONAL COOPERATION AGENCY

NOVEMBER, 1981

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PREFACE

In response to the request of the Government of the United Arab Emirates, the Japanese Government decided to conduct a feasibility study on the Wadi Al Bassierah Basin Water Resources Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to the United Arab Emirates a study team headed by Mr. Fujio Matsumoto from December, 1979 to October, 1981.

The team exchanged views with the officials concerned of the Government of the United Arab Emirates and conducted a field survey in the Wadi Al Bassierah Basin. After the team returned to Japan, further studies were made and the present report has been prepared.

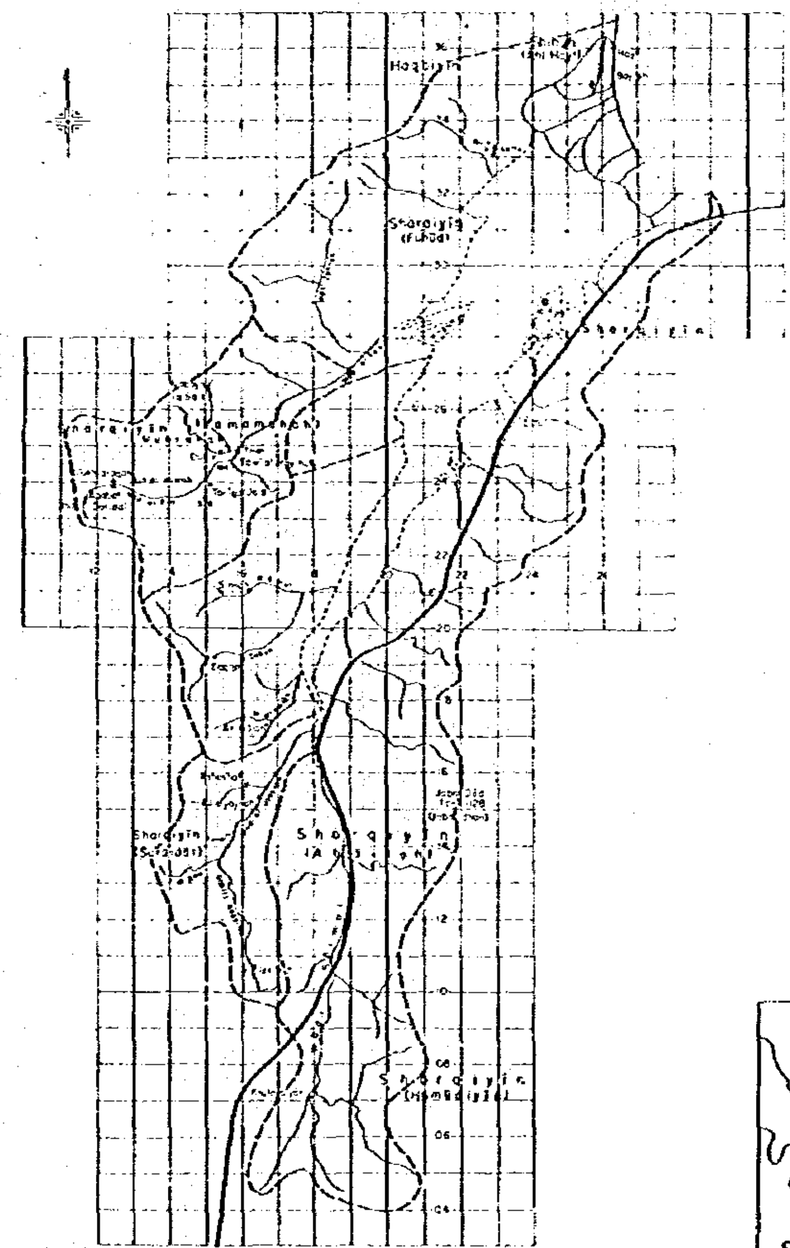
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

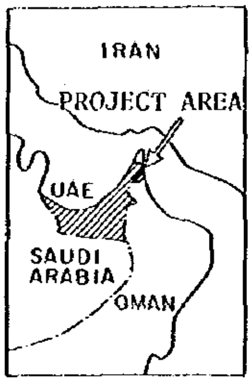
I wish to express my deep appreciation to the officials concerned of the Government of the United Arab Emirates for their close cooperation extended to the team.

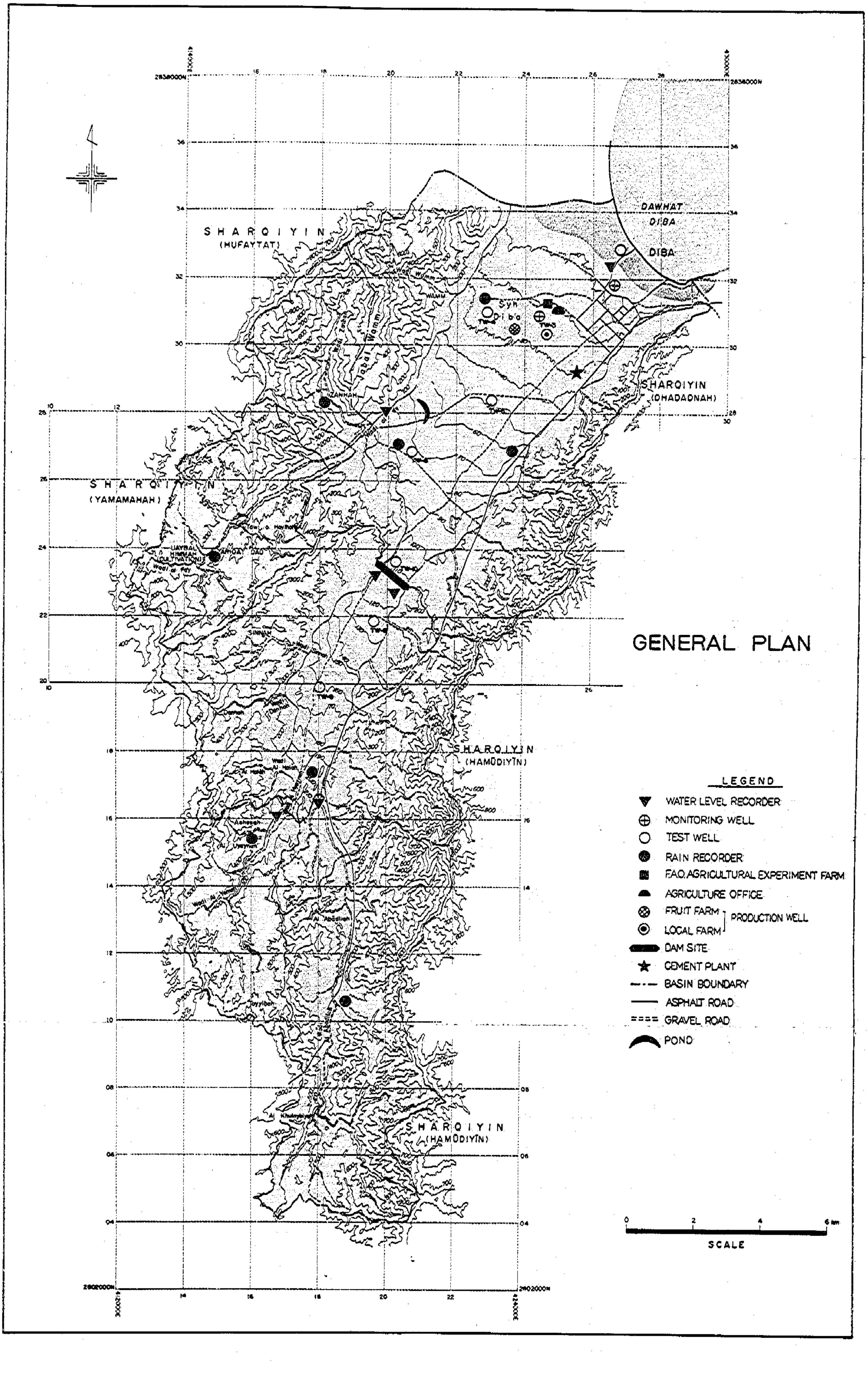
December, 1981

Keisuke Arita
President
Japan International Cooperation Agency

LOCATION OF THE PROJECT






GENERAL PLAN
LEGEND
WATER LEVEL RECORDER
MONITORING WELL
TEST WELL
RAIN RECORDER
F.A.O. AGRICULTURAL EXPERIMENT FARM
AGRICULTURE OFFICE
FRUIT FARM
LOCAL FARM
PRODUCTION WELL
DAM SITE
CEMENT PLANT
BASIN BOUNDARY
ASPHALT ROAD
GRAVEL ROAD
POND
SCALE
0
2
4
6 km
DAWHAT DIBA
DIBA
SHARQIYIN (HUFAYTAT)
SHARQIYIN (DHADADNAH)
SHARQIYIN (YAMAMAHAH)
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MEASURES AND GLOSSARIES

MEASURES

Length

mm	millimeter(s)
cm	centimeter(s)
m	meter(s)
km	kilometer(s)

Area

sq.cm or cm^2	square centimeter(s)
sq.m or m^2	square meter(s)
sq.km or km^2	square kilometer(s)
ha	hectare(s)

Capacity

l or lit	liter(s)
cu.m or m^3	cubic meter(s)
MCM or 10^6 m^3	million cubic meter(s)
barrel	31.5 gallon (U.S.) = 36 gallon (U.K.)
gallon	4.546 lit(s) (U.K.) = 3.785 lit(s) (U.S.)

Weight

g	gram(s)
kg	kilogram(s)
ton or m.t.	metric ton(s)

Others

kw	kilowatt(s)
MW	megawatt(s)
%	percent
°C	centigrade

GLOSSARIES

DAO	Dibba Agriculture Office
ERD	Eastern Regional Department
FAO	Food and Agriculture Organization
MAF	Ministry of Agriculture and Fisheries
MEW	Ministry of Electric and Water
UAE	United Arab Emirates
UNESCO	United Nation Educational, Scientific and Cultural Organization
USBR	United States Department of Interior, Bureau of Reclamation
ETO	Reference Crop Evaporation
ET crop	Crop evapotranspiration

SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. General Descriptions of the Project Area

A.1. The Wadi Al Bassierah basin of about 260 sq.km is situated in the eastern region of the United Arab Emirates, facing the Oman gulf at its downstream most. Shaping a long rectangle of 30 km long and 6 to 10 km wide, the basin extends along the main flow of the Wadi Al Bassierah. The road networks available in the basin are the trunk highway linking Dubai on the coast of the Arabian gulf to Fujeirah on the coast of the Oman gulf and the highway running along the Batina coast.

A.2. It is generally said that the climate in the eastern coastal area of the UAE is not so severe in comparison with that in the other areas of this country. The Year Book of Water Resources Survey published by the Ministry of Agriculture and Fisheries (MAF) in September, 1977, carries that the annual mean temperature and humidity were 28.4 °C and 55.9 percent respectively for the two years of 1978 and 1979 whereas the annual rainfall during the said two years was 35.3 mm. The annual rainfall from 1973 to 1976 shows a heavy fluctuation ranging from 70 mm to 200 mm, a greater part of which took place in January and February.

A.3. Extending in a rectangle in the north-east direction, the Wadi Al Bassierah provides a mountain area of about 500 m in elevation, a central gravel plain of about 100 m in elevation and coastal residential areas and farm lands of which hinterland is about 10 m or less in elevation. Geologically, the basin is comprised of submarine explosives and related igneous rocks from the Paleozoic Permian to lower Cretaceous. Soils are mainly comprised of desert sand, sand and gravel and dusty rock sand in their mixture. The wadi alluvium can be specified into the wadi fan soils and the coastal plain soils.

A.4. The wadi system in the basin consists of the main flow of the Wadi Al Bassierah running about 30 km and a number of its tributaries large and small in scale. The surface flow through these wadis is observed as floods and a small amount of base flow. The floods take place once or twice a year, and flow down to the Oman gulf. The surface flow and groundwater are two major water resources available at present. Recently many modern tube wells have been provided in the basin and come to supply a water of 2.9 MCM per annum in total inclusive of 0.6 MCM of domestic water for 14,700 inhabitants and 2.3 MCM of irrigation water.

A.5. In the western region of the UAE inclusive of the Wadi Al Bassierah basin, extensive farming has been carried out in fruit plantations of which major products are dates and vegetables raised among dates palm trees. In the basin as well as in the other areas, most farm lands, about 490 ha in total, are concentrated to the coastal area. The agricultural population is some 1,100 persons of which about 30 percent is reportedly alien laborers. The major fruit trees in the basin consist of dates palm, citrus fruits, mango, banana. Vegetables raised are 15 kinds. Production of each vegetable in the eastern region inclusive of Dibba is found to be tomato ranking first occupying 24 percent of the total, water melon second occupying 17 percent and green pepper third occupying 14 per cent. As regards tree crops, date comes first by 77 percent, lemon second by 12 percent and mango third by four percent.

A.6. Along the sea shore of the basin, fisheries are prosperous specially in Sharjah and Fujeirah having each fishing port. The 1977 record of the MAF shows that Fujeirah inclusive of Dibba produced 5,140 tons of marine products per year, occupying eight percent of the total national marine production, which ranks second after the production in Ras Al Khaimah. The price of these marine products amounted to 4,670 DH/ton equivalent to about 38 percent of the price quoted in Dubai by 12,300 DH/ton.

A.7. In the administrative aspect, the downstream basin is divided into, from the west, Oman, Sharjah and Fureira of the UAE. Along the coastal line, a town called "Dibba" has been formed for farmers and fishermen to live in. On the other hand, some 10 villages are dotted along the tributaries in the upstream basin. The population in the basin inclusive of that in Oman was estimated at 14,700 as of September, 1980, which can be brokendown into 13,200 of the UAE people and 1,500 of the Oman. Recently, old houses in Fujeirah have been pulled down and, instead, new concrete houses have been constructed under the coastal area development project. An increasing population has, however, been requiring new housing projects in the eastern and western parts of Dibba and in the upstream basin. These housing projects together with a cement plant project have been under implementation. Besides the governmental organizations, such public facilities as primary school and women's center for cooking, handicraft and maternal education have been provided. Furthermore, a hospital with 45 beds was established in 1969, and managed by foreign doctors.

A.8. The agricultural extension services and veterinary services in the basin have been rendered by the Eastern Regional Department of the MAF and the Dibba Agricultural Office. The scope of extension services covers the land preparation of plantations and provision of mechanized farming works by tractors free of charge on request of plantation or farm owners. Fertilizers have been supplied to farmers under governmental subsidies by 50 percent. On the other hand, domestic water and electric power have been supplied by the Ministry of Electricity and Water.

B. Outline of the Project

B.1. The Wadi Al Bassierah Basin Water Resources Development Project consists of the two major development plans, that is, the water resources development plan and agricultural development plan. The former aims to utilize the surface runoff brought about by the annual rainfall of 130 mm on an average through constructing a dam and a pond to recharge groundwater whereas the latter aims to increase farm production through provision of modernized facilities, soil improvement and through introduction of a new irrigation method for raising fruit trees and vegetables.

B.2. A positive development plan of the water resources in the Al Bassierah basin has been formulated to store, for recharging groundwater, the flood discharge appearing once or twice a year in the proposed dam that will be constructed across the main stream of the Wadi Al Bassierah. Furthermore, the groundwater runoff as well will be prevented from flowing down in vain to the Oman gulf. In addition, a systematic water operation plan has been formulated for the most effective and efficient water utilization possible that will be realized through monitoring and controlling the sea water intrusion into the coastal area of the basin.

B.3. A variety of alternative studies on the above basic concept of the water resources development in the basin has resulted in the proposal that a dam should be constructed in the midstream of the main flow of the Wadi Al Bassierah to secure a water of about 0.9 MCM per annum through groundwater recharging. In the coastal area sea water intrusion has taken place, resulting that brackish water of 4,000 micro-mhos/cm in electric conductivity is used for irrigation. Under the circumstances, monitoring wells will be provided to observe the fluctuation of groundwater so that the pump operation will be restricted when the groundwater table goes below the minimum permissible level of EL 1.5 m.

B.4. In due consideration of the limited water resources available in the basin, three alternative agricultural development plans have been proposed, that is, plans to develop (1) vegetable farms of 75 ha, (2) fruit-tree plantations of 65 ha and (3) vegetable farms of 30 ha and fruit-tree plantations of 40 ha. Therefore, the entire agricultural lands of the UAE inclusive of the present cultivation area of 280 ha will increase to about 360 ha if the plan to develop vegetable farms of 75 ha is selected. Apart from it, the cultivation area of 210 ha, which belongs to Oman country, extends in the basin, therefore, the total cultivation area in the basin will reach 570 ha in case that the above-mentioned plan is selected.

B.5. Soil improvement has been planned for the proposed farms as part of the agricultural development. The present field soils with a low moisture content containing much gravel and sand will be replaced with favorable soils for farming. The proposed farm plot size is about 0.5 ha that is equivalent to the averaged size of existing farm plots. Irrigation water will be all supplied through pipelines, and drip irrigation in which water is supplied to each tree and to each agricultural plant will be employed. Tomato, cucumber, egg plant and cabbage have been selected as the crops to be raised in the proposed farms taking into consideration of the actual yield of them in the basin whereas fruit-trees of citrus, mango, dates palm and the other deciduous fruits will be grown in the plantations in order to stabilize and increase their production.

C. Evaluation

C.1. In evaluating the Project, not only the direct benefit brought about by the strengthening and stabilization of irrigation water supply but also various impacts to the society of inhabitants should be taken into consideration. The Project will produce effects on the stabilization of the people's livelihood as follows;

- Increase in the self-sufficient rate of agricultural products through the stabilized irrigation water supply;
- Prevention of disasters and sea water intrusion into the costal zone through the construction of Al Bassierah dam ;
- Prevention of soil salination through supply of irrigation water in high quality; and,
- Increase in the employment opportunities.

C.2. The necessary Project cost is estimated at DH 47.8 millions in total, that is, DH 25.7 millions for Al Bassierah dam, DH 15,9 millions for Al Fay pond and Dh 6.2 millions for irrigation facilities (the averaged cost of the three alternative plans)

C.3. The investment in the water resources development, that is, the construction of Al Bassierah dam and Al Fay pond is DH 41.6 millions in total wheras the annual rechargeable groundwater through these facilities is 0.9 MCM, resulting in the raw water cost of about DH 4.6 per cubic meter. This raw water cost is within the range of DH 1.3 to 6.4, the production cost of fresh water at sea water desalination plants that are under construction in the UAE.

C-4. Presently the domestic water is supplied at 3.3 DH/cu.m in Dibba (1.5 fils/gallon). Therefore, the rechargeable groundwater amounting to 0.9 MCM per annum will result in the benefit of DH 3.0 millions. The gross farm income will reach about DH 42,300/ha in vegetable cropping and DH 21,300 in fruits production.

D. Conclusion

D.1. A population of about 13,200 persons (1.5 percent of the total population of 877,240 persons in the UAE), farm lands of about 280 ha (1.3 % of the total farm lands of 21,550 ha in the UAE) in the territory of the UAE and a population of about 1,500 persons and farm lands of 210 ha in the territory of Oman directly depend upon the water resources in the basin. In due consideration of this fact, the feasibility study on water resources development and agricultural development has arrived at the following conclusion;

D.2. A comparative study on several alternative plans for the water resources development has arrived at the conclusion that Al Bassierah dam should be constructed at the midstream of the Wadi Al Bassierah main flow and Al Fay pond in the lower basin of the Wadi Al Fay in order to strengthen the groundwater recharge for development of the water resources in the basin. The proposed dam site has a catchment area of about 122 sq.km that is equivalent to 47 % of the total catchment area of this wadi. The water use in the basin in consideration of groundwater to be developed under the Project could be summarized as follows;

Water Resources Development

Proposed plan	Construction Cost (MDH)	Recharging Capacity (MCM/a)	Natural Recharge (MCM/a)	Total Rechargeable Amount (MCM/a)
C'-9	41.6	0.9	2.9	3.8

Allocation to Domestic and Irrigation Uses

(Unit: MCM/annum)

Alternative Plans	Domestic	Irrigation	Total
A	0.7	3.1 (570 ha)	3.8
B	0.7	3.1 (560 ha)	3.8
C	0.7	3.1 (565 ha)	3.8

Note: (a) The total rechargeable groundwater of 3.8 MCM/ annum consists of the augmented recharge of 0.9 MCM/annum and the existing natural recharge of 2.9 MCM/annum.

(b) The domestic water of 0.7 MCM covers the domestic water supply to 13,200 persons in the UAE (0.48 MCM) and 1,500 persons in Oman (0.05 MCM) and the industrial water supply to the marble factory (0.07 MCM) and to the cement factory (0.10 MCM).

(c) The breakdown of the irrigation water of 3.1 MCM/annum is tabulated below;

	Area(ha)	Plan-A	Plan-B	Plac-C
° Existing vegetable farms in the UAE	50	0.30	0.30	0.30
° Existing date plantations in the UAE	230	1.04	1.04	1.04
° Existing date plantations in Oman	210	0.96	0.96	0.96
° Proposed fruit-tree plantations	-	-	0.73 (65 ha)	0.43 (40 ha)
° Proposed vegetable farms	-	0.73 (75 ha)	-	0.3 (30 ha)
° FAO farm	5	0.07	0.07	0.07
Total	495	3.1	3.1	3.1

The above-mentioned domestic water supply has been planned based on the population as of 1980. However, the water demand will inevitably increase in parallel with an increase in population, upgrading of the living standard and strengthening of the self-sufficient policy of food, etc. Taking it into consideration, the water demand after 10 years and 20 years has been forecast. During the 20 years, the population is estimated to increase to 26,600 persons. On the assumption that the present water consumption of 100 lit/capita/day increase to 200 lit/capita/day, the domestic water required after 20 years is computed at 1.94 MCM approximately that is equivalent to 3.6 times of the present demand.

D.3. Being exposed to the severe shortage of water resources, the allocation to domestic and irrigation uses will be not easy even after the implementation of the Project, resulting in the above-mentioned limited acreages of the proposed agricultural lands. However, the following yields of agricultural crops and gross income can be expected every year.

Item	Yield (ton)	Gross Income (Plan A) (DH 1,000)
Vegetables	4,290	8,237
Fruits	2,300	12,226
Total	6,590	20,463

D.4. In consideration of the limited water resources in the basin, the agricultural development has been planned premising the farm lands of about 570 ha inclusive of the existing farm lands of 490 ha as well as the fruit-tree plantations of 40 to 65 ha and vegetable farms of 30 to 75 ha that will be newly developed under the Project. In 1978, the UAE produced 71,860 tons of vegetables which can be converted into the per capita consumption/day of 220 grams, that is , almost the same level of the world average of consumption. However, the market abounds with imported vegetables. This fact indicates that vegetable consumption in the country exceeds the production. Under the circumstances, the intensive study was conducted on the newly reclaimed farm in addtion to that on the fruit-tree plantation to be developed. Tomato, cucumber, egg plant, cabbage and melon have been proposed as the five most important vegetables with high marketabilities in the UAE. Furthermore, a cropping program has been prepared for the whole farms in the way that one farm plot should be cultivated with two crops at maximum to avoid co-growing with many crops in one plot.

E. Recommendations

E.1. Al Bassierah dam will be firstly constructed in the implementation schedule of the Project, followed by the construction of Al Fay pond, a facility to further strengthening the recharge of groundwater in the basin. The final design and construction of these facilities will be carried out based on the related descriptions in this feasibility study report for which the relevant topographic maps and the cross sectional and longitudinal drawings are essentially required.

E.2. This feasibility study presents a trial allocation of water resources within the basin to domestic water for the population of 14,700 persons and agricultural water to meet the water requirements in the existing vegetable farms of 50 ha, dates palm plantations and the proposed farms. However, the increasing population will naturally result in a greater demand of domestic water as well as perishable vegetables than the present ones. To cope with the increaseing demand of water, the desalination of sea water will be inevitably required. As regards the agricultural water use in future, irrigation water presently supplied to the date palm plantations of 230 ha in total should be saved as much as possible for the stabilized water supply to the proposed fruit-tree plantations and vegetable farms since the water consumption of vegetables amounting to 250 mm to 500 mm is nearly a half of that of dates palm amounting to 900 mm to 1,300 mm, that is, if irrigation water presently supplied to dates palm is used for raising vegetables, the double cropping of vegetables a year or cropping of vegetables in an area about two times as large as the present cropping area will become possible. In consideration of the shortage of water that will become more serious in future, pipeline systems should be employed for water conveyance and irrigation to minimize the water conveyance loss. It will be necessary to replace the existing earth canals, which connect the existing pumps and vegetable farms of 50 ha dotted in the lowest basin with pipelines. The existing production wells in the coastal zone, specially these located in the existing farms should be integrated. Instead of them, integrated production wells should be constructed by three kilometers inland from the coastal line to supply irrigation water to this zone.

E.3. The hydrological and hydrogeological data employed in the study are not fully reliable from the statistic point of view. Therefore, it is recommended to continue the hydrological observation at least a 10-year period in future with the observation network established by the JICA study team, and a similar hydrological study to what is indicated in the feasibility study should be conducted to reconfirm and verify the quantity of water resources evaluated in this report when the observation data of several years are collected in future. In this aspect, it is desirable to replace the present one-week automatic gauges with long-term gauges of about three months to save labor force required for the observation. After the construction of Al Bassierah dam, the discharge data at this dam will be essentially important to judge the effect produced by the dam, and the observation itself will become easy. Therefore, it is specially recommended to install three-month automatic gauges to observe the storage water level and water levels at the spillway and at the floodway of this dam. To observe the storage water level, a tower of about 16 m high or a pit excavated on one of the abutments will be required.

E.4. The concentrated over-pumping of groundwater that exceeds the groundwater recharge has caused the sea water intrusion into the coastal area, and brought about damages on agricultural production. It is necessary to control groundwater in order to prevent water contamination and damages by saline water caused by sea water intrusion and to preserve the groundwater resources. The principles and methods of controlling groundwater can be said in short to keep the groundwater table higher than a certain elevation. For controlling groundwater, the groundwater table at the observation well Nos. TW-3 and BH-1 having been installed by the study team should be observed, and the groundwater lifting at all the production wells should be restricted, if necessary, in order to keep the groundwater table at TW-3 higher than 1.5 m in elevation. The observation well Nos. TW-3 has been located near to the production well for the FAO experimental farm, therefore, it should be removed somewhere free from the interference caused by the groundwater lifting at this production well.

E.5. In addition to the facilities for recharging groundwater such as dams and ponds that will be constructed in future, many hydrological observation equipment will be required for the comprehensive management of water use in the basin. Therefore, these observation equipment should be always carefully checked and fixed so that they will present highly reliable data. A comprehensive water utilization schedule will be established based on the data summed up every year. The competent authorities of water management consists of the MAF and the MEW of the UAE. On the other hand, inhabitants using water belong two emirates of Sharja and Fujeirah in the UAE and Oman in the aspect of administration. Under the situations, it is recommended to establish the water utilization committee (WUC), a coordinating organization among administrative units concerned, for comprehensive utilization, operation and management of water resources in the basin.

CHAPTER I. INTRODUCTION

The Government of the UAE made a request to the Government of Japan in January, 1979, for technical cooperation in the water resources development in the UAE. In compliance with the request, the Government of Japan dispatched a preliminary survey team to the UAE through the JICA. The preliminary survey team made a field survey and a series of discussions with the UAE authorities concerned, and prepared the minute of discussions with the MAF in December, 1979, in respect of the scope of works for the feasibility study and the relevant work schedule for the Wadi Al Bassierah Basin Water Resources Development Project located in the northern part of the UAE.

Although the Project has been given a high priority among various development projects in the UAE, it was clear that the basic data for the study on water resources development were short and a time-consuming basic survey should be carried out whereas the MAF expressed its strong wishes to expedite the relevant study for early implementation of the Project.

Along with this direction given by the MAF, a study schedule in two phases was made up, phase I for the basic survey and Phase II for the feasibility study, to formulate a water resources development plan in the basin and an agricultural development plan for farm lands of about 570 ha in total inclusive of both the existing and proposed farm lands.

On the other hand, the final design of Al Bassierah dam was carried out in parallel with the feasibility study as part of the Wadi Al Bassierah water resources development program. The minute of discussions prepared by the MAF and the JICA preliminary survey team is summarized below;

- Phase I: This phase of about one year period from December 1979 to December, 1980, is for data collection and basic study on water resources and agricultural development. Based on results of the basic works the development plans inclusive of alternative plans are formulated.

- Phase II: This phase of about 10 month period from December 1980 to October, 1981, is for the feasibility study and the formulation of development plans for water resources and agriculture in the basin based on data and information collected in Phase I as well as results of hydrological surveys on surface water and groundwater.

To carry out the above-mentioned works, the JICA dispatched a study team to the UAE and let it conduct field surveys and studies. This report is the outcome of the field works in the UAE and the home office works in Japan of the study team. The Japanese advisory group members, the study team members and the UAE counterparts personnel assigned to the works are listed below;

- Japanese Advisory Group

	Title	Name	Position
1.	Leader	Mr. Noboru Kano	Director, River Administration Division, Hokkaido Development Agency, Prime Minister's Office
2.	Soil	Dr. Shiro Terazawa	Chief, Laboratory of Soil Physics, Department of Soil and Fertilizers, National Institute of Agricultural Science, Ministry of Agriculture, Forestry and Fisheries

3.	Geology	Dr. Kazuo Kuroda	Chief of Water Resources Section, Environmental Geology Department, Geological Survey of Japan, Agency of Industrial Science and Technology, Ministry of International Trade and Industry
4.	Hydrology	Mr. Katsuyoshi Ishizaki	Chief of Hydrology Division, Public Works Research Institute, Ministry of Construction
5.	Dam	Mr. Tokuhisa Matsumoto	Chief of Fill Dam Division, Public Works Research Institute, Ministry of Construction
6.	Irrigation	Mr. Akihiko Kubota	General Manager of Shinano River Basin Survey Office, Hokuriku Region Agricultural Administration, Ministry of Agriculture, Forestry and Fisheries
7.	Coordinator	Mr. Katsuhiko Ohshima	JICA
8.	Coordinator	Mr. Toshio Nakamura	JICA

° Study Team Members

	Title	Name	Working Period at Field
1.	Team Leader	Mr. Fuijio Matsumoto	Dec.18,'79 to Mar.16,'80 May 20,'80 to Jul.21,'80 Aug.17,'80 to Sep.19,'80 Dec. 5,'80 to Jan.18,'81
2.	Regional Development	Mr. Shoichiro Higuchi	Jan.11,'80 to Jan.20,'80

3.	Geology/Ground-water	Mr. Mitsuru Yoshikawa	Jan.11,'80 to Jan.29,'80 Jun.10,'80 to Jul.21,'80 Sept.2,'80 to Oct. 3,'80 Jan.16,'80 to Feb.16,'81
4.	Electric Pro-specting	Mr. Masao Kozima	Jan.24,'80 to Mar.24,'80
5.	Electric Pro-specting	Mr. Makoto Uwotani	Jan.24,'80 to Mar.24,'80
6.	Boring	Mr. Izumi Kato	Jan.24,'80 to Mar.24,'80 May 20,'80 to Aug.21,'80
7.	Hydrology	Mr. Masafumi Okubo	Dec.18,'79 to Mar.16,'80
8.	Hydrological Analysis	Mr. Takamasa Matsui	May 20,'80 to Jun.20,'80
9.	Soil	Mr. Norio Koiwa	May 20,'80 to Jun.20,'80
10.	Soil & Agri-culture	Mr. Kazuo Nakacayashi	Nov.18,'79 to Feb.17,'80
11.	Agriculture	Mr. Hirokazu Koriki	May 20,'80 to Jun.20,'80
12.	Design of Facilities	Mr. Munehisa Murayama	Jun.20,'80 to Aug.21,'80 Dec. 5,'80 to Feb. 2,'81
13.	Cost Estima-tion/Implemen-tation	Mr. Tadashi Takagi	Jan.16,'81 to Feb.16,'81
14.	Economy	Mr. Tetsuo Dokiya	Sep. 2,'80 to Mar.11,'80
15.	Survey	Mr. Yasunobu Ito	Jan.11,'80 to Mar.11,'80 Dec. 5,'80 to Feb. 2,'81
16.	Survey	Mr. Mumei Watanabe	Jan.11,'80 to Mar.11,'80 Dec. 5,'80 to Feb. 2,'81

° UAE Counterparts Personnel

	Name	Position
1.	Mr. Obaid M. Karki	Assistant Deputy Minister for Water & Soil Resources Affairs

2.	Mr. Khalil Ataya	Assistant Director
3.	Mr. Taissir Adlbi	Main Counterpart
4.	Mr. K. Kurian	Counterpart
5.	Mr. Auday Al Khairalla	Soil Laboratory
6.	Mr. Ali Badawi	General Manager of Eastern Regional Department
7.	Mr. Noor M. Kamaludeen	Counterpart, ERD
8.	Mr. Seid H. Almuddin	Assistant Counterpart
9.	Mr. Khalfan	General Manager of Dibba
10.	Mr. Amin Ab Al Sarag	Counterpart
11.	Mr. Fawaz Baser	Soil Laboratory P.E

CHAPTER II. BACKGROUND

2-1. General Conditions of the UAE

(1) Geography, Meteorology and Rainfall

The UAE is located in the northern part of the Arabian peninsula in lat. 25°N and long. 55°E covering about 77,700 sq.km of the land that extends 520 km long from east to west and 380 km long from north to south. Its national land of which greater part is a desert land faces the Arabian gulf in the north, and borders on Qatar and Saudi Arabia in the west and the south, respectively, and on Oman in the east. Seven independent emirates are comprised in the UAE which are, from the western side, Abu Dhabi (67,340 sq.km, 86 % of the total of the UAE), Dubai, Sharjah, Ajiman, Umm Al Qiwain and Ras Al Khaima which face to the Arabian gulf and Fujeirah which faces to the Oman gulf. Table A.2.1 -1 of Appendix shows the land areas of the respective emirates.

The UAE has a mountainous area of about 1,000 m in elevation in its eastern region. In the piedmont a number of large and small wadis have developed, and supply precious water resources to the UAE by flooding in winter (rainy) seasons. The UAE has a high temperature and humidity throughout the year. According to the records of temperature observed in Dubai in 1979, the annual mean temperature was 27.4°C and the yearly mean humidity was 60.1 %. The highest temperature was 41.3°C in July whereas the lowest was 15.2°C in January. The monthly records of temperature and humidity are shown in Table A.2.1 -2 of Appendix.

(2) Population and Aliens

The annual statistic report of 1979 published by the Centeral Statistic Department, the Ministry of Planning, reveals that the population of this country in 1978 was 877,460 in total consisting of

620,870 males (71%) and 256,470 females (29%). The population is classified by age groups as follows;

Age	Population (percent)
35 to 44	127.030 (14.5 %)
25 to 34	241,960 (27.6 %)
15 to 24	178,960 (20.4 %)

However, about 70 % of the working population of the UAE is reportedly aliens such as Indians and Pakistanis (23 %), Bangladeshis (6 %), Iranians (6 %) and some from the other Arabian nations. The new-born babies in 1987 counted 26,673, being equivalent to three per cent of the total population. The population in 1978 is indicated in Tables A.2.1-3 and -4 of Appendix.

(3) Petroleum

The statistic data published by the Central Statistic Department in 1979 explained that petroleum production, the major industry of the country, was 667,700 thousand barrels in 1978, that is, 1.8 millions barrels per day. Abu Dhabi is the largest oil producer among the three oil producing emirates, yielding almost 79 % of the total. Dubai is the second yielding 20 % and Sharjah is the third yielding the rest of one percent.

Production and Export of Crude Oil in 1978

(Unit: 1,000 barrels)

Emirates	Production	Daily Export	Export to Japan
Abu Dhabi	527,851	1,428.8	172,744
Dubai	131,841	368.0	5,615
Sharjah	8,078	22.0	-
Total	667,770	1,818.0	178,359

About 88 % (589,717 barrels) of the total production was exported to 17 countries among which Japan was ranked first importing 30 % (178,359 barrels) of the UAE's total exports. France came second importing 16 % (92,178 barrels), and the third was the USA importing 13 % (78,694 barrels). The total quantity of these three countries accounted about 59 % of the total exports of the UAE.

The imports of Japan from the UAE can be brokendown to 97 % from Abu Dhabi and the rest three percent from Dubai. The detail on production and export of crude oil is shown in Tables A.2.2 -1 to 2.2 -4 of Appendix.

(4) Agriculture

Recently agriculture of the UAE has remarkably developed. The agricultural lands increased by 1.7 times as many as before in the five years from 1973 to 1978, and the total area of farm lands reached 21,550 ha out of which fruit tree plantations occupied the largest part of 9,650 ha (44.8 % with an increase rate of 1.9) and the second largest was vegetable fields of 3,100 ha (14.4 % with an increase rate of 1.3). Contrarily, other crops fields were slightly reduced in acreage occupying only five percent of the total farm lands. Hence, agriculture in the UAE can be characterized by concentrative growing of fruit trees and vegetables.

Growing Acreage of Fruit Trees, Vegetables and Other Field Crops in 1987

Region	Acreage (ha)	Vegetables (ton)	Dates/Fruits (ton)	Field Crops (ton)	Total (ton)	Ton/Ha
South	7,000	10,742	14,612	14,619	39,973	5.7
Center	3,720	17,039	5,726	4,493	27,258	7.3
East	3,010	28,575	14,172	8,319	51,066	17.0
North	7,820	15,499	12,217	221	27,937	3.6
Total	21,550	71,855	46,727	27,652	146,234	

The above table shows the cropping acreages of various crops by by regions. As shown in this table, the North region occupied 17 %, the South region 32 % and the Central region 17 %, respectively, whereas the Eastern region marked extremely higher crop production than these of the other regions. Such high production resulted from its favorable conditions in climate, rainfall, soils, etc., in comparison with these of the other regions.

Out of the major eleven crops raised in fruit tree plantations of 9,650 ha (44.8 %), dates are produced by 38,990 tons per annum occupying 83 % of the total fruits production whereas the monetary value has come only to DH 64,3 millions equivalent to 75 % of the total monetary amount of DH 86.0 millions. Next comes lemons whose annual production is marked by 3,210 tons or 17 % and the monetary value occupies about 13 %. The third is oranges whose annual production occupies two percent and the monetary value four percent. The detail on agriculture is presented in Tables A.2.3 -1 to 2.3 -5 of Appendix.

(5) Water Resources

Utilization of water resources in the UAE is characterized by the limited use of surface runoff depending much on groundwater and desalinated water. The surface runoff being utilized is flooding water caused by the rainfall of about 130 mm in the winter (rainy) seasons, which takes place in the wadis developing in the piedmont areas of the Oman mountain range running in the north-eastern part of the country. After flowing down the piedmont areas, the flooding water is temporarily stored in farm ponds in the major dates plantations in coastal agricultural lands through many intercepting ditches provided, and then used for irrigation by gravity system and recharging groundwater. Recently studies have been just started to pursue the approaches to better utilization and more effective control of such flooding water.

Groundwater recharged with the surface runoff is the most precious water resources in the UAE, and utilized, in most cases, by pumping-up through tube wells with approximately 60 m deep. In 1979 the wells counted 272 in total in the UAE 213 wells of which are located in the three emirates of Sharjah, Fujeirah and Ras Al Khaima. Besides these tube wells, there are five springs and 30 falages developed in the areas of mountain side, gravel plain, eastern coast and Al Ain, and the water resources have been used as irrigation water and potable water for villages in the respective areas.

Groundwater has been the major water resources of the UAE. Since this country has been promoting modernization of urban areas and their vicinity as well as industrialization by investing with the so-called oil money that is earned from petroleum export that increased by 1.7 times as much as in 1971, the rapid modernization of urban life and industrial development have induced the augmentation of water requirement although it has been covered mainly by groundwater. The sharp increase in water demand can be proved by the fact that for the six years from 1972 to 1978 the length of pipeline laid for water supply almost doubled to 337.8 km. And the country has planned to make the better use of desalined sea water against yearly increasing water demand. The UAE has a plan to provide 37 units of desalination plants with a daily production capacity of 10,000 to 20,000 cu.m/unit by the end of 1981 along the coastal areas of the Arabian sea in order to secure a fresh water of 537,000 cu.m/day throughout the country. This total amount of water is equivalent to the volume to sufficiently support a municipality populated by one million people. The detail on the desalination plants presently under installation is shown in Table A.2.4.-1. of Appendix.

2-2. National Economy

Before 1958 when petroleum was discovered in the UAE, the national economy had been dependent on traditional socio-economy system which, according to long-cultivated wisdom for life, had been established on agriculture (mainly dates palm growing and animal husbandry of sheep, goat and camel) in the hardship of the arid zone, as well as fisheries in the northern and eastern regions and re-export trading in Dubai. The discovery of petroleum in Abu Dhabi, however, has recently come to alter the country's policy decidedly toward its modernization.

(1) National Income

The recent remarkable economic growth of the UAE almost octupled the nominal gross domestic production (GDP) from Dh 6,400 millions in 1972 to DH 52,264 millions in 1979. Hence, the GDP per capita in 1979 amounted to DH 58,618, equivalent to US$ 15,843. The Government of the UAE has powerfully invested to the developement of infrastructures with a huge income from petroleum, which allows the GDP to be maintained high through increasing oil export business.

On the other hand, the private sector also has taken a positive attitude toward investment to a variety of construction projects in the UAE. More than 90 percent of its national finance has been relying on the oil income of Abu Dhabi which plays a vitally important role in the economic development of the UAE.

Besides the performance of the Development Bank of the UAE, active investment has been made to the private sector by 52 commercial banks, five limited licensed banks with 11 representative bank offices, two merchant banks, seven investment firms, four financing companies, two foreign exchange brokers and four discounting firms (as of 1978), which have financed mainly those sectors of commercial firms (38 %) and construction firms (33 %).

(2) International Trade Balance

The major export item of the UAE is crude oil, and some re-export business is noted in Dubai, whereas very little is the export of local products. The statistics reveal that the total export in 1979 was marked by DH 38,102 millions (US$ 10,298 millions) of which DH 34,492 millions (US$ 9,332 millions) was earned by oil export, occupying more than 90 % of the total export. The detail on export business is illustrated in Table A.2.5 -1 of Appendix.

On the other hand, the total import in 1979 was registered by DH 20,056 millions (US$ 5,420 millions) of which DH 3,610 millions were for the re-export business, occupying about 18 % of the total and DH 16,446 millions (US$ 4,444 millions), about 82 %, were for domestic consumptions mostly by industrial machines and equipment, automobiles and foods. Hence, the trade balance is registered substantially in black by over-export at the ratio of 3:2. The country-wise balance of payments of the UAE are shown in Tables A.2.5 -2 to 2.5 -3 of Appendix.

(3) National Budgest

Having 16 ministries and seven administratives, the Government of the UAE holds the national budget of DH 12,300 millions for fiscal year 1980. The budget allotted to the following five ministries occupies 64 % of the total budget; particularly the allocation to the Ministry of Defense is the largest by 36.6 %. And the allocation to the ministries other than the above five is below three percent for each.

(1)	Ministry of Defence	36.6 %	DH 4,500 millions
(2)	Ministry of Education	8.8 %	1,081
(3)	Ministry of Health	8.7 %	1,071
(4)	Ministry of Interior	5.9 %	730

(5)	Ministry of Public Works and Housing	4.4 %	538

Total Allocation of the Five Ministries:

	64.4 %	DH 7,920 millions
Total Budget:	100.0 %	DH 12,300 millions

Taking the actual budget in 1978 as the base, the budget in 1979 increased by 13 % and that in 1980 by 79 %, respectively. The detail is shown in Table A.2.5 -4 of Appendix.

Having the largest area and population in the country, Abu Dhabi emirate holds a key to the national economy with its abundant oil resources and keeps the strongest right to voice. (Ref. to Table A.2.2-4 of Appendix.) Each of the emirates has its own bugdet besides the national budget; however, it is hard to know how the emirates execute the budgets due to no data available on their own budget execution except that for Abu Dhabi.

The MAF which is responsible for execution of the Wadi Al Bassierah Water Resources Development Project can secure the budget of only DH 80 millions, equivalent to 0.65 % of the national budget in 1980. The national budget of the UAE from 1978 to 1980 in brokendown in Table A.2.5 -4 of Appendix.

2-3. Investment to Agriculture and Water Resources Development

(1) General

The budget allocated to the MAF increased by 9.5 % during the two years from 1978 (DH 73 millions) to 1980 (DH 80 millions). The Ministry has intended to make investment for water resources development mainly to fundamental investigations and studies on dam constructions at Wadi Bih, Wadi Ham, Wadi Al Bassierah and other small wadis, and some detailed design and implementation planning works have been under way for these projects. Furthermore, the groundwater exploitations have been conducted by tube well borings at the piedmont areas of the Oman mountain range in the eastern and the northern parts of the UAE where potential aquifers are expected.

The total farm land in the UAE was estimated at 23,000 ha in 1980 whereas 21,600 ha in 1978.

The MAF divides the whole UAE into four districts, and provides the district offices respectively. (See Organization Chart of Fig. 2.3-1 of Appendix). The offices administer several related branch offices. Being in direct contact with farmers for rendering services, these branch offices have been carrying out their extension works such as distribution of agricultural chemicals and fertilizers, and subsidizing service for parts of their costs. The existing farms and farm lands are tabulated below;

	Area	Farm Number	Cultivation
o	South	2,058	8,045 ha
o	Center	2,759	4,326
o	North	2,752	7,805
o	East	2,828	3,180
	Total	10.397	23,356

Source: MAF data, 1979

The MAF provides experiment farms in each area. The FAO's extension farm in Ras Al Khaima Emirate and its branch farms in Dhaid and Dibba conduct various cultivation tests. etc.

(2) Five-year Plan (1978 to 1982)

The five year plan prepared by the MAF in 1977 comprises the following six major schemes including those carried over and some newly proposed. The estimated total cost required for implementation of the five year plan is about DH 577 millions.

- Marketing of farm products;
- Upgrading of farming techniques;
- Rendering successful extension services;
- Encouraging farmers for agricultural production;
- Developing water resources; and,
- Protecting crops in cultivation.

Projects Carried Over:

Some schemes, taking up in the five-year plan, are carried over from the year before 1978, including the following items at the total budget of DH 434 millions;

- Crediting: To give loans to farmers and fishermen for their management and purchasing of input materials (Budget: DH 386 millions)
- Survey and study for water resources development: (Budget: DH 15 millions)
- Establishment of the Service Center for Agricultural Production and the Central Agricultural Research Institute, fisheries survey and development and extension works for animal husbandry and fruit tree plantations (Budget: DH 33 millions)
- Establishment of meteorological stations and the MAF-related offices (Budget: DH 33 millions)

Newly Proposed Development Projects:

The budget allocated to new projects is about DH 142.6 millions.

- Basic surveys inclusive of aerial surveys for water resources development plan, Phase I (Budget: DH 4 millions), and feasibility studies inclusive of water balance study for Phase II, (Budget: DH 10 millions), and detailed designs for Phase III (Budget: DH: 2 millions) with the total budget amounting DH 16 millions.
- Agricultural researches and experiments (Budget: DH 95.4 millions)
- Education and training of the Ministry' staff (Budget: DH 5,6 millions)
- Marketing for animal busbandry, fisheries and others (Budget: DH 25.6 millions)

The source of the above data is the English version translated from the original in Arabic in March, 1980, regarding the five-year plan of agriculture and fisheries (1978 to 1982).

(3) Budget for Municipal Water

The development of domestic water and industrial water has been made by the Ministry of Electricity and Water (MEW) independently from the development of agricultural water resources, and no detailed study has been made on the local water balance even in using the groundwater. Hence, there are some problems arising about local water shortage and intrusion of saline water in the coastal areas.

The budget allocated to the MEW in 1980 amounted to DH 291 millions, about a half of which, DH 150 millions, is to be invested for the water resources development.

The water cost for domestic supply is seven fils per gallon (DH 15.5 per cu.m) of which 1.5 fils are collected from consumers and the balance, 5.5 fils, borne by the Government of the UAE.

CHAPTER III. THE PROJECT AREA

3-1. General Features

3-1-1. Location and Road Networks

The Wadi Al Bassierah basin is located in Lat. 25°30' and Long. 56°20' extending in the region about 300 km north-east from the highest peak of the Oman maountain range (3,018 m) that runs from east to west in the extreme eastern part of the Arabian peninsula, and most downstream portion of the basin faces the Oman gulf. The basin has an area of about 260 sq.km, the second largest wadi basin in the UAE, extending about 30 km along the main course with a width of 6 to 10 km at both the midstream and downstream portions. As a whole of the basin, it is slime rectangle developing north to south in the upstream and north to east in the downstream.

The characteristic feature of the basin is that the basin develops in the north-east direction from the Oman mountain range to open to the Oman gulf, whereas most of the other wadi basins develop in the east and west directions. Both the eastern and the western mountains of the basin, adjacent to the other wadi basin, have an elevation of about 500 m, the plain in the midstream in the basin has an elevation of about 100 m and the coastal area close to the residential area and farm lands has an elevation below 10m approximately.

As regards the road system, a two-lane highway runs through the upstream basin connecting Dubai facing the Arabian gulf with Fujeirah facing the Oman gulf, and a coastal road running along the Oman gulfin Fujeirah emirate connects Dibba in the basin with Fujeirah. Furthermore, a road linked to the Dubai-Fujeirah trunk road goes through the basin to Masafi.

3-1-2. Social Conditions

(1) Towns, Villages and Population

Facing the Oman gulf, Dibba town area is adjacent to the southern most of Mazandalan peninsula, a sporadic land of Oman. Extending several kilometers from north to east, the coastal line of Dibba forms a quarter-arc shape inlet. The lower portion of the Wadi Al Bassierah basin includes Sharja and Fujeirah and part of Omana the western neighbor. No specific boundary mark exists between the UAE and Oman, but only simple sign board and an Oman guard stationing. In Dibba, the residential area develops along the coastal line, farm lands extend in the area by 3.0 km times 1.0 km as its hinterland and the gravel plain opens toward the upper basin.

In the basin there exist about 10 villages inclusive of Dibba along the sea shore, and several others are dotted in the middle and upper basin.

The population in the basin as of September, 1980, is about 13,200 persons, 3,700 persons (28 %) of which are resident foreigners, and the total number of families is 1,340 households. The working population is 870 persons for agriculture (7 %) and 370 persons for fisheries (3 %) as shown in Table A.3.3 -1 of Appendix.

(2) Houses, Schools and Hospital

As a component of the Fujeirah coastal area development program, housing development has been achieved in Dibba area by replacing traditional old houses with new concrete houses. The Ministry of Public Works and Housing is trying to build more houses in the eastern coastal area of Dibba and the central part of the gravel plain to meet an increasing demand by a sharp increase of population. According to the housing program, the construction of community roads has ben under way, and in the other areas, the major road construction has been proceeded prior to housing works for some construction works of houses.

As the public facilities, there are elementary schools in Sharja and Fujeirah emirates, which provide the ladies' cultural centers giving guidances in cooking, handicraft, maternal education, etc.

In Dibba a hospital with 45 beds was established in 1969, and has been operated by foreign doctors. This hospital had been the largest one in the area before 1979 when another hospital was built in Fujeirah. Major endemic in the area is malaria.

(3) Water Supply

The sources of water supply to Dibba depend on three tube wells bored in the lot of the MEW's office at the upstream area of the new residential area. Water is pumped up to the 30 m elevated storage tanks (200,000 gallons in capacity), and is supplied to individual houses by gravity system after chrolination. This water is conveyed through asbestos pipe works, providing a variety of pipes with diameters of 16", 12", 8" and 4". Furthermore, two artesian wells with pumps are ready to serve water against emergency. The well capacity and actual water supply amount are shown below;

Well No.	Well Depth	Well Dia.	Facilities	Averaged Pumped Amount (cu.m/day)
No. 1	60 m	12"	Electric pump	360
No. 2	60 m	12"	-do-	500
No. 3	60 m	12"	-do-	210

The above table reveals that about 13,200 people in Dibba area are supplied with water of nearly 1,300 cu.m/day, which can be converted to 100 lit/day/capita. Usually, the service hours of water supply last 8 to 10 hours a day (07:00 to 11:00 and 12:00 to 18:00 or

18ç;00 to 20:00). For the mountain villages, tank lorry services are rendered for water supply.

(4) Power Supply

There exists in Dibba a power station with generating capacity of 11.0 MW, and Gidofa power station located 40 km south of Dibba can appropriately supply the power by 2.0 MW to Dibba area out of its total capacity of 24.0 MW. The peak demand in the area is 5.7 MW in summer and 1.8 MW in winter, respectively. The largest power consumer is a marble tile factory which needs 300 KW of power for its operation.

The capacities of the installed equipment in Dibba power station are shown below;

Equipment No.	Generator Output	Type
No. 1	350 KW	Diesel engine type
No. 2	500 KW	-do-
No. 3	9.4 KW	Gas turbine

3-2. Physical Conditions

3-2-1. Topography

The Wadi Al Bassierah basin of about 260 sq.km is divided into the following three areas in terms of topography and geology;

(i) Ruus Al Jabal area located in the north-western portion of the basin. The area is mainly underlain by limestone;

(ii) The central mountain area covering the upper Wadi Al Bassierah basin and the south-eastern mountain zone. The area is underlain by serpentinite and schists; and,

(iii) The gravel plain, a wadi bed having a wide flooding plain thickly filled with gravels, and the adjoining sand beach strip.

The gravel plain is 16 km long and one to five kilometers wide with the maximum elevation of 175 m. Its upper portion shows an averaged slope of 1/85 whereas the lower portion 1/105. Water courses are not stabilized in the gravel plain.

The Wadi Abadellah, the Wadi Uyaynah and the Wadi Al FAy, etc., are relatively large wadis flowing into the gravel plain. Most of such large wadis have gallery along their valley-wall since floods have down-cut consolidated gravel layers covering these wadis to a depth of 10 m to 20 m. The planes (lower terrace) with an elevation of 200 m to 400 m and the averaged slope of 1/50 in the Wadi Abadellah are one of typical diluvial terrance planes. Such terrace planes are continuously observed along the both banks in the lower gravel plain up to the piedmont. Little vegetation is observed in the mountain areas but acacia bushes with about 3.0 m high are dotted in the gravel plain.

3-2-2. Wadis

The main stream of the Wadi Al Bassierah flows about 30 km in its full course, and has two representative tributaries, the Wadi Uyaynah and the Wadi Al Fay on the left bank, and a number of small wadis on the both banks. These wadis, which are running through the mountain valleys, leave the trace of runoff water in the past.

Small areas along these valleys are planted with dates and vegetables by using surface runoff or groundwater, particulary the lands along the Wadi Uyaynah have been prosperously cultivated with these crops. The midstream of the Wadi Al Bassierah, comparatively large in its width, runs down to the farming areas in the fan-like gravel plain, joining numerous well-developed small tributaries.

In the extreme downstream of the farming areas, four wadis pour into the Oman gulf, and two of them are intercepted by the sea-side road while the other two are provided with an open canal and a concrete culvert, respectively, but the culvert crossing the sea-side road is usually plugged by sea sand.

3-2-3. Meteorology and Hydrology

(1) Meteorology

The history of meteorological and hydrological observations in the UAE is not very long. The full scaled observation inclusive of rainfall, flood, spring, faraj and groundwater started in 1965 by dividing the UAE into nine hydrologic zones. The Department of Water Utilization, Bureau of Public Works, which was responsible for such observation before the independence, published the first edition of the Water Resources Survey Year Book in 1967, and the second edition in 1970. The MAF took over the duty from the said bureau in 1971 when the UAE became independent, and has published the Year Book since 1977 when its first edition was published.

Out of the above-mentioned nine zones, the third hydrological zone covering Batina coastal plain includes the Project Area. This zone occupies the entire eastern coastal area facing the Oman gulf. The Wadi Hum, which flows to the Oman gulf through the capital of Fujeirah, has the largest wadi basin in this zone, and the Wadi Al Bassierah basin, that is, the Project Area, and the Wadi Siji, that is, the hinderland of Khor Fakkan follow.

The meteorological observation in the Wadi Al Bassierah basin has been made at Dibba since 1965. Since 1971 the Dibba office under the MAF has been responsible for the meteorological observation. Adjacent observation stations are located in Masafi, Khor Fakkan and Fujeirah, etc. Rainfall was the sole observation item at Dibba station before the JICA study team established a comprehensive observation stations in the Wadi Al Bassierah.

The averaged values of the meteorological observation data at Dibba station for seven years from 1973 to 1979 are as follows;

Wind velocity:	173 km/day
Temperature:	27.6°C
Relative humidity:	68%
Pan-evaporation:	3,600 mm/year
Rainfall:	99 mm/year

Table A.3.4.-1 and Figure A.3.4 -1 of Appendix show the details of the above-mentioned data, and Figure A.3.4 -2 of Appendix shows meteorological data observed at the ten major observation stations in the UAE from 1968 to 1976. And Tables A.3.4-2 to 3.4-9 of Appendix show monthly meteorological data observed at Dibba.

(2) Precipitation

The mathematical mean annual precipitation based on observed records at 35 rainfall stations in the UAE from 1966 to 1979 stands at 100.9 mm. the mean annual precipitations recorded are 134.4 mm at 14 stations in the mountain region, 68.9 mm at seven stations in the desert foreland and west coast, 97.8 mm at 13 stations in the gravel plains and 102.6 mm at four stations inclusive of Dibba station, respectively. The isohyetal map based on the above-mentioned data is shown in Map 3-4.

Dibba station has observed the precipitation since the hydrological year of 1965/66 as shown in Table A.3.4-7 of Appendix. The said table of the precipitation concentratively appears in the three-month period from January to March.

(3) Tidal Level

Tidal level in the eastern coast has been observed at Khor Fakkan. The main features are shown below;

- HWOST: 2.13
- LWOST: 1.82
- MSL: 1.36
- HWONT: 1.08
- LWONT: 0.30
- Datum level: -

Source: Halcrow Marine data

(4) Hydrology

1) General

The hydrological study on the Wadi Al Bassierah has been carried out aiming finally to evaluate the groundwater recharge for future water use and probable flood for design of the proposed dam. The back data for this purpose are rather poor. The records on daily rainfall covering a 10 year period are only reliable. Fortunately the flood runoff in three occasions were observed by the study team during the field survey period in addition to a series of hydrogeological investigations made by the study team under the significant cooperation of the MAF. Therefore, the aforesaid aim could be achieved by applying the data so far available.

The hydrological study, in the background, for a water resources evaluation is supposed to be practical and convenient to simulate the phenomena through a model as simple as possible. A structural mathematical model is, therefore, employed to simulate the flood runoff, evapotranspiration, soil retention and groundwater recharge adopting the recorded rainfalls as input parameter.

2) Hydrological Observation Networks

The JICA team established a hydrological observation network in the Wadi Al Bassierah basin for its own study and also for future observation. Eight automatic rain gauges and six automatic flood gauges have been installed at key spots that represent the major sub-basins. Furthermore, for continuous observation of groundwater tables, the nine newly drilled test wells have been equipped with groundwater gauges. The location of gauges are shown in Figure 3-1. The actual observation with these gauges started in September, 1980.

3) Surface Hydrology

No observation of flood runoff has been made up to the end of 1979. Immediately after the commencement of the study, a flood took place on 30th December, 1979. And the rainfall records and flood marks were studied by the team. The floods on 30 April and 2 May, 1981, were caught by flood gauges which have been under operation since September, 1980. The analysis on the said floods together with the related rainfalls are described below;

Rainfall

As mentioned previously, the rainfall record at Dibba does cover the whole period after the installation of gauges. The missing data were interpolated by a correlation with the rainfall record at Sharjah which has the longest observation record in the UAE.

A long term observation of rainfall has been made only at Dibba, however, the record at Dibba is not considered to represent the basin-wide rainfall. On the other hand, the rainfall distribution over the basin has been observed since the installation of observatory network by the JICA team, that is, of 1980 and 1981. The monthly rainfall at each spot from October, 1980 to June, 1981, is given in Table A.4.1-1 of Appendix. The isohyet of total rainfalls during the period is shown in Map 4.1-2.

Only 10 years annual rainfall records at Dibba show no missing. The maximum rainfall so far recorded at Dibba is 246.5 mm in the hydrological year of 1976/77. This rainfall is of the return period of 35 years. The mean annual rainfall is 99.4 mm. The maximum daily rainfall recorded is 66 mm with the return period of 10 years whereas the mean annual maximum daily rainfall is 32 mm.

The probable annual maximum daily rainfalls at Dibba are as follows;

Probability (year)	Rainfall (mm/day)
2	33
5	52
10	65
20	79
50	98
100	113
200	128
500	151
1000	168
10000	230

Dibba station was equipped with an automatic rain gauge in 1978, therefore, the record of hourly rainfall intensity and rainfall duration are available only for these three years. Judging from the rainfall records inclusive of those measured by gauges set up by the JICA team, the duration of most rainfalls is around four hours and the intensity is relatively high.

The hourly rainfall distribution which generated the floods on three occasions show 70 % concentration within the first two hours. The design rainfall is, therefore, decided to be of a four-hour duration and of the following hourly distribution;

First hour	10 %
Second hour	60 %
Third hour	20 %
Fourth hour	10 %

The rainfalls at Dibba station are considered not directly applicable to the basin wide rainfall. Therefore, the rainfall depth applied to sub-basins is determined by multiplying the Dibba rainfall by a certain rainfall factor which is defined based on the sub-basin characteristics.

The rainfall factor is supposed to be divided into two categories; one is on the mean basin elevation and the other is on the basin size. The factor concerning to the basin elevation is determined adopting the relationship that the mean annual rainfalls and station elevations at Dibba are 99 mm vs 20 m and 160 mm vs 450 m, respectively. The factor concerning to the basin size is applied to as the equivalent reduction factors which have been adopted to this region by the USBR.

Table A.4.1-5 of Appendix shows the said rainfall factors for the 11 sub-basins of the basin which are defined in accordance with their characteristics on topography, geology, drainage system, etc. The observed rainfall factors by nine rain gauges are also given in the said table.

Flood Runoff

A thunder storm attacked the basin on December 30, 1979, and brought about rainfall of 19.6 mm at Dibba and 41.0 mm at Masafi, generating a conservable flood. Based upon the field inspection of flood marks and the collection of information from inhabitants, the peak discharges of the flood at the major spots of the basin are estimated as follows;

	Uyaynah	Al Fay	Zannah	Dibba
Basin area (sq.km)	18	26	12	260
Peak discharge (cu.m/sec)	21	35	14	14

Six flood gauges in the basin recorded flood runoffs on April 30 and May 2, 1981. The flood discharges and the related rainfalls are concluded as shown in Tables A.4.1-3 and -4 of Appendix.

The runoff coefficients from the right bank wadi system such as the Wadi Abadelah, Wadi Uyaynah and the dam site are one percent or less. While from the left bank system such as the Wadi Al Fay and the Wadi Zanhah is remarkable reaching 19 %. The runoff coefficient of Dibba which represents the whole basin is about two percent.

The rainfall loss estimated from the said flood runoff reaches 20 mm/hr at maximum and 6 mm/hr at minimum.

As for the evaluation of the design flood, since the observed hydrographs are poorly available, a unit hydrograph is estimated by applying the lag-time dimensions graph method proposed by the USBR. The estimated unit hydrograph shows very good coincidence with the observed pattern of floods that took place in April and May.

The probable floods at the strategic spots in the basin are estimated by adopting the afore-described factors such as the probable daily rainfalls, design hourly distribution of rainfall, rainfall loss, unit hydrographs, etc., as shown in Table A.4.1-38 of Appendix. The design flood for the spillway of the dam is taken to be 2,320 cu.m/sec with a 10,000 year probability.

(4) Hydrologic Balance

The water resources in the Wadi Al Bassierah Basin are mostly groundwater which is originated from only the rainfall within the basin. The rainfalls are brought by thunder storms which is accompanied by the cold front in winter seasons, and generate the flush flood once or twice a year. The flood rushes down through the mountain wadis, recharges groundwater in the gravel plain and flows down into the Oman gulf through Dibba oasis.

In order to evaluate the mode of groundwater recharging under the present conditions as well as in case that its augmentation is made by the Project, the hydrologic circulation shall be treated comprehensively and structurally taking into consideration the hydrologic behavior. These kinds of treatment si very practical and convenient to adopt a storage model (so-called tank model) method. Therefore, the hydrologic balance analysis was conducted in this method.

Time-series data on the rainfall, surface runoff, groundwater head, etc., are indispensable to construct a precise storage model. As for the basin, however, the data other than these of rainfalls are poorly available. The construction of highly precise model is, therefore, actually impossible. However, to clarify the approximate hydrologic balance, particularly the hydrologic behavior of groundwater in the basin and to make possible to evaluate the effect of groundwater resources development, the storage model method is employed intrepidly. As a matter of fact, the result introduced from the kinds of model involves an allowance to some extent, and shall be understand the extent of allowance.

The storage model to be applied to the basin is composed of 11 series of tanks which represent 11 sub-basins in different natures. The series of tanks are connected each other in accordance with the actual drainage systems. The division and inter-connections of sub-basins are given in Figure 3-3. The verifying data for the model construction are the afore-stated observed flood runoffs, base flows in the mountain wadis, groundwater draft at Dibba oasis, the velocity of groundwater, pan evaporation at Dibba station and so forth. The input parameter of the model is the daily rainfall data obtained at Dibba station up to 1979/80 year and the basin mean rainfall for 1980/81 year.

Among a series of tanks which represents a sub-basin, the lowest tank is deemed to command the groundwater or the base flow and others control the surface runoff, evapotranspiration and soil retention. The surface runoff from the upper sub-basin flows into the top-most tank of the just downstream sub-basin. The runoff from the lowest tank inflows into the bottom tank of the downstream basin.

The evapotranspiration takes place from the storage tanks. When the first tank becomes empty, it takes place within the defined rate from the second and then third tanks. It does not take place from the bottom tank.

The bottom tank of a groundwater basin is functionated with the concept of specific yield. The concept is expressed by the limited section area of the tank. It is 0.015 for the groundwater tank and 1.00 for others

The model parameters adopted finally by several tens of trial runs are shown in Figure 3-4. A schematic illustration of storage model for the basin is given in Figure 3-5.

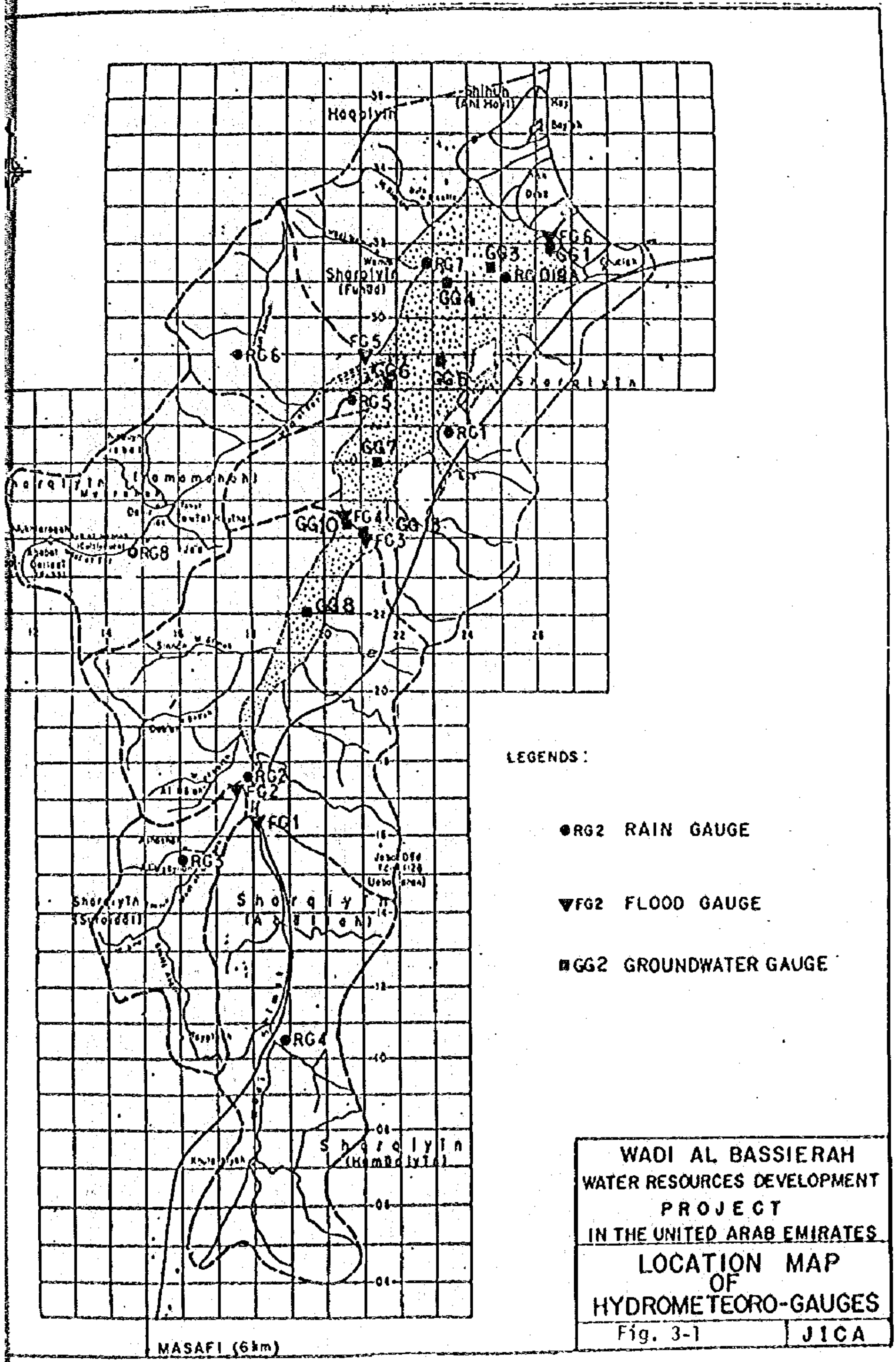
The hydrologic balance of the past 21 year mean of the basin simulated by the storage model is shown in the following table.

	Depth (mm)	Volume (MCM)	Percentage of Rainfall
Rainfall	128	33.3	100.0
Evapotranspiration	109	28.3	85.0
Surface runoff	8	2.1	6.2
Groundwater recharge	11	2.9	8.8
Groundwater runoff	11	2.9	8.8

The evapotranspiration reaches 85 % or 109 mm against the mean annual rainfall of 128 mm. Out of the remained 19 mm, the surface runoff to be waste out to the Oman gulf is 8 mm, 2.1 MCM or 6.2 % of rainfall and 11 mm, 2.9 MCM or 8.8 % of rainfall recharging groundwater.

The whole groundwater under circulation, 2.9 MCM, is deemed to be utilized in the moment. Therefore, the potential water to be developed is 2.1 MCM of surface runoff which is wasted out to the gulf.

Figure 3-6 illustrates the simulated annual runoff coefficients of the basin for the recent five years together with the same of the neighboring five wadi basins and other basins in similar nature. The coefficients are in a wade range in accordance with the basin size and the amount of rainfalls. However, from the general trend, the simulated coefficients of the basin are within the trend and feasible.



WADI AL BASSIERAH
WATER RESOURCES DEVELOPMENT
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LOCATION MAP OF HYDROMETEORO-GAUGES

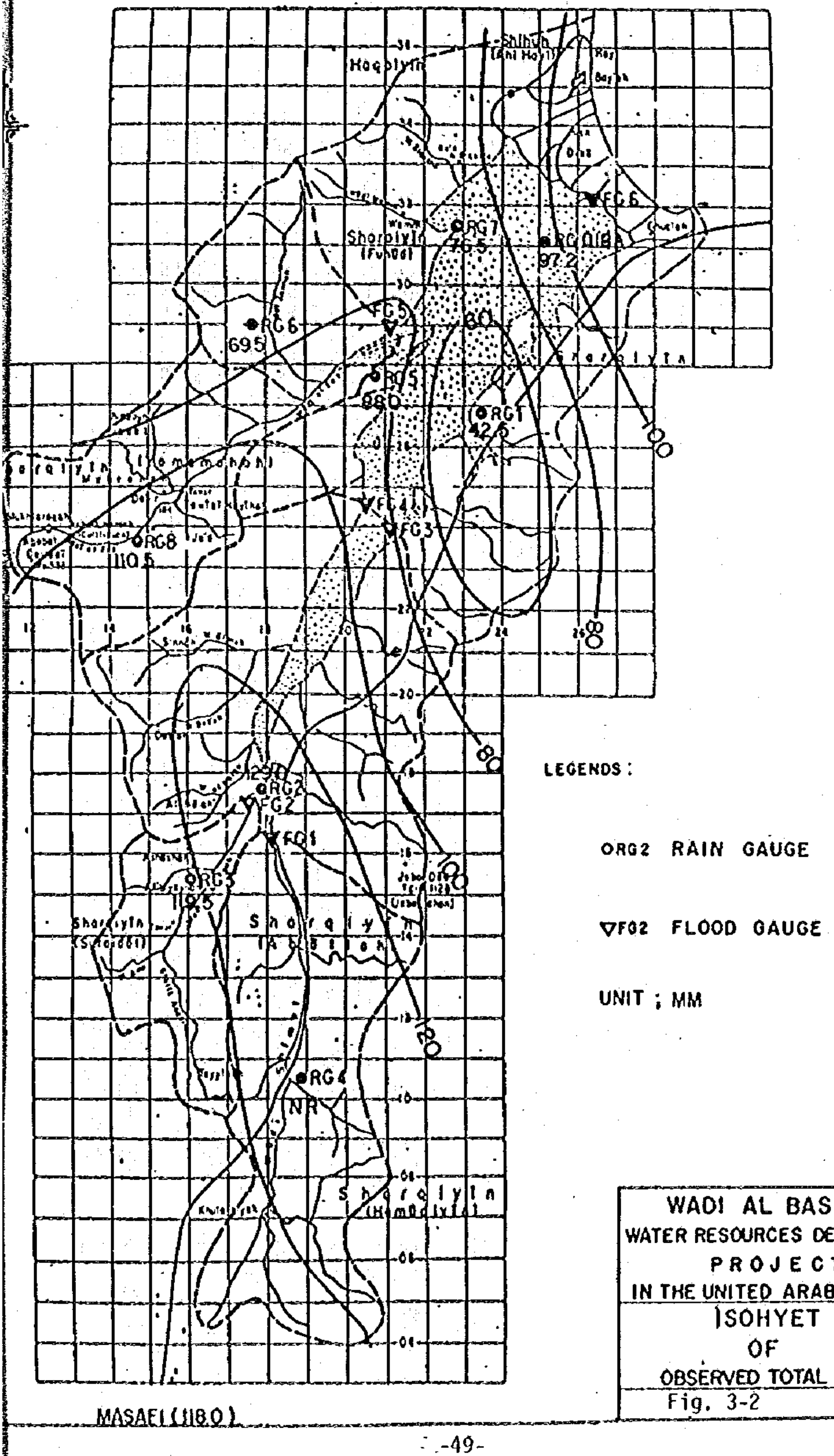
Fig. 3-1 JICA

Table 3-1 Monthly Rainfall Record of Wadi Al Bassierah Basin in 1980/81

(unit: mm)

Gauge / Month	1	2	3	4	5	6	7	8	Dibba	Masafi	Basin Mean
10	0.0	0.0	0.0	NR	0.0	0.0	0.0	0.0	0.0	24.0	0.5
11	3.5	2.0	9.0	NR	1.5	10.5	10.5	2.5	1.0	10.2	5.1
12	0.0	0.0	0.0	NR	0.5	0.0	0.0	0.0	0.0	1.0	0.0
1	0.0	12.5	1.0	NR	0.0	0.0	1.0	0.0	0.2	3.4	2.4
2	13.5	21.5	13.5	NR	37.0	20.5	0.0	55.0	0.2	2.2	21.8
3	3.0	15.0	11.5	NR	5.5	9.5	1.0	2.5	24.2	22.6	9.2
4	18.0	42.5	38.5	NR	17.5	21.5	21.5	25.0	38.8	12.8	29.3
5	4.5	35.5	46.0	NR	26.0	7.5	42.5	25.5	32.8	41.8	30.0
6	0.0	0.0	0.0	NR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7											
8											
9											
Total	42.5	129.0	119.5	NR	88.0	69.5	76.5	110.5	97.2	118.0	98.3

Note: NR = No Record



WADI AL BASSIERAH
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ISOHYET
OF
OBSERVED TOTAL RAINFALL

Fig. 3-2 | JICA

Table 3-2 SUMMARY OF FLOOD RUNOFF OBSERVED ON APRIL AND MAY 1981

Basin Name	Basin Area (km²)	Gauge	Date	Daily Basin Rainfall (mm)	Flood Volume (1,000m³)	Flood Depth (mm)	Runoff Coefficient (%)
Abadelah	43	FG-1	30-4	37.0	16.3	0.38	1.02
			2~3-5	31.9	9.6	0.22	0.69
Uyaynah	17	FG-2	30-4	36.8	3.4	0.20	0.54
			2~3-5	45.1	4.4	0.26	0.58
Dam Site	122	FG-3		-	19.8	-	-
		FG-4	30-4	-	6.0	-	-
		Total		36.5	25.8	0.21	0.58
		FG-3		-	31.0	-	-
		FG-4	2~3-5	-	5.8	-	-
		Total		38.4	36.8	0.30	0.78
Al Fay & Zanhah	49	FG-5	30-4~1-5	22.6	209.2	4.27	18.89
			2~3-5	17.6	-	-	-
Dibba	240	FG-6	(30-4)	28.7	147.4	0.61	2.13
			(2~3-5)	24.6	-	-	-

Table 3-3 RAINFALL FACTOR

	Basin			Observed		
No.	Name	Area (km²)	Mean Elevation (m)	Basin Rainfall (mm)	Factor to Dibba Rainfall	Adopted Factor
1	Abadelah	48	540	120.2	1.24	1.39
2	Uyaynah	18	400	119.5	1.27	1.33
3	Jabal Dee	20	550	129.0	1.33	1.51
4	Sinnah	25	380	115.2	1.19	1.25
5	UP.GR.PL.	11	170	127.0	1.31	1.09
6	R-B Hill	23	310	49.9	0.51	1.17
7	Al Fay	26	440	101.8	1.05	1.35
8	Jabal Wamm	39	520	74.5	0.77	1.37
9	L.GR.PL.	14	70	82.6	0.85	0.94
10	R.GR.PL.	26	40	70.8	0.73	0.89
11	Coast St.	10	20	95.6	0.98	0.91
Total/Mean		260	293	97.8	1.02	1.25

Table 3-4 PROBABLE FLOODS

Return Period (Year)	Area (km²)	Dam Site	Al Fay	Dibba	Uyaynah
		122	26	260	18
10,000	P	2,320	780	3,210	490
	V	27,070	6,370	45,380	4,050
500	P	1,430	490	1,980	290
	V	16,050	3,810	27,180	2,160
200	P	1,170	410	1,630	240
	V	12,840	3,060	21,880	1,720
100	P	1,000	350	1,390	200
	V	10,740	2,580	18,430	1,430
50	P	830	290	1,160	160
	V	8,650	2,090	14,980	1,150
30	P	710	250	990	140
	V	7,200	1,730	12,450	940
20	P	630	220	870	120
	V	6,310	1,500	10,760	780
10	P	480	170	670	90
	V	4,740	1,140	8,180	570
5	P	340	130	480	60
	V	3,290	810	5,790	380
3	P	250	90	340	40
	V	2,260	550	3,940	240
2	P	170	60	230	20
	V	1,510	370	2,660	110

Notes: P; Peak Discharge (m^3/sec)
V; Volume (1,000m^3)

Fig. 3-3 SUB-BASINS

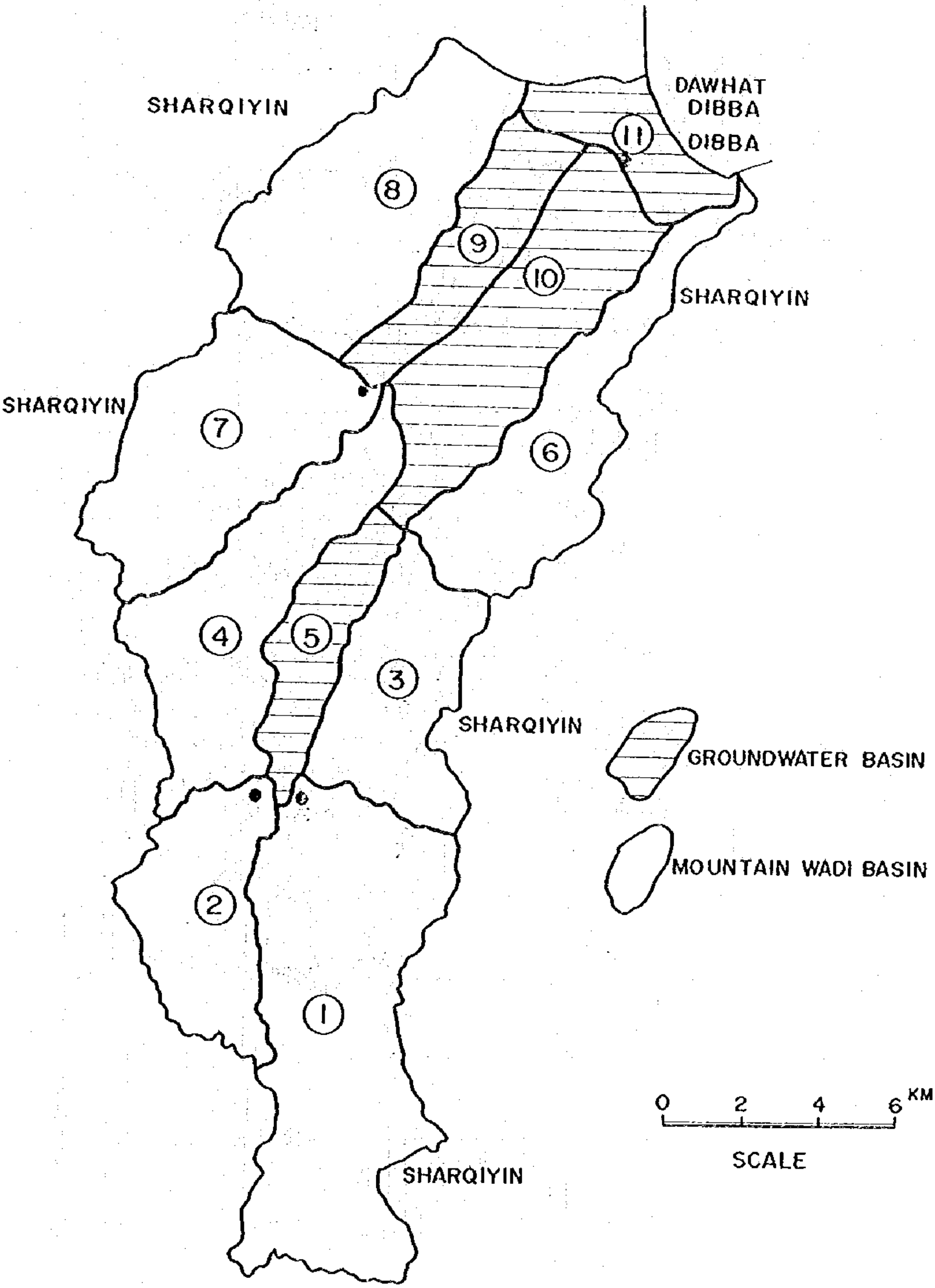
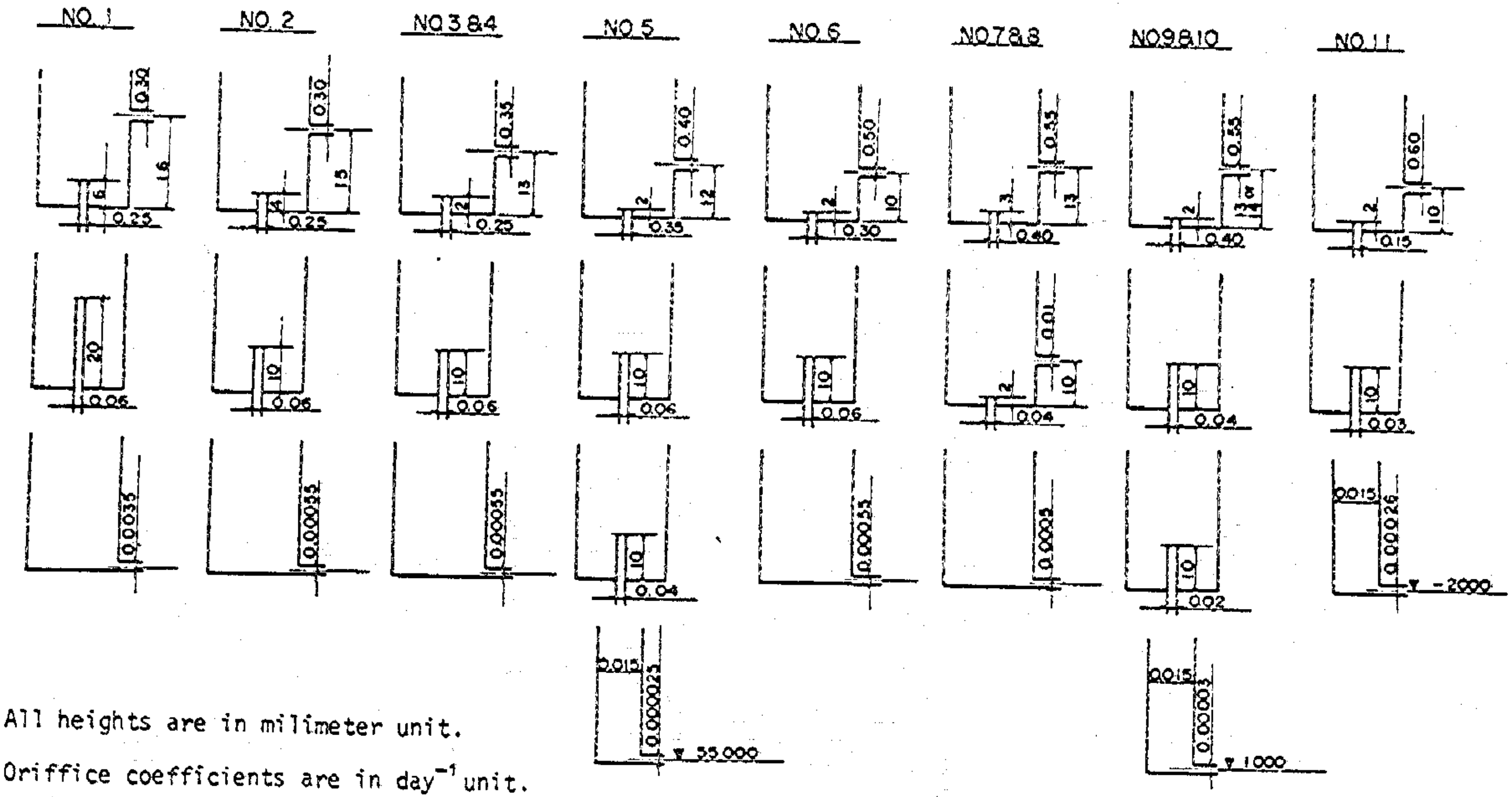


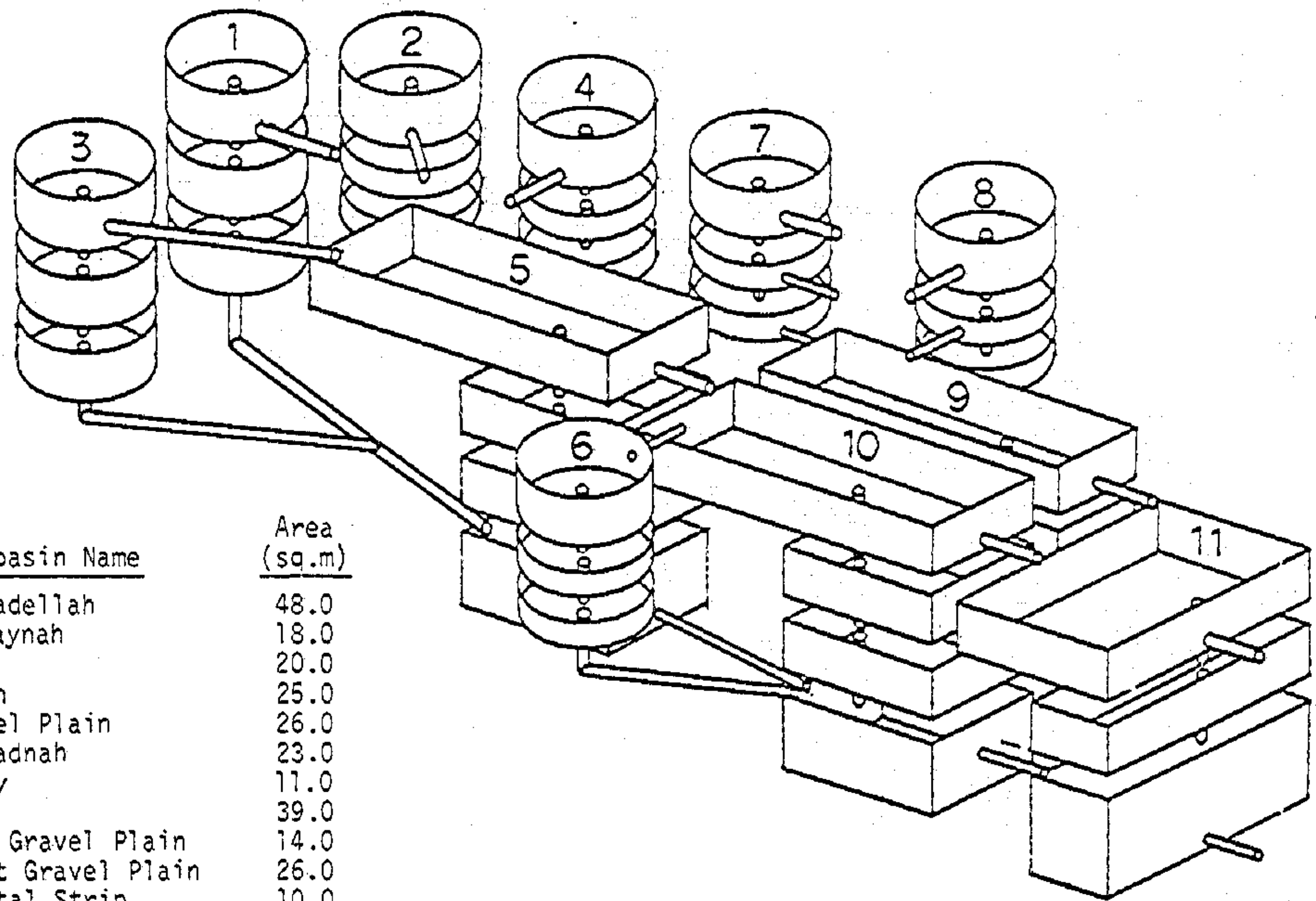
Fig. 3-4 DIMENSIONS OF STORAGE TANKS FOR SUBBASIN



Notes: All heights are in milimeter unit.

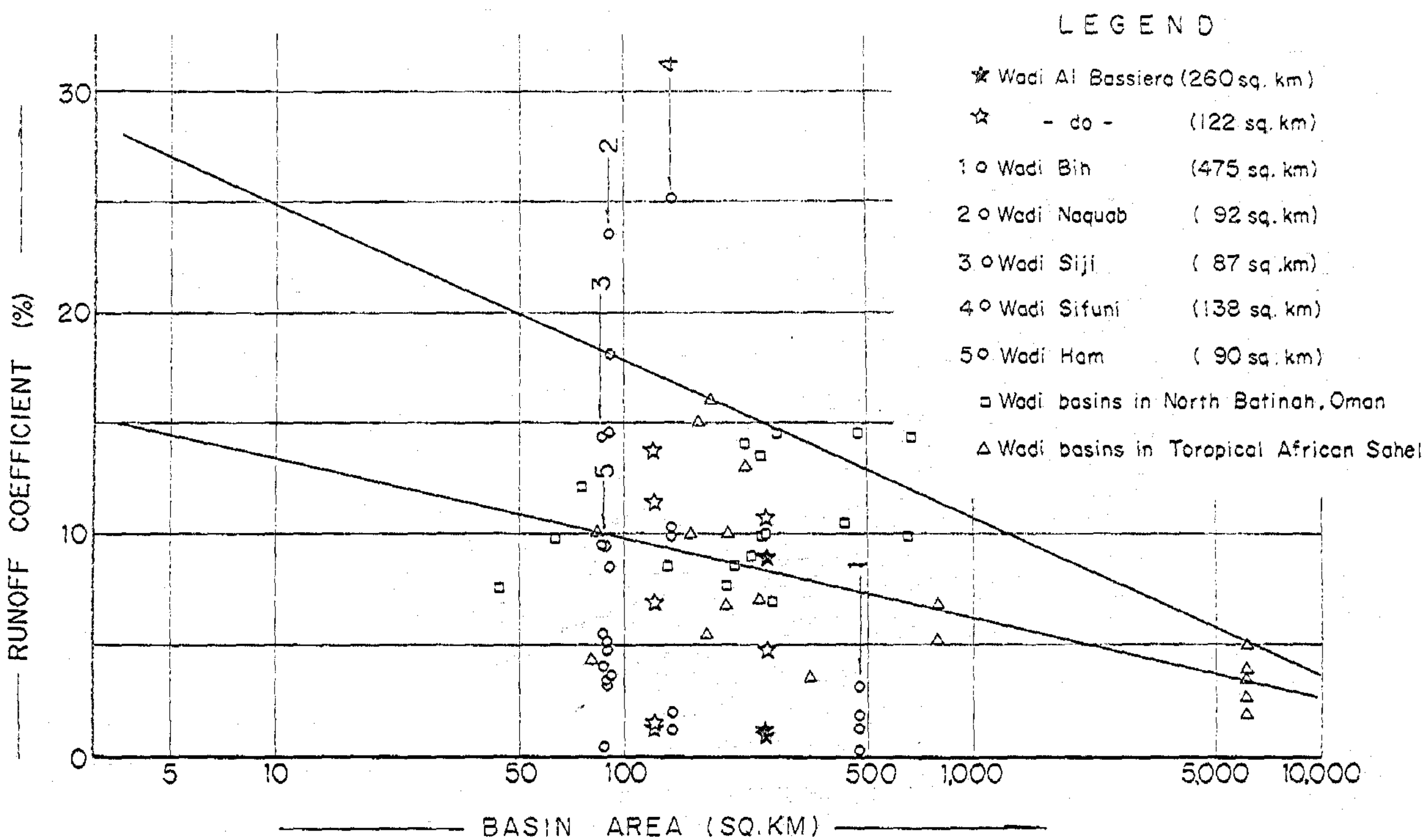
Oriffice coefficients are in day^{-1} unit.

Fig. 3-5 SCHEMATIC ILLUSTRATION OF HYDROLOGIC STORAGE MODEL FOR WADI : AL BASSIERAH BASIN, UAE



Basin No.	Sub-basin Name	Area (sq.m)
1	Wadi Al Abadellah	48.0
2	Wadi Al Uyaynah	18.0
3	Jabal Dee	20.0
4	Wadi Sinnah	25.0
5	Upper Gravel Plain	26.0
6	Jabal Dhadadnah	23.0
7	Wadi Al Fay	11.0
8	Jabal Wamm	39.0
9	Lower Left Gravel Plain	14.0
10	Lower Right Gravel Plain	26.0
11	Dibba Coastal Strip	10.0
Total/Mean		260.0

Fig. 3-6 BASIN AREA/RUNOFF COEFFICIENT RELATION



3-2-4. Geology and Soils

(1) Geology

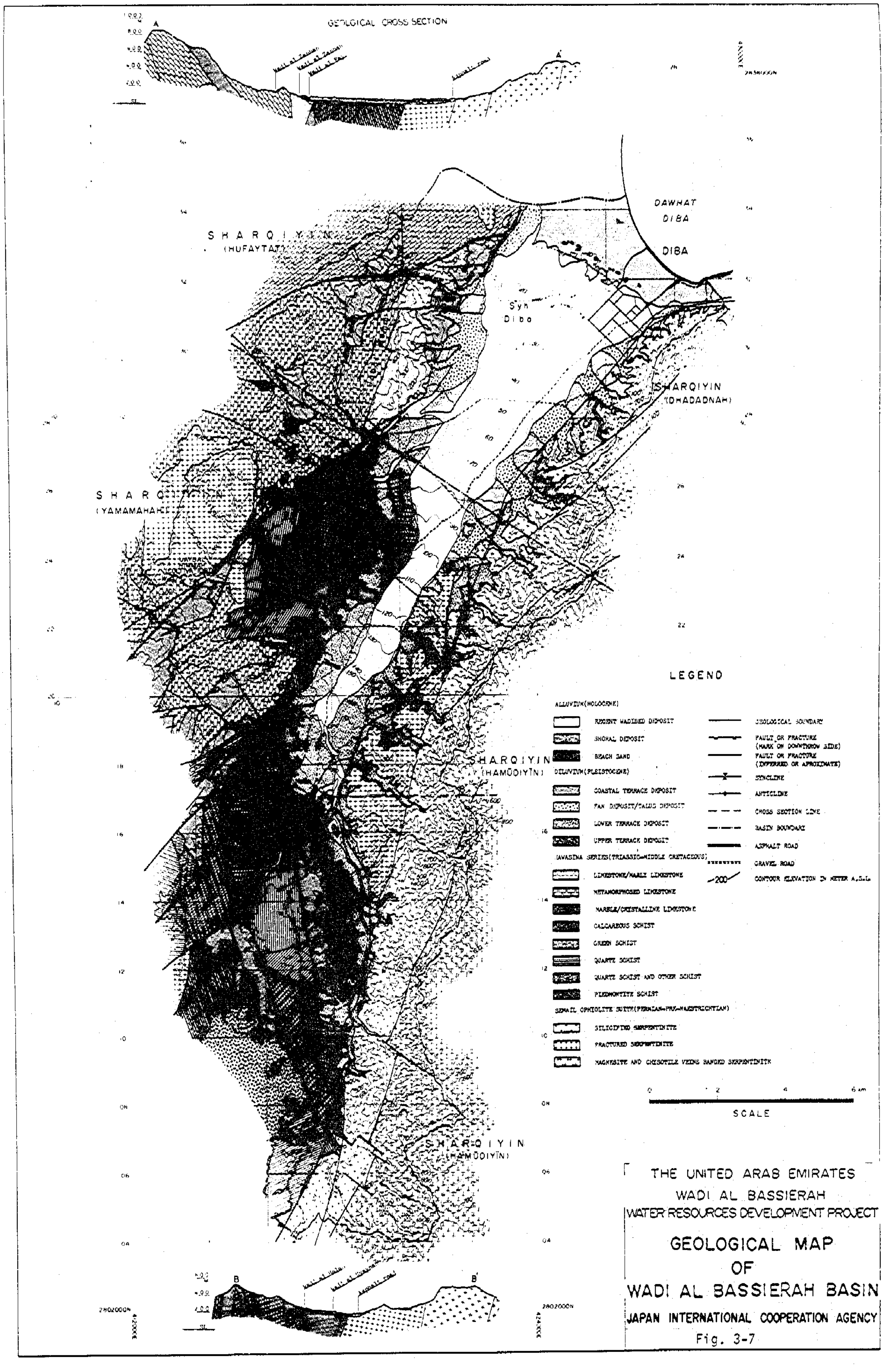
The Wadi Al Bassierah basin and its vicinity are underlain by the following rocks;

(a) Permian to lower Cretaceous submarine explosives and related igneous rocks which area locally called the "Semail suite";
(b) Triassic to Cretaceous marine sedimentary rocks which are called the "Hawasina series";
(c) Terrace gravel layers deposited in the Neogene to Quaternary Diluvium ages which cover the above-mentioned two old rocks; and,
(d) Present wadi bed deposits of Alluvium age.

Specially, the Hawasina series is metamorphic rocks derived from siliceous rocks, limestone and submarine explosives. The alternating beds of mainly marble, crystalline limestone and chert crop out in the north-western portion of the Wadi Al Fay (on the left bank) whereas various crystalline schists such as calcuceous, green and quartz schists expose on the wedge masses in the Wadi Al Fay and the Wadi Abadellah basins.

The electric sounding and drilling investigation conducted in this survey have revealed that the bed rocks are overlain by younger clastic deposits, the terrace gravel layer. the accumulation of these deposits is more than 150 m thick in the lower gravel plain, and about 60 m thick in the middle portion and the proposed Al Bassierah dam site.

The deposits are mostly composed of sand and gravel. Except the coastal area, the bed rocks are overlain by talus deposits, upper terrace deposits, lower terrace deposits and recent wadi bed deposits in this order. In general, the high terrace deposits have been tightened with the secondary carbonates, and have the facies of conglomerate. The lower terrace layers have been also consolidated to a complete extent or to some extent. Figure 3-7 shows the geologcial map of the Wadi Al Bassierah basin.



THE UNITED ARAB EMIRATES
WADI AL BASSIERAH
WATER RESOURCES DEVELOPMENT PROJECT

GEOLOGICAL MAP OF WADI AL BASSIERAH BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3-7

(2) Soils

° Soils in the Wadi Fan

The FAO-UNESCO World Soil Map of 1/5,000,000 in scale indicates that the soil associations of calcic yermosols, calcic regosols and lithosols as well as fluuisoles are distributed in the basin.

Soils in the gravel plain consisting of wadi deposits have developed on the wadi fan having a gentle slope. The ground surface is covered by the desert cobbles in various sizes (one to 20 cm). The cobbles are underlain by the silt layer whose width gradually becomes thick (five to 15 cm) toward the lower wadi fan. There exist stone and gravel layers under the silt layer. In general, the soil forming has been immatured, and no matured section of soils is recognized. There are some extremely hard layers which prevent plants from rooting to them.

The accumulation of silt is partially observed under acacia bushes or in depressions. the silt seems to affect, to a great extent, the permeability of surface layers. As already mentioned, the geological conditions of mountains surrounding the Wadi Al Bassierah on the left bank are quite different from these on the right bank. Under the circumstances, soils on the both banks show direct effects of each host rock.

There exist a plenty of pebbles and breccia (0.5 to 20 cm) at the test pit Nos. 7, 8 and 13 whose basic materials are peridotite and serpentinite. The upper surface of stones and gravels forming the desert cobbles are covered by a dark and lustrous film called the desert vanish which is composed of ferrous and manganese oxides adhered to the above-mentioned stones and gravels. Furthermore, the lower surface of stones and gravels below 50 cm from the ground surface has been coated by a thin shell of carbonate of lime. These stones and gravels adhere closely each other.

Soils on the left bank (test pit No. 12) consist of sandy loam containing much while, chestnut and green breccia whose host rocks are chart and limestone. There hardly exist big gravels. Furthermore, the desert vanish of the desert cobbles and thin calcareous shells are also hardly recognized. Soils in the central portion of the Wadi Al Bassierah (test pit Nos. 1 and 9) contain a plenty of gravels derived from the mountainous systems on the both banks.

° Soils in the Coastal Plain

Soils in the coastal plain on the downstream reaches in the basin are relatively thick. The surface layer is mostly composed of sandy loam or loamy sand. The lower layers are of sand. Similarly to the soils in the wadi fan, there are gravels derived from the rocks forming the mountain systems on the both banks which are different from each other. Furthermore, development marine alluvial soils are recognized along the coastal line. Soils in the right bank area (test pit Nos. 2 and 10) are composed of dimly yellowish sandy loam, and contain many gravels derived from peridotite and serpentinite systems (40 to 44 %). Under the above-mentioned layer exists a gravel layer accompanied by coarse and fine sand. In general, it is recognized that the lower are soils, the higher is their soil salinity.

Soils in the left bank area (test pit Nos. 3, 4, 6 and 11) contains gravel of less than five percent. The surface soils consist of dark brown sandy loam or loamy sand whereas the lower layers mostly consist of sand. It is a tendency that the soils of the left bank area is a little clayey than these of the right bank area. In the lowlying sand beach strip along the coastal line, marine deposits of which major component is beach sand have been developed. In the sub-layers at the test pit No. 5, many splinters of shell and coral are observed. The surface soils are dark brown in color and wet. The soil salinity is as high as 4.0 to 13.9 mhos/cm. This high soil salinity and formation of solubilization clearly show that the soils are under the influence of sea water. Further descriptions on the soil survey are made in Appendix 3.5-2, and the data are summarized in Figure 3-8 and 3-4.

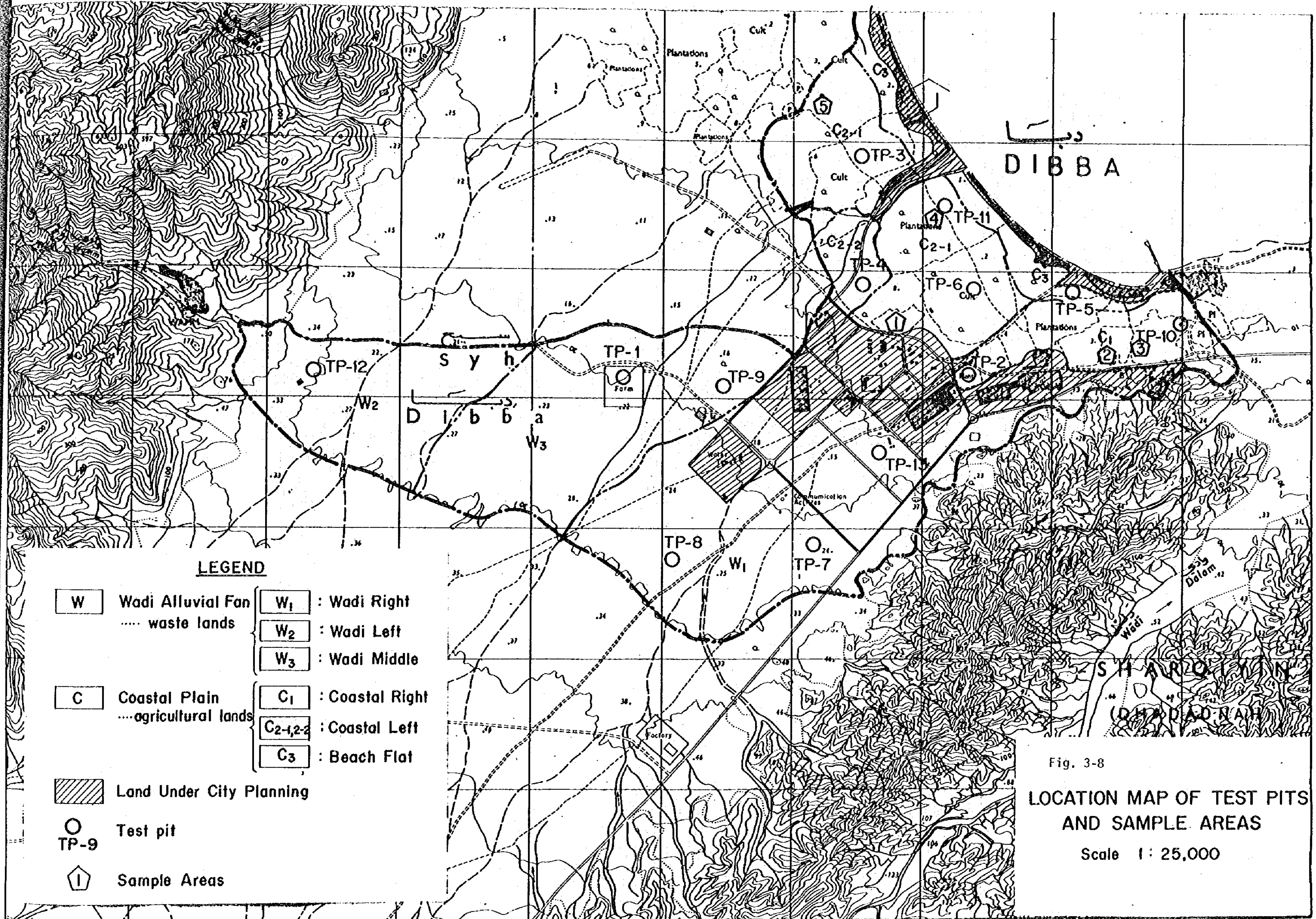


Fig. 3-8

LOCATION MAP OF TEST PITS AND SAMPLE AREAS

Scale 1 : 25,000

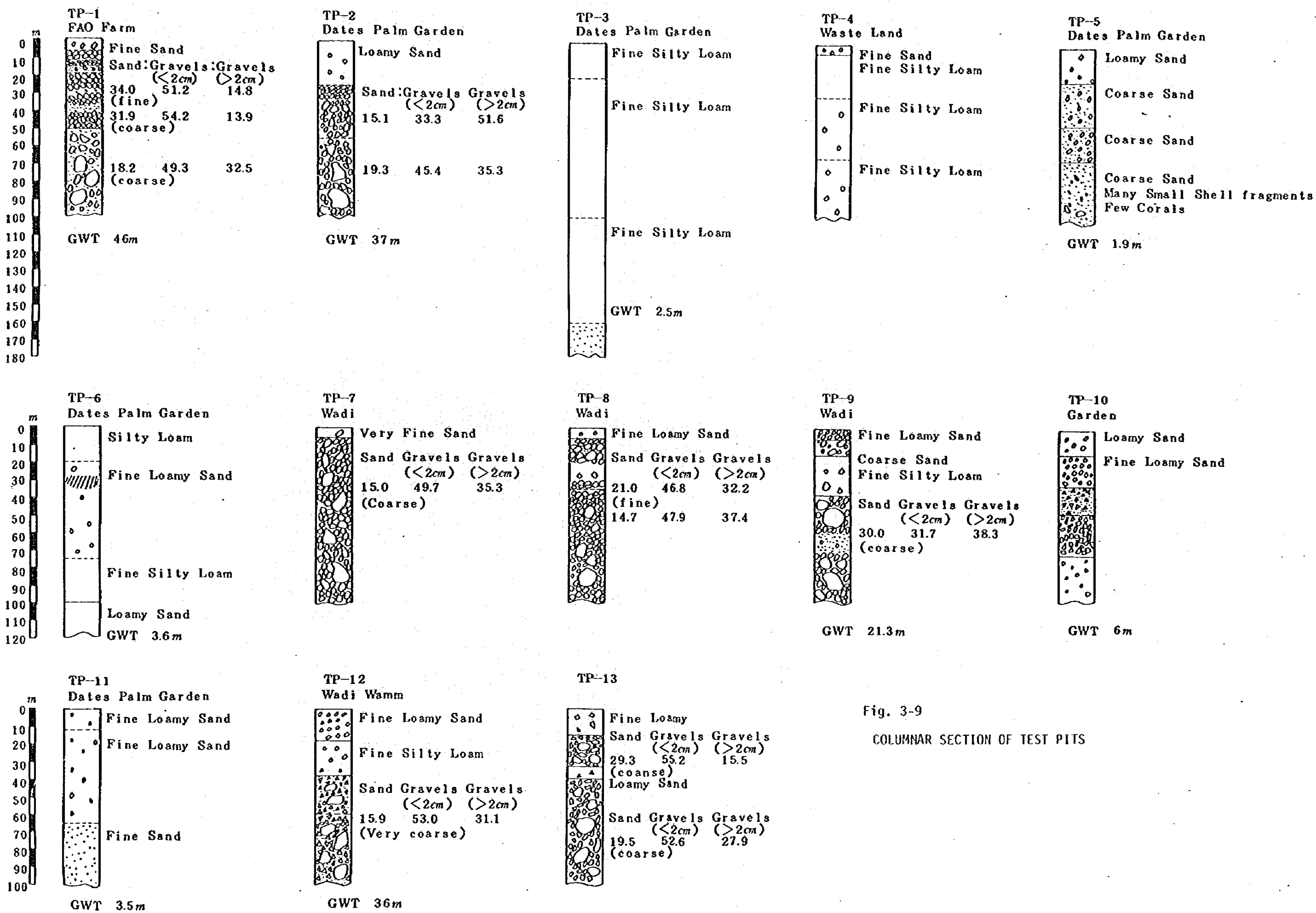


Fig. 3-9

COLUMNAR SECTION OF TEST PITS

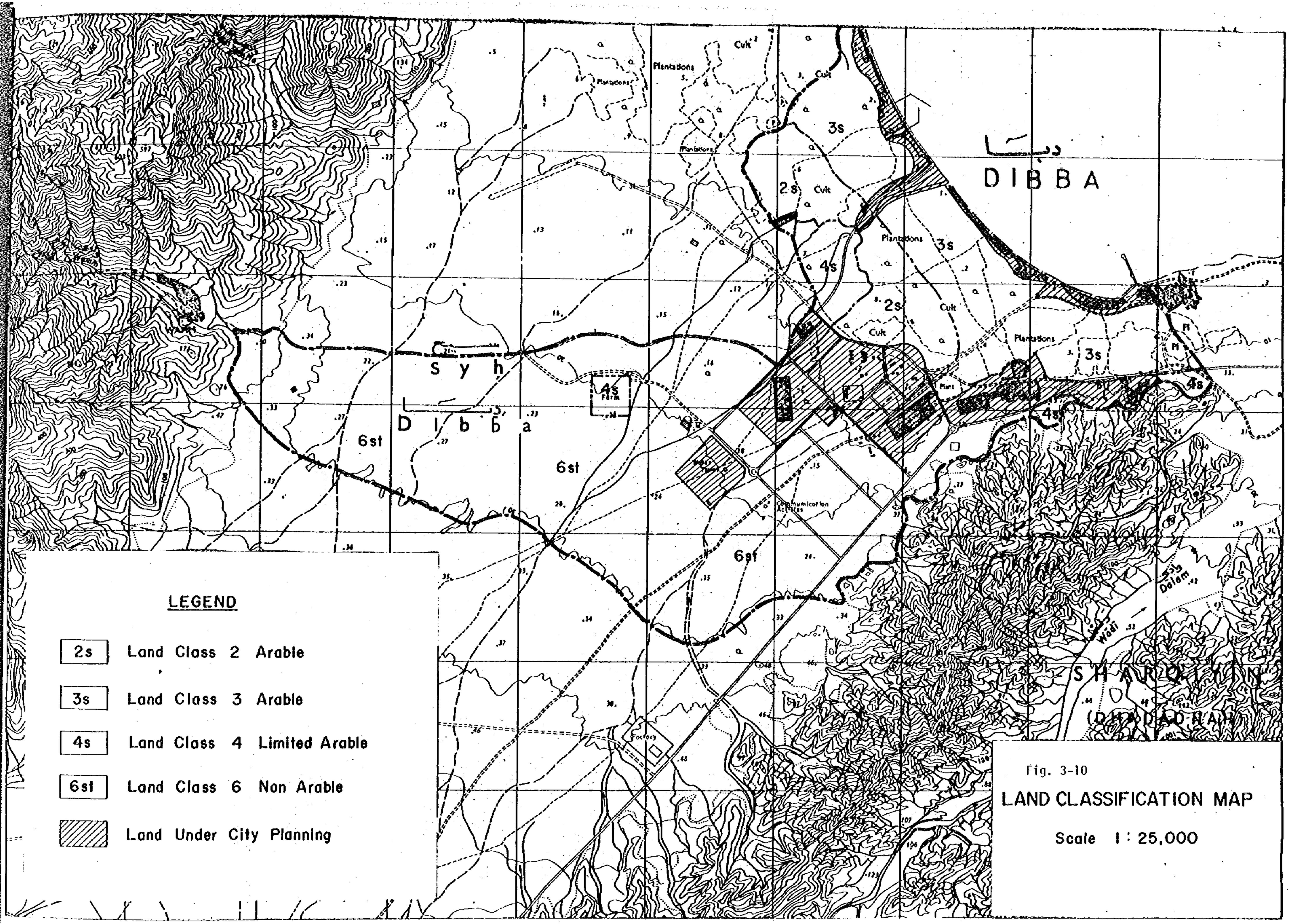


Fig. 3-10
LAND CLASSIFICATION MAP
Scale 1 : 25,000

3-2-5. Hydrogeology

(1) General

In 1968 Sir W. Halcrow and Partners conducted a hydrogeological study over the trucial states inclusive of the Wadi Al Bassierah basin. This is the sole systematic hydrogeological study so far conducted in the Wadi Al Bassierah. In this feasibility study, a hydrogeological study has started in December, 1979, covering the following items;

- General survey of groundwater use;
- Geological mapping inclusive of aero-photo interpretation;
- Geoelectric prospecting;
- Intake rate test;
- Groundwater mapping;
- Test well drilling inclusive of electric logging;
- Aquifer pumping test;
- Groundwater gauges installation; and,
- Groundwater sampling, chemical analysis and dating by environmental isotopes.

The present groundwater use is described in the following section. The result of geological mapping has been discussed in the foregoing section.

(2) Geoelectric Prospecting

The geoelectric prospecting was conducted with both vertical and equidepth soundings. The vertical sounding was performed at 55 spots covering the whole gravel plain to mainly detect the bed rock depth. The bed rock could be detected within 40 m to 70 m deep at the upper gravel plain but not detected at the lower plain due to the depth exceeds 100 m.

The equidepth sounding aims to prospect the salt water wedge around the coast by tow observatory lines of two kilometers in total and to explore the gravel layers and bed rock surfaces. These results are verified by the drilling of test wells of which explanation is made hereinafter.

(3) Intake Rate

The intake rate test was conducted at ten pits dug on three typical groundwater recharging areas; they are the existing wadi flow channels, fan and coastal strip.

The intake rate of the wadi bed is extremely large amounting to 0.5 cm/min (7.2 m/day) on an average. The rate of the farm and sand beach is around 0.2 com/min (2.9 m/day).

(4) Groundwater Mapping

Simultaneous observations of groundwater inclusive of water level, water temperature and electric conductivity were conducted at 60 selected wells four times from February to December, 1980. The maps of groundwater table, temperature and electric conductivity in July, 1980 are shown in Maps 3.6-4, 3.6-7 and 3.6-10 of Appendix, respectively.

The groundwater gradient at the lower gravel plain is remarkably small showing 1/2,700 on an average, and the gradient at the upper plain is 1/76.

The electric conductivity of groundwater at the coastal area shows a large value ranging from 2,000 to 6,000 micro mho/cm in comparison of that of 1,000 micro mho/cm or less in the other areas. This fact indicates that the sea water has intruded into the coastal aquifers.

The electric conductivity of groundwater around the water supply tower and the FAO farm shows the lowest value of 500 micro mho/cm or less in the Wadi Al Bassierah basin. This kind of low electric conductivity zones can be seen in the upper reaches of the Wadi Al Bassierah. The groundwater with a low electric conductivity seems to be young water brought about by recent floods.

The similar distribution to that of the electric conductivties is observed the groundwater temperature distribution. The younger water stands high in temperature whereas the groundwater which is relatively old or mixed with sea water show a low temperature.

(5) Aquifers

15 test wells were drilled aiming at the classification of aquifers, confirmation of bed rock depth and aquifer pumping test. Figure A.3.6-46 of Appendix indicates the geological profile of the basin based on the drilling results as well as the geoelectric prospecting and the electric logging of wells. As shown in the profile, the aquifers located in the Wadi Al Bassierah basin can be divided into three major categories, that is, the gravel layers, talus deposits and weathered bed rocks.

The gravel layers are sub-divided into three layers. The recent wadi bed deposits are composed of uncemented, well-sorted and coarse sand and gravel layers of which maximum thickness so far confirmed is 55 m. The mean thickness of the layers at the upper reaches is about 15 m. The lower terrace layer is the second aquifer from the ground surface and consists of much subrounded gravel and cemented to some extent. The layer exposes in the Wadi Abadellah basin. The maximum depth so far confirmed is 30 m. The third aquifer is composed of rounded gravels containing more cementing calcareous materials. The consolidation of the layer is high. No outcrop of the layer is seen in the Wadi Al Bassierah basin, however, the layer can be correlated to the hard gravel layer which crops out at the Masafi plateau. The The layer is 50 m thick at maximum.

The talus deposits consist of clayey layer with angular gravels and are situated directly on the bed rocks. Their thickness increases to 35 m in the upper reaches. A small amount of groundwater is withdrawn from the bed rock as well as talus deposits in the upper gravel plain.

Out of the above-mentioned aquifers, these which are practically important are the three gravel layers. The sand layer of the top most. The

lower terrace deposits at TW-4 suggest that the Oman gulf has once embayed into the basin, and this horizon is considered to indicate the Wurm Maximum.

(6) Hydraulic Characteristics of Aquifers

Results of the aquifer pumping test are summarized below;

Hydraulic Characteristics of Aquifers

Aquifers	Transmissibility (m/day)	Specific Yield	Remarks
Recent wadi bed deposits	13,000	0.012	
The lower terrace deposits	1,800	0.005	
The upper terrace deposits	200	0.003	
Coastal Sabkha	1,600	0.100	(for reference only)

(7) Behavior of Groundwater

The time-series observation of groundwater head has been just commenced in the Wadi Al Bassierah basin, therefore, its seasonal fluctuation, response to rainfalls, etc., have not been verified up to date. The groundwater head in the lower gravel plain draw-down 3 to 30 cm per month from June to September, 1980. The main cause of this draw-down is supposed to be the continuation of non-recharge and consumption of groundwater in the lower basin.

(8) Quality and Age of Groundwater

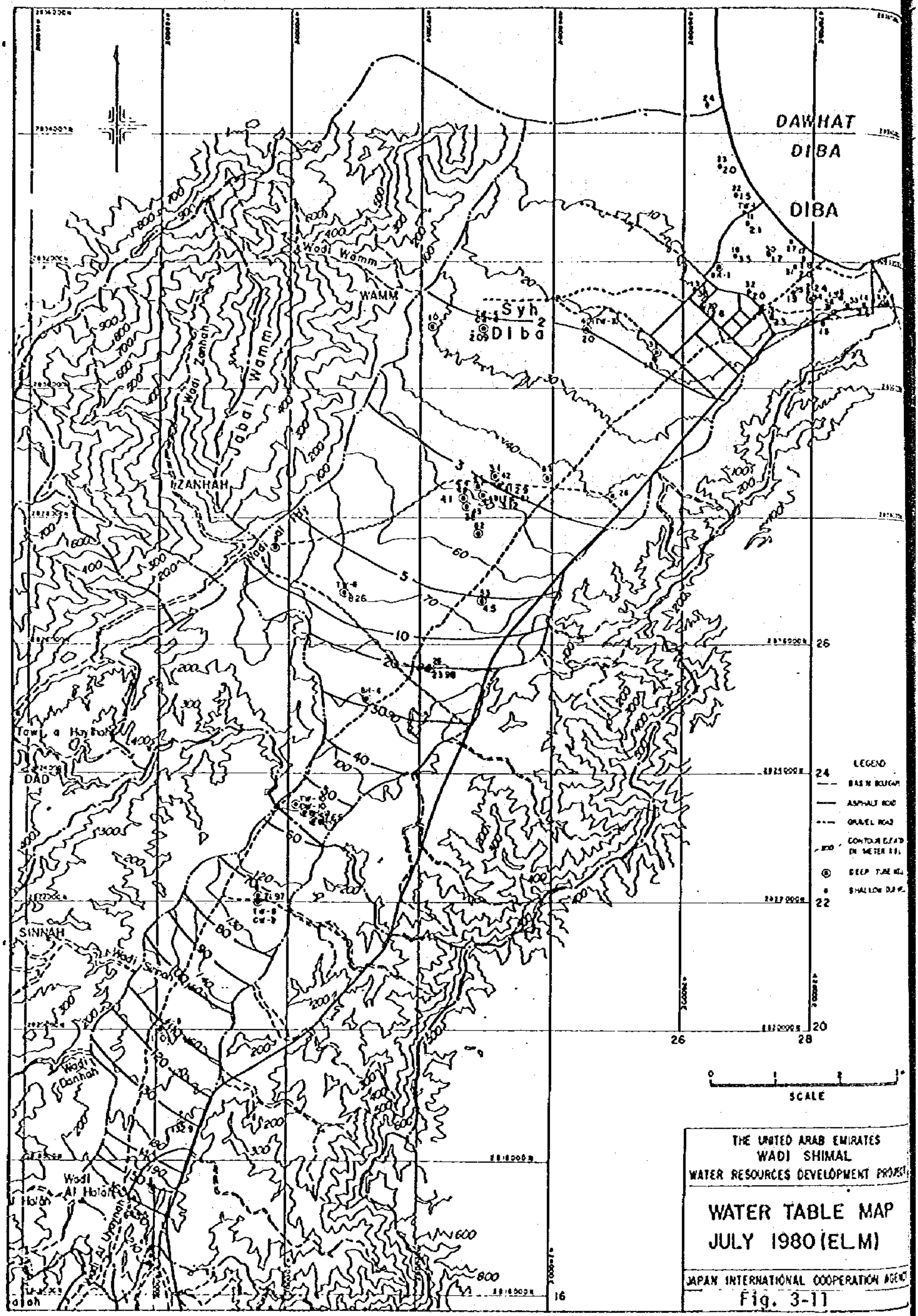
The groundwater samples were taken, in parallel with the groundwater mapping, for chemical analyses and detection of environmental isotopes. The most groundwater in the Wadi Al Bassierah basin belongs to the non-carbonate hardness type, and the groundwater evolution caused by its flow is hardly recognized. All the groundwater except the stagnant water in the terrace deposits and the coastal water has a similar quality.

Among the existing and newly drilled wells, 14 wells were selected to detect the environmental isotope concentrations such as tritium, radon and oxgen in the groundwater. Groundwater was sampled from these wells at a three-month interval in June 1980 to January 1981.

The tritium concentration over the basin is classified into three groups; the first and the second grounds are those which indicate 15 TR or less and are in the recent wadi bed deposits. The third group is that of 15 TR or more, and contained in the lower terrace deposits.

The radon concentration over the basin is similar to that of tritium. Where a high radon concentration is, a high tritium is detected. The third group of groundwater in the upper reaches of the

Wadi Al Bassierah is the mixture of the recent rainy water and the circulating water. It seems that the recent rainy water is by hundreds times larger than the circulating water in quantity.
This ground of groundwater indicates more than 30 Bq of radon concentration. The first group is seen in the low concentration zone of the lower reaches, and supposed to be the mixture of stagnant and circulating waters.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DIBA
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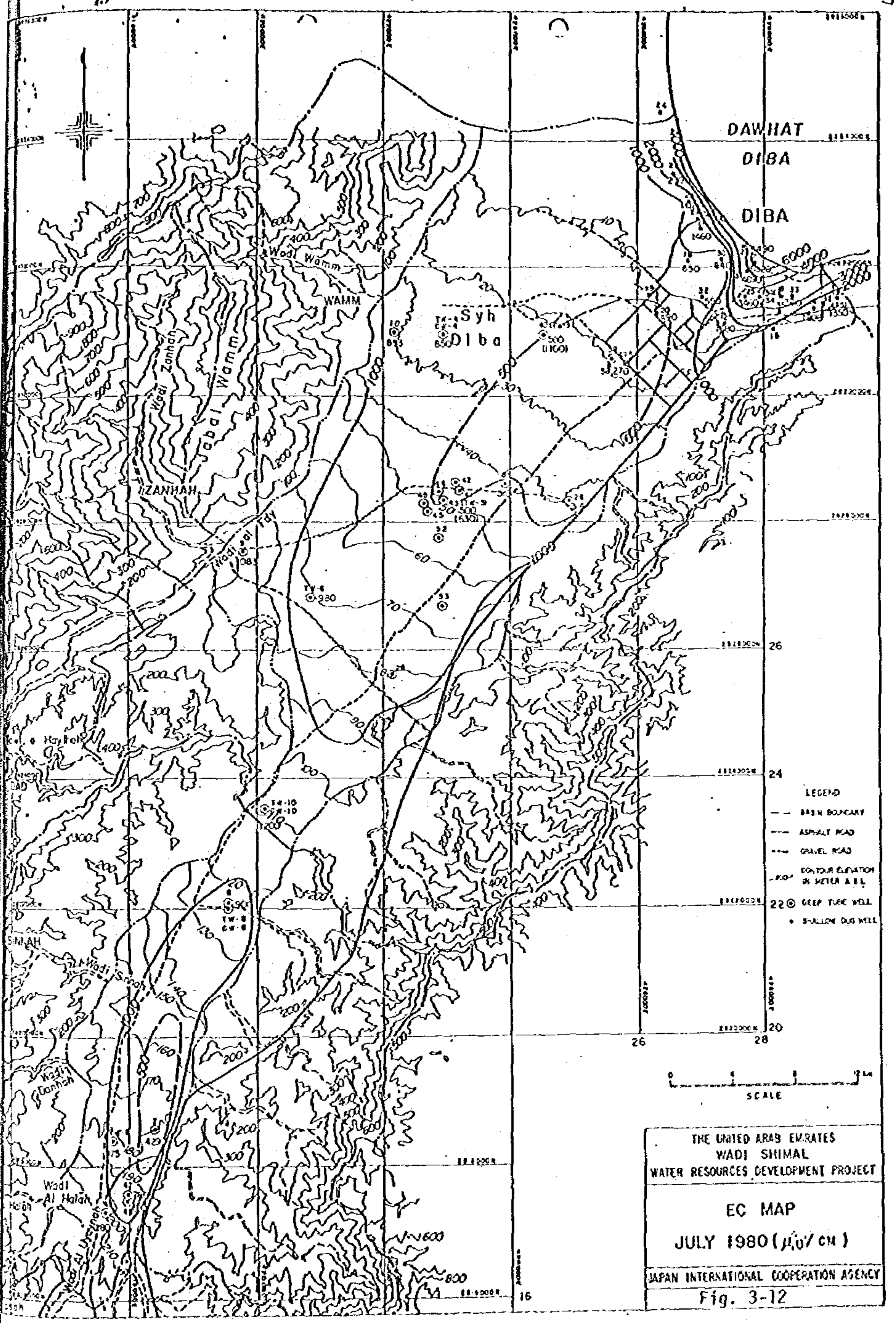
Wadi Wamm
WAMM
Jabal Wamm
Wadi Zanhah
ZANHAH
Tawi a Hayihah
DAD
SINNAH
Wadi Sinnah
Wadi Danhah
Wadi Al Halah
Halah
LEGEND
SCALE
THE UNITED ARAB EMIRATES
WADI SHIMAL
WATER RESOURCES DEVELOPMENT PROJECT
WATER TABLE MAP
JULY 1980 (EL.M)
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 3-11

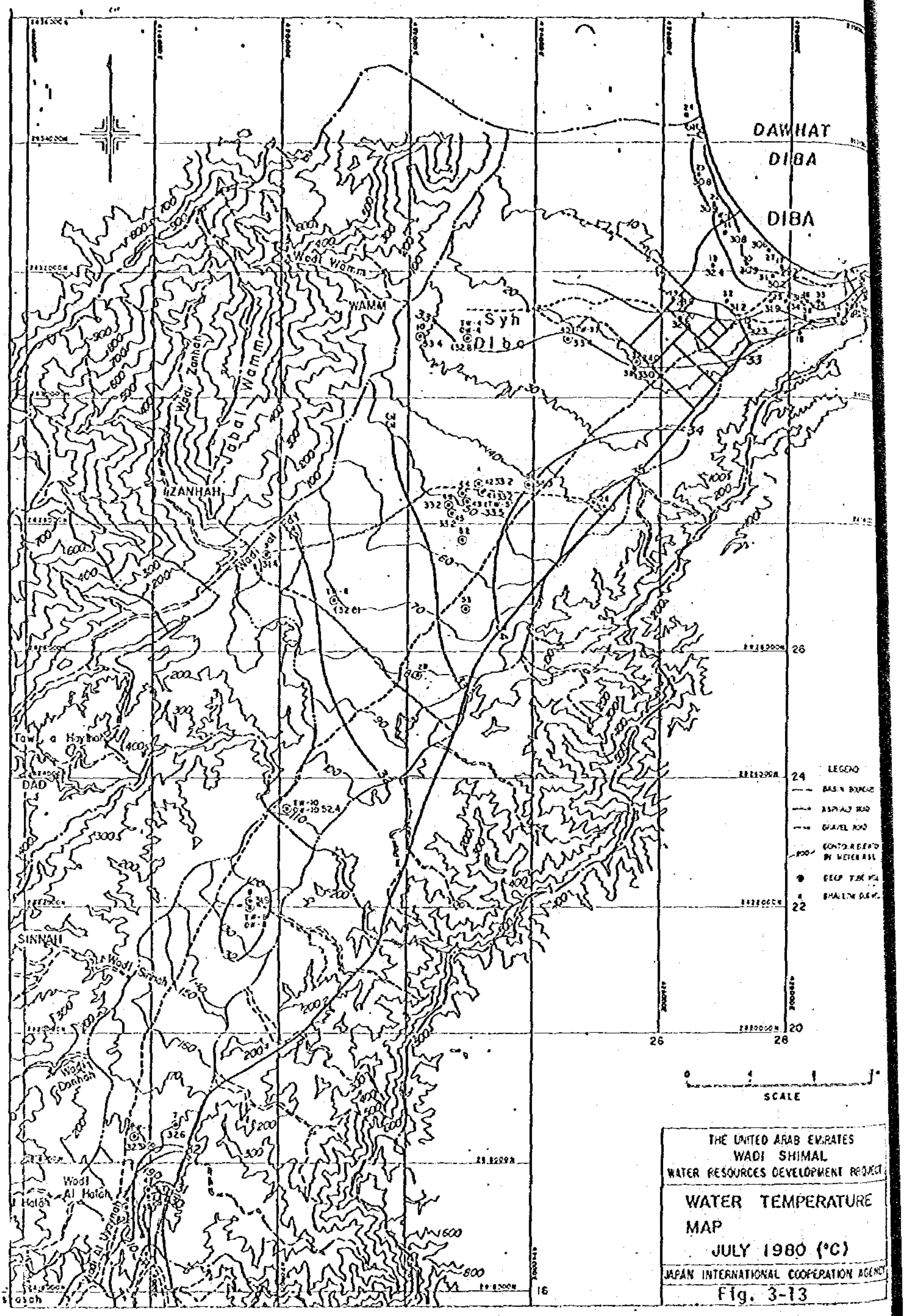


THE UNITED ARAB EMIRATES
WADI SHIMAL
WATER RESOURCES DEVELOPMENT PROJECT

EC MAP
JULY 1980 (μ℧/cm)

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3-12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Wadi Zanhah
Jabal Wamm
ZANHAH
Wadi al Fay
Towi a Hayhah
DAD
SINNAH
Wadi Sinnah
Wadi Danhah
Wadi Al Halah
Halah
LEGEND
BASIN BORDER
ASPHALT ROAD
GRAVEL ROAD
CONTOUR ELEVATION IN METER A.S.L.
DEEP TUBE WELL
SHALLOW DUG WELL
SCALE
THE UNITED ARAB EMIRATES
WADI SHIMAL
WATER RESOURCES DEVELOPMENT PROJECT
WATER TEMPERATURE MAP
JULY 1980 (°C)
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig. 3-13

Fig. 3-14　GEOLOGIAL PROFILES OF WADI AL BASSIERAH BASIN