4.5 Land Use

4.5.1 Present Land Use

Farms in the Study Area are classified, from the topographic viewpoint, into those along the coastal area that make use of the well water and those in the mountain region that utilize the spring water and falaj.

In terms of water use, these farms are further divided into four types (Table 4.5.1, 4.5.2 and Fig. 4.5.2) which are outlined below.

1) Traditional belt farms along the coastal line which are irrigated through pumping shallow wells.

Wadi Basin	Area (ha)
Wadi Ahin	540
Wadi Bani Ghafir	1,830
Wadi Al Fara'	1,680
Wadi Bani Kharus	1,440
Wadi Al Ma'awil	2,090
Total	7,580*

2) Farms as old as a thousand years located in the gravel plains and at the foot of the mountains which make use of spring water or falaj.

Wadi Basin	Villages	Area (ha)	Sub-total (ha)	
Wadi Bani Ghafir	Daris	12.9		
	Al-Wustah	19.6	3 villages	66.7
	Ali	34.2		
Wadi Al Fara'	Jamma	71.4		
	Al-Hazam	43.4		
	Shubaykah	22.7		
	Wishal	151.4	8 villages	894.9
	Mazahit	5.0		
	Wabal	197.4		
	Al-Rustaq	327.0		
	Al-Awabi	76.6		
Wadi Bani Kharus	Khatum	13.0	1 village	13.0

- Continued.

Wadi Basin	Villages	Area (ha)	Sub-total (ha)	
Wadi Al Ma'awil	Al-Ajal	43.7		
	Al-Hibrah	116.4		
	Afi	137.6	6 villages	654.9
	Muslimat	111.7		
	Nakhal	236.5		
	Tawiyah	9.0		
Total				1,629.5 ≒ 1,630*

3) Farms along the Wadi in the mountain region that make use of relatively flat land and head race. (They are on terrace fields because of canals along the contour line that distribute spring water, groundwater, surface water, and falaj.)

Wadi Basin	Area (ha)
Wadi Ahin	73
Wadi Bani Ghafir	231
Wadi Al Fara'	189
Wadi Bani Kharus	256
Wadi Al Ma'awil	46
Total	795*

4) Newly developed farms irrigated by deep well along the coastal line located in the upper stream of type-1 farms above.

Wadi Basin	1981-82	1983-84	Total (ha)
Wadi Ahin	620	620	1,240
Wadi Bani Ghafir	1,100	440	1,540
Wadi Al Fara'	1,960	1,010	2,970
Wadi Bani Kharus	1,030	670	1,700
Wadi Al Ma'awil	1,280	1,340	2,620
Total	5,990	4,080	10,070*

Note: * Source from aerial photographs 1:10,000, 1981 MAF OMAN.

The present land use areas classified above are summarized below.

1.	Traditional farms along the coast (1981 Aerial Photographs)	7,580 ha
2.	Farms in the gravel plains and at the foot of the mountains (1981 Aerial Photographs and Field Survey)	1,630 ha
3.	Farms with head race in the mountain region (1981 Aerial Photographs and Field Survey)	795 ha
	Sub Total	10,005 ha
4.	Newly developed farms (1981 - 1982 Ministry of Housing Data)	5,990 ha
5.	Newly developed farms (1983 - 1984 Ministry of Housing Data)	4,080 ha
	Sub Total	10,070 ha
	Grand Total	20,075 ha

The Study Area has a total farmland of about 20,000 ha in the five wadi basins.

The date farms close to the coastal line have often been deserted because of intensified salinity problems. In the case of Al Musana'ah, the deserted areas amount to about 26% (80 ha) of the sample area of about 300 ha.

In addition, the villages along the coastal line have, in an extensive area, farms which appear to have been cultivated some 10 years ago or so. These farms cover a wide area, however, the lack of data would not allow the accurate estimate.

In August 1985 farm owners who had cultivated more than fifty years in the coastal line in the same place were interviewed. According to the interviews, the reason for deserting farms was not only due to salinity but also to the lack of labor force, low crop productivities in the unit farm and lack of funds for renewal all pumping facilities.

Farms are also being deserted at the mountain area and gravel plains in the upstream area and at other areas where falaj and spring water are made use of. These farms are in average about 10% of the existing farm areas but reach 30 to 40% in certain villages.

Deserted or ruined farms were surveyed in relation to falaj systems by air photos (1981) in the lower basin of wadi Al-Fara'. The areas of ruined farms and active farms are 337 ha and 451 ha in area respectively, shown in Table 4-5-5 and Fig. 4-5-4.

There are some falaj poorly operated and maintained because facilities were constructed deep in the ground more than a thousand years ago. The discharge at some other falaj has declined substantially because of the long-term changes in natural environment.

The farms with falaj spring water with the above conditions are at present often left uncultivated for lack of water; however, in the previous year when the groundwater resources were sufficient, 15% or so of these farms were occasionally planted with upland crops.

Detail land uses have been surveyed in the selected four sample areas (Saham, Al-Suwaiq, Al-Musana'ah and Barka). The sample area in Al Musana'ah (Fig. 4-5-3) is characterized by seven distinctive land use zones as follows:

1 Outside the sample area, Al Musana'ah town is located on the coastal sand dune, schools, police station, and a newly developed residential area are located on the outskirts of the town.

2 The area in the second zone close to the coastal line is characterized by soil with a high salinity level and, therefore, by special local vegetation resistant to high salinity. Part of this area used to be planted with date, but it is at present deserted. (Of the total 79 farms in the sample area, 30 farms or about 80 ha have been deserted.)

3 The area in the third zone is primarily planted with date and partly with alfalfa and lime.

4 In the next zone the area is mainly planted with lime and alfalfa and partly with old date.

5 The area in this fifth zone is located upstream of the old national road and is mainly planted with vegetables and partly with other crops like alfalfa, lime, and mango, etc.

6 The area in the sixth zone has recently been developed upstream of the new Highway and is currently planted with alfalfa for sale. This area is still introducing crop rotation of various vegetable crops.

7 In addition to the above six types of farm areas, there is an area (outside the sample area further upstream above the farm zone) which currently lies in the gravel plains but has been fenced and registered at Ministry of Housing and Ministry of Agriculture and Fisheries for future development.

The present crop intensity for different types of planted crops was estimated by surveying 20 farms along the coastal line of the Study Area.

In case of the mountain region, two representative households were sampled. The average farm size of these 22 sample households was about 10 feddans.

The average ratio of planted area is as follows (also see Table 4-5-3)

Crops	Planted Area (%)
Date	25.2
Alfalfa	15.7
Vegetable	13.0
Lime	11.0
Mango	7.5
Banana	0.1
Grape	0.1
Fallow	27.0
Total	100.0

4.5.2 Study of Present Land Use

The Agriculture Census in 1979 revealed the scale of farm ownership in the area of Batinah Coast: about 44 percent of the farmers hold land less than 1.0 ha, about 45 percent hold land between 1.0 ha and 5.0 ha, about 10 percent hold land more than 5.0 ha, and about 15 percent are landless farmers. (Table 4-5-4)

The census also clarified the scale of farm ownership in the mountainous area: about 79 percent hold land of around 0.5 ha only, about 13 percent hold land between 0.5 ha and 1.0 ha, and only about 8 percent hold land more than 1.0 ha. As a result, about 92 percent of the farmers in the mountainous area hold land less than 1.0 ha.

Recently, the Government has begun to dispose of the national land extending in the upper basin of the wadi by scale of 10 feddan (4.2 ha) parcels to those Omani nationality citizens who wish to farm there. The policy of the Omani Government, thus, will increase the number of farmers owning 10 feddan of land in the area.

On the other hand, the scale of farming land is not expected to be expanded in the mountainous area, and the younger sons of the farming families, (eldest sons are successors) are prone to leave their home villages where the expansion of the farm land is not expected and additional irrigation water sources are unavailable. Such influx of the farm children to towns has resulted in rapid depopulation of the mountainous villages.

The Government has promoted the farm land disposal scheme for the people who are well-qualified, and land reclamation has been making the good progress in the gravel plain. A considerable large acreage of these newly reclaimed farm lands at the time of the Agriculture Census in 1979 were registered during the period between 1981 to 1985 when such land development was enacted. The newly registered farm land has been fenced with barbed wire and levelled for farming, and provided with tube-wells and/or houses for farm management.

The status of land reclamation by districts is described below. (Fig. 4-5-2)

1) Barka Area (Wadi Al Ma'awil and part of Wadi Bani Kharus)

In this district, land reclamation has mostly been carried out on both sides of Al Rustaq Road about 12 km long, and along the road to Khatum village. On both sides along National Highway No.1, almost all of the land has been reclaimed and disposed of in strips of 3.0 to 4.0 km width.

2) Al-Musana'ah Area (Wadi Al Fara', Wadi Bani Kharus and Wadi Bani Ghafir)

Land reclamation has been promoted on both sides of the Al Rustaq Road for about 20 km distance (Al Muladdah side) and on both sides of the road to Jamma village for about 10 km.

3) Al-Suwaiq Area (Wadi Bani Ghafir)

In this area as well, the land disposal has been promoted in the upper basin of the Wadi along the road to the villages.

4) Saham Area (Wadi Ahin)

The newly reclaimed land has been greatly increased along the national highway.

As a whole, in the area along the road, about 10,000 ha of the newly reclaimed land, almost equivalent to the acreage of the existing farm land, has been developed into farm land which had to depend on groundwater sources.

"Sultan Decree No 5/80. Land Act" was issued in 1980 to regulate the disposal of the reclaimed farm land.

Recently, farm land disposal has been widely promoted in the area along National Highway of the Batinah Coast not far from Muscat, the capital of the country. On the other hand, the groundwater sources for irrigation for the existing farm land has been adversely affected by sea water intrusion in the coastal area. Under the circumstances, the Water Resources Council has prohibited land disposal as described below.

The areas where land disposal is prohibited in the Study Area are as follows:

1 The area 48 km long x 3.0 km wide along National Highway (No.1) down to sea between Seeb and Barka

2 The area 55 km long x 7.0 km wide along National Highway (No.1) down to sea between Barka and Al-Suwaiq

3 The areas where the regulation has been applied since 1981 and new wells and aflaj digging is prohibited within 3.5 km far from existing mother wells and aflaj

The people who wish to obtain the reclaimed land should have qualifications as follows:

1 To have Omani nationality

2 To engage in farming themselves

3 To be adults over 21 years of age

Well-qualified persons can have right to be owners of the newly reclaimed land of averaging 10 feddan but maximum 15 feddan (6.2 ha).

For the first three years after disposal, however, the land is deemed as rented from Government, and after three years the land can be owned by the relevant persons with approval of the Central Committee of the Ministry of Housing. If the new land owners could not use the land for farming or could use it for any other purposes than those applied in the procedures, the land ownership by such persons would be cancelled. When persons wish to obtain land for other purposes than farming (namely, housing lots, commercial lots, industrial lots, etc.), they should get approval from Ministry of Housing after obtaining permission of the authorities concerned and the local Chamber of Commerce in charge.

Agricultural land in the land use survey area is divided so that about 88 percent is located in the coastal area while about 12 percent is located in the mountainous area including piedmont.

Of the agricultural land in the coastal area, tree crops are 44 percent, alfalfa 16 percent, vegetables 13 percent, and the remaining 27 percent is left as fallow land due to lack of irrigation facilities. For farm land under cultivation, the date palm as major crop is cultivated on about 25 percent of the total farm land in the coastal area. Date palm is mainly grown on the mixed crop farms. (Table 4-5-3 and Fig. 4-5-3)

The land use in the mountainous area including the gravel plain and piedmont area, different from that in the coastal area, is occupied mostly by date mono-culture farms. The dates farms occupy about 73 percent of the whole farm land except for the coastal area where vegetable cropping farms with winter crops as major crops total about 17 percent, and fallow land totals about 10 percent. (Table 4-5-2)

The land use ratio in the coastal area is about 73 percent, while that of the mountain area including the gravel plain and piedmont area is about 90 percent. There is not so much multi-cropping observed in the Area, although a considerable number of the date-vegetable mixed farms exist.

The reclamation of new farm land has progressed without ensuring the appropriate water sources for irrigation. Such development has a potential to deteriorate the existing farm land in the coastal area and to turn the long-cultivated fertile land into waste land. Consequently, land development should be regulated more stringently in the future. The trend of agricultural land use in the Project area is to center about the latest development farm land along the National Highway and the on-going development farm land in the upper basin. It seems that the present date-based cropping pattern will change to one to produce vegetables and forage as major crops. In addition, mechanized farming in the area will be introduced for agriculture modernization which will enable production of vegetables as major crops plus fruity crops and forage like banana, papaya and alfalfa in the newly reclaimed farm land.

More effective and efficient use of the existing farm land and water availablity should be further surveyed and studied for the coastal area. Specific areas of study should include the provision of fundamental farming facilities for the coastal area and types of highly efficient land use for the mountainous area where further farm land expansion is not expected or where only small scale land could be further developed due to large elevation differences in topography.

Especially for the mountainous area, where conditions such as greater work volume and costly transportation of products than those of the gravel plain and the coastal area are factors, the Government should make a policy to provide or improve the farm roads to offset this economic disparity.

1) Agriculture Modernization in the Coastal Area

In the existing farms in the coastal area, water is pumped up from shallow wells and temporarily stored in concrete tanks. It is then conveyed through channels for irrigating farm land. These channels, mostly earth lined, have heavy leakage resulting in ineffective water use.

Cropping in the farms is also ineffective and as a whole the farms are far from the planned type of farm since they typically have only a few banana trees or a date palm planted around a water tank. In other words, many of these "farms" are really only backyard size. Under the present ineffective and inefficient circumstances, the existing farms should be improved by planned farm management and providing local, suitable irrigation systems and on-farm facilities so as to raise the level of the farm economy in the Batinah Coast Area. It is also strongly recommended to create a specialized group of experts to design and improve irrigation systems and on farm facilities as well as extension of improved farming techniques.

2) Agriculture Modernization in the Mountainous Area

The farms in the mountainous area are small in scale and limited in both land and water resources. In addition, unfavourable mountainous topography leads to ineffective farming due to differences in elevation of fields. Moreover, the long distance to the markets for agricultural products has resulted in their local consumption only. In the future, therefore, improvement in the major road in access to the markets should be undertaken one by one to break away from local consumption agriculture to commercialized sales in wide markets with newly developed products. In this connection, the Government should make a policy to provide farm road networks to promote effective farm land utilization as well as to stabilize the social order.

Table 4-5-1 Land Use Classification by Topographical Condition

(Unit: ha)

Wadi Basin	Location	Coastal area	Gravel plain	Piedmont area	Mountain cultivation	Total
Ma'awill	Barka area	2,090	-	-	-	2,090.0
	Al-Ajal	-	-	43.7	-	43.7
	Hibra	-	116.4	-	-	116.4
	Afi	-	137.6	-	-	137.6
	Al-Muslimat	-	111.7	-	-	111.7
	Nakhl	-	-	236.5	-	236.5
	Other Villages	-	9.0	-	46.0	55.0
	Sub Total	2,090	374.7	280.2	46.0	2,790.9
Bani Kharus	Bilah, Bu Abali area	1,440	-	-	-	1,440.0
	Al-Abiyad	-	-	-	53.5	53.5
	Layjah	-	-	-	36.1	36.1
	Istal	-	-	-	41.6	41.6
	Al-Musaynaah	-	-	-	58.0	58.0
	Other Villages	-	13.0	-	67.0	80.0
	Sub Total	1,440	13.0	0	256.2	1,709.2
Fara	Al-Musana'ah area	1,680	-	-	-	1,680.0
	Jammah	-	71.4	-	-	71.4
	Al-Hazam	-	43.4	-	-	43.4
	Al-Shubaykah	-	22.7	-	-	22.7
	Wishal	-	-	151.4	-	151.4
	Wabal	-	-	197.4	-	197.4
	Al-Rustaq	-	-	327.0	-	327.0
	Al-Awabi	-	-	76.6	-	76.6
	Al-Fashah	-	-	-	28.8	28.8
	Amq	-	-	-	18.9	18.9
	Other Villages	-	-	5.0	141.0	146.0
	Sub Total	1,680	137.5	757.4	188.7	2,763.6
Bani Ghafir	As Suwayq area	1,830	-	-	-	1,830.0
	Daris	-	12.9	-	-	12.9
	Al-Wustah	-	19.6	-	-	19.6
	Ali	-	34.2	-	-	34.2
	Al-Hawqein	-	-	-	83.7	83.7
	Other Villages	-	-	-	148.0	148.0
	Subtotal	1,830	66.7	0	231.7	2,128.4
Ahim	Khishdah area	540	-	-	-	540.0
	Al-Heil	-	-	-	8.4	8.4
	Al-Ghozeifah	-	-	-	23.5	23.5
	Other Villages	-	-	-	41.0	41.0
	Sub Total	540	0	0	72.9	612.9
Grand Total		7,580	591.9	1,037.6	795.5	10,005.0

Source: Aerial Photographs 1/10,000 1981 MAF, OMAN

Table 4-5-2 Present Land Use in the Gravel Plain, Piedmont and Mountain Area

(Unit: ha)

	Wadi Basin	Villages	Dates	Seasonal Crops	Fallow	Total
1.	Ma'awail	AL-Ajal	29.0	2.1	12.6	43.7
2.	"	Al-Hibra	76.2	40.2	-	116.4
3.	"	Afi	85.7	22.4	29.5	137.6
4.	"	Al-Muslimat	61.4	31.4	18.9	111.7
5.	"	Nakhl	184.5	8.0	44.0	236.5
	Sub Total		436.8	104.1	105.0	645.9
6.	Bani Kharus	Al-Abiyad	51.4	2.1	-	53.5
7.	"	Layjah	28.3	0.8	7.0	36.1
8.	"	Istal	31.4	10.2	-	41.6
9.	"	Al-Musaynaah	50.0	8.0	-	58.0
	Sub Total		161.1	21.1	7.0	189.2
10.	Al-Fara'	Jammah	58.6	12.8	-	71.4
11.	"	Al-Hazam	36.0	7.4	-	43.4
12.	"	Al-Shubaykah	18.4	3.5	0.8	22.7
13.	"	Wishal	78.7	40.5	32.2	151.4
14.	"	Wabal	142.2	46.4	8.8	197.0
15.	"	Al-Rustaq	275.3	39.4	12.3	327.0
16.	"	Al-Awabi	61.7	14.9	-	76.6
17.	"	Al-Fashah	24.0	4.8	-	28.8
18.	"	Amq	12.8	6.1	-	18.9
	Sub Total		707.7	175.8	54.1	937.6
19.	Bani Ghafir	Daris	6.2	3.5	3.2	12.9
20.	"	Al-Wustah	9.0	5.6	5.0	19.6
21.	"	Ali	10.9	8.2	15.1	34.2
22.	"	Al-Hawq in	72.8	10.9	-	83.7
	Sub Total		98.9	28.2	23.3	150.4
23.	Ahin	Al-Heil	8.4	-	-	8.4
24.	"	Al-Ghozeifah	21.0	2.5	-	23.5
	Sub Total		29.4	2.5	-	31.9
	Grand Total		1,433.9	331.7	189.4	1,955.0
	Ratio		(73 %)	(17 %)	(10 %)	(100 %)

Source: Aerial Photographs 1/10,000 1981 MAF, OMAN

Table 4-5-3 Crop Intensity in the Sample Farms

(Unit : Feddan)

Area	Barka					Musana'ah							Suwayq				Saham				Mountain Area		Total	
Sample farms / Crops	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	R.	A.	Feddan	Ratio (%)
Dates	-	11	1.4	-	2.6	0.5	-	2.7	1.5	6.0	3.3	2.5	1.0	6.0	6.0	2.0	1.9	0.7	1.2	3.0	2.5	0.5	56.3	25.2
Lime	-	5	0.5	-	-	-	-	-	-	-	-	-	1.0	3.0	3.0	1.0	0.8	0.15	2.0	7.0	1.0	0.1	24.55	11.0
Mango	-	0.1	-	-	-	2.0	3.2	-	-	0.5	-	2.0	-	-	0.3	-	1.2	0.05	0.5	7.0	-	-	16.85	7.5
Banana	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	0.2	0.1
Grape	-	-	-	-	-	-	-	-	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	0.25	0.1
																								43.9
Alfalfa	-	5.0	-	5.2	1.9	2.9	2.8	1.2	-	3.0	0.6	2.0	2.3	1.0	1.4	1.0	-	0.1	0.3	0.2	1.5	2.8	35.2	15.7
Vegetables	8.6	-	-	3.9	2.1	3.5	3.6	-	-	0.5	-	2.75	-	-	2.5	-	-	-	-	-	-	1.6	29.05	13.0
Fallow	12.1	3.8	1.0	4.2	-	7.0	6.6	6.1	-	-	-	6.5	-	1.0	-	2.5	8.6	-	-	0.8	1.0	-	61.2	27.4
																								56.1
Total	20.7	25.0	2.9	13.3	6.6	15.9	16.2	10.0	1.5	10.0	3.9	16.0	4.3	11.0	13.2	6.5	12.5	1.0	4.1	18.0	6.0	5.0	223.6	100.0
Livestock																								Average
Goat	25	25	13	4	-	-	-	5	-	4	-	7	-	2	4	15	-	6	7	2	6	3	128	7.5
Sheep	6	4	1	-	-	-	-	5	5	-	-	-	-	13	8	-	5	4	3	-	4	-	58	3.4
Cattle	4	2	4	-	-	-	-	-	-	1	-	-	-	-	3	4	3	-	-	4	-	-	25	1.5
Camel	0	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	-	-	-	-	5	0.3
Dounkey	1	1	-	1	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	1	-	-	7	0.4

Source : Survey Team JICA, 1983.

Table 4-5-4 Estimated Farm Size by Holding and by Area

(BATINAH REGION)

(HAJAR AL-GHARBI REGION)

SIZE (Ha.)	HOLDING (No.)		RATIO (%)		AREA (Ha.)		RATIO (%)	
	BATINAH	HAJAR	BATINAH	HAJAR	BATINAH	HAJAR	BATINAH	HAJAR
TOTAL	20,130	6,380	100	100	46,126	2,624		
WITHOUT LAND	308	44	1.5	0.7	-	-	-	-
UNDER 0.5	5,236	4,972	26.0	78.0	1,201	828	2.6	31.6
0.5 - 1	3,542	858	17.6	13.5	2,559	600	5.5	22.9
1 - 2	4,950	264	24.6	4.1	7,272	335	15.8	12.8
2 - 5	4,114	198	20.4	3.1	12,389	463	26.9	17.6
5 - 10	1,254	22	6.2	0.3	8,664	150	18.8	5.7
10 - 25	594	22	3.0	0.3	8,274	248	17.9	9.4
25 - 50	110	-	0.6	-	3,898	-	8.4	-
50 - 100	22	-	0.1	-	1,868	-	4.1	-
More than 100	-	-	-	-	-	-	-	-

Source: Final Results of the Census of Agriculture, 1978/1979.

Table 4-5-5 Active and Ruined Farms in the Lower Drainage of Wadi Al-Fara'
(Identified by 1981 Air-photos)

	Location	Active farm (sq. km)	Ruined farm (sq. km)
1.	Falaj Al-Ali -Al-Wustah -Al-Daris	0.821	1.037
2.	Al-Shubaikhah Al-Hazam	0.623	0.506
3.	Al-Mazahit -Wishal -Al-Sahra' -Al-Mizfah	2.153	1.712
4.	Al-Mamansur	0.095	0.113
5.	Jamma'	0.820	0
	Total	4.512	3.368

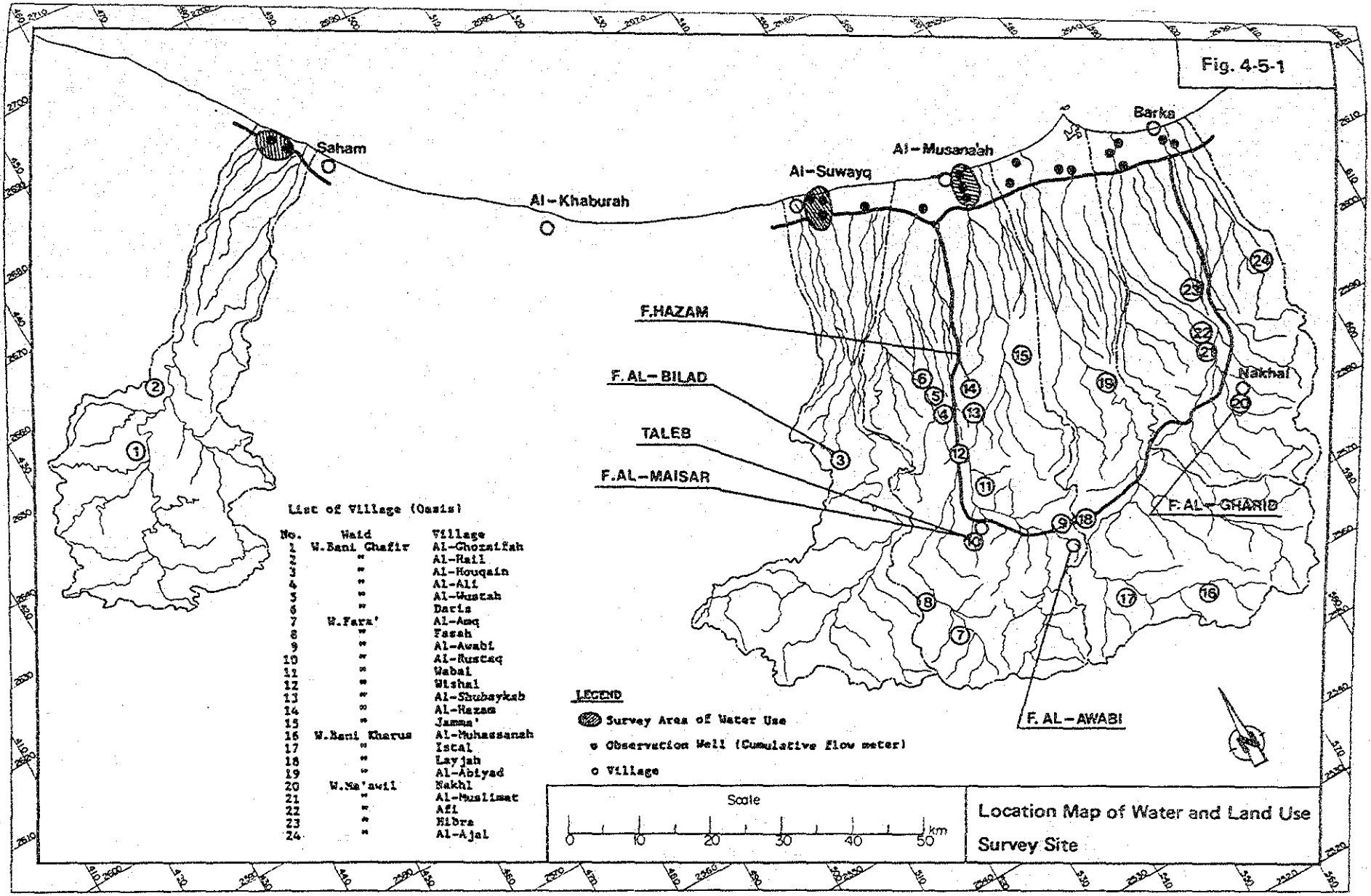


Fig. 4-5-1
Saham
Al-Khaburah
Al-Suwayq
Al-Musanaʻah
Barka
Nakhal
F.HAZAM
F.AL-BILAD
TALEB
F.AL-MAISAR
F.AL-GHARIB
F.AL-AWABI
List of Village (Oasis)
No. Wadi Village
1 W.Bani Ghafir Al-Ghozaifah
2 " Al-Hail
3 " Al-Houqain
4 " Al-Ali
5 " Al-Wustah
6 " Daris
7 W.Farz' Al-Amq
8 " Fasah
9 " Al-Awabi
10 " Al-Rustaq
11 " Wabai
12 " Wishal
13 " Al-Shuhaykah
14 " Al-Hazam
15 " Jamma'
16 W.Bani Kharus Al-Muhassanah
17 " Iscal
18 " Layjah
19 " Al-Abiyad
20 W.Na'awil Nakhl
21 " Al-Muslimat
22 " Afi
23 " Hibra
24 " Al-Ajal
LEGEND
Survey Area of Water Use
Observation Well (Cumulative flow meter)
Village
Scale
0 10 20 30 40 50 km
Location Map of Water and Land Use Survey Site

Fig. 4-5-2 Present Land Use Map

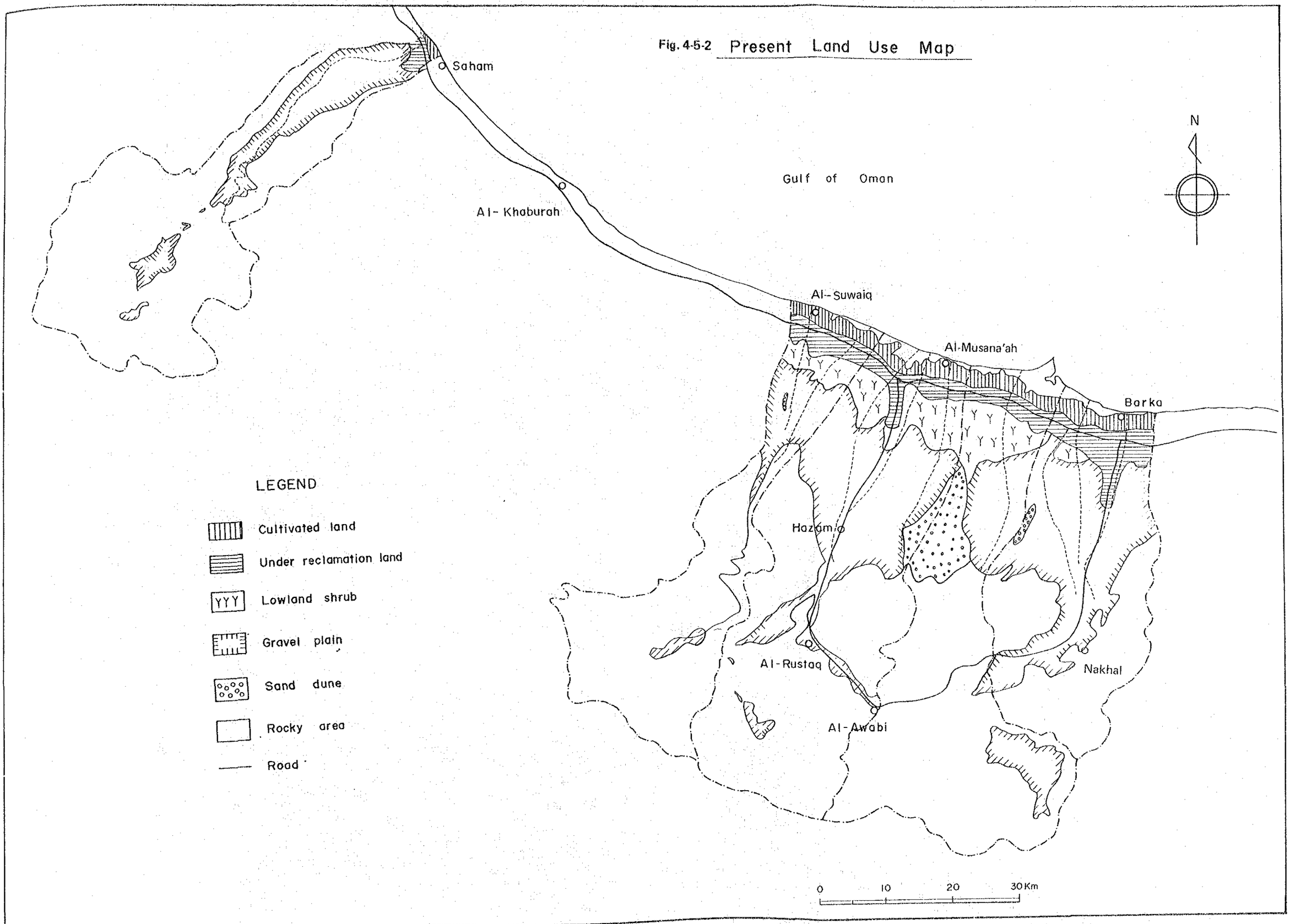


Fig. 4-5-3 Present Land Use in the Sample Area (Al-Musana'ah 300ha)

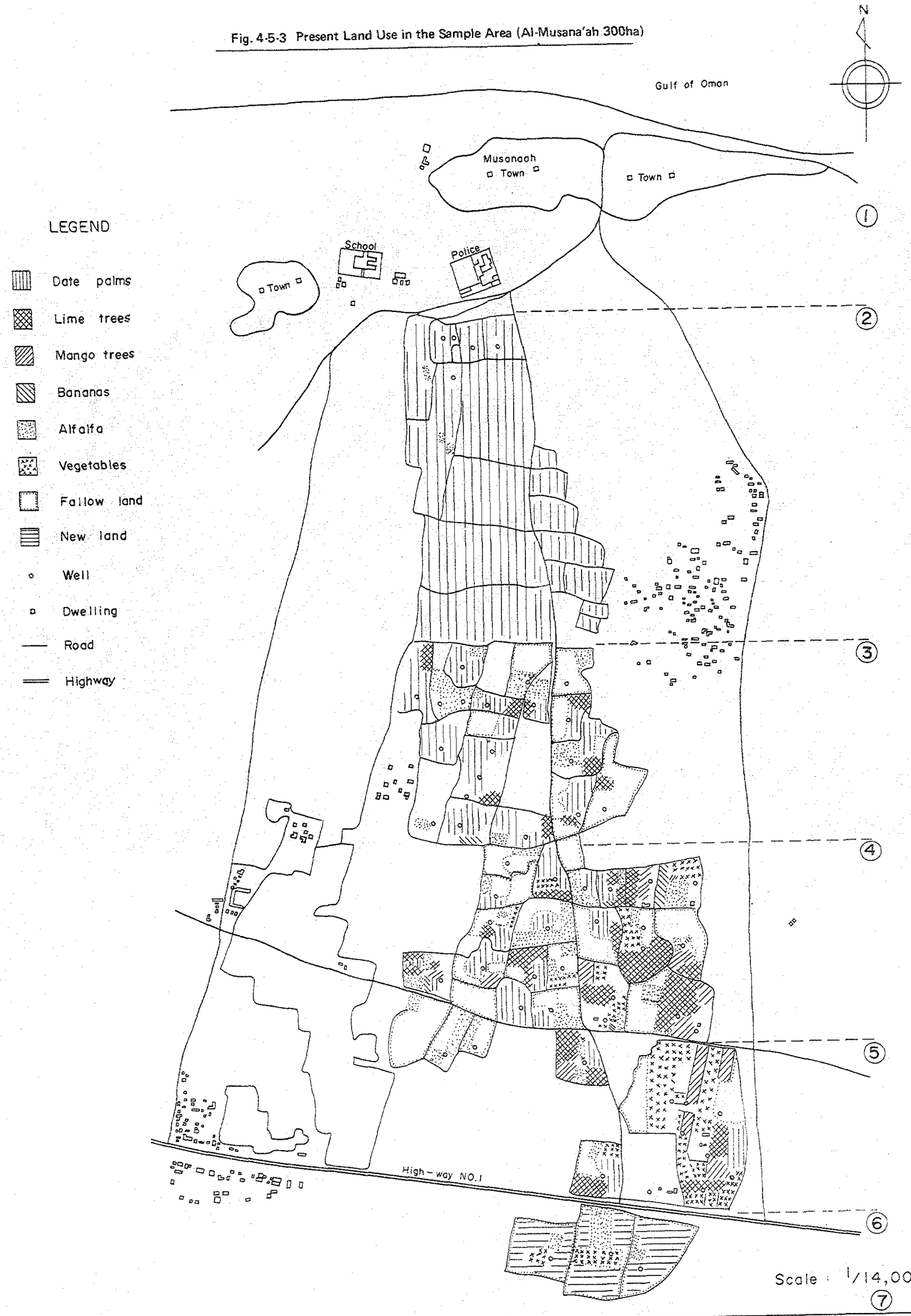


Fig. 4-5-4 Farm and Falaj in the Lower Drainage
(Identified by 1981 Air-photoes)

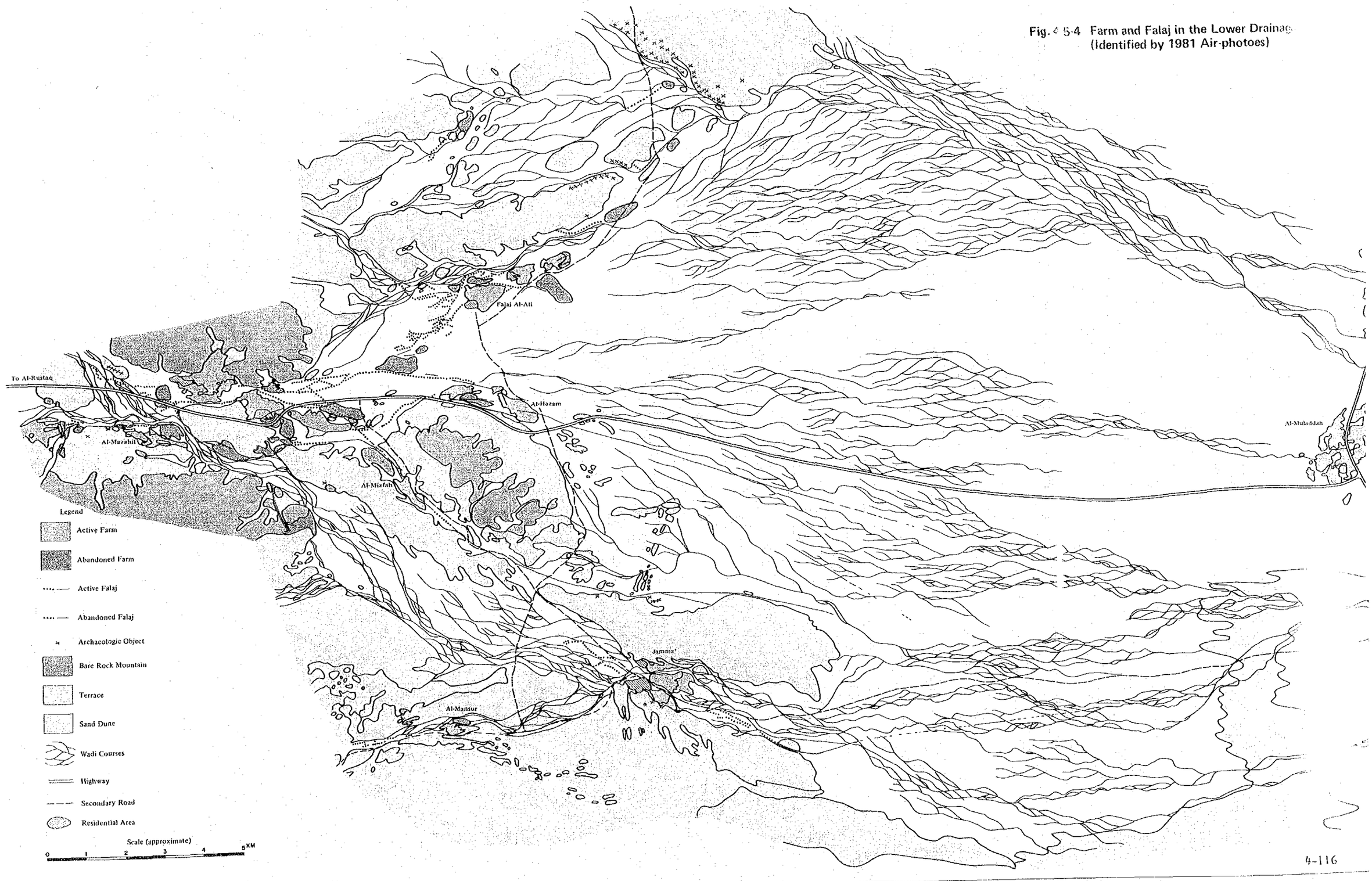
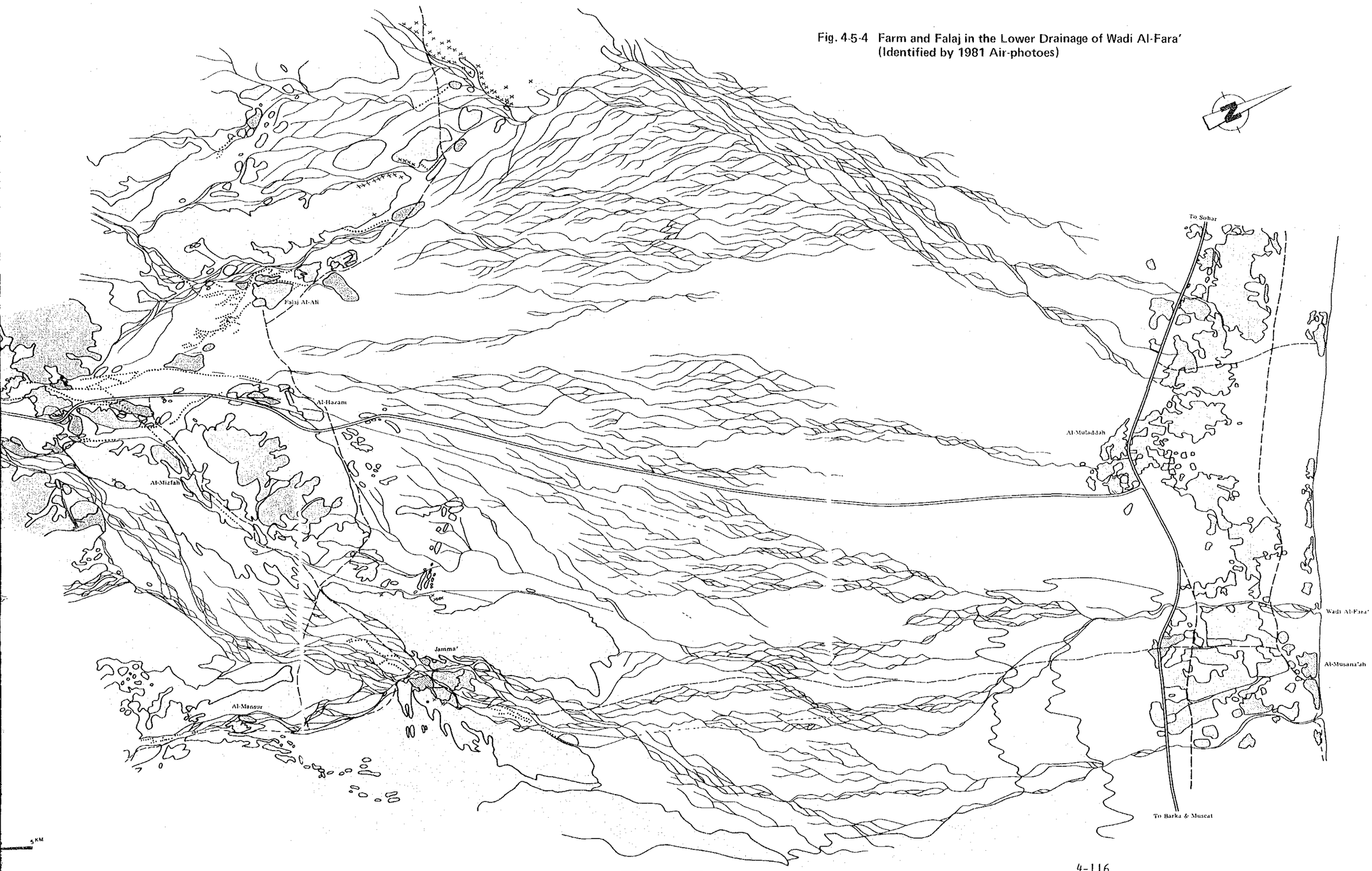


Fig. 4-5-4 Farm and Falaj in the Lower Drainage of Wadi Al-Fara'
(Identified by 1981 Air-photoes)



4.6 Water Use

4.6.1 Present Water Use

Salt acummulation in the farm land of the Batinah Coast is believed to be a critical factor to reduce local agricultural production. Many people believe this is caused by excessive consumption of the groundwater for irrigation particularly in the coastal areas.

To confirm this matter, the water consumption survey was conducted in the Wadi Ma'awil basin and other four Wadi basins and direct observation of the actual water consumption was made to estimate the present basin-wide water consumption by kind of water consumption in the area.

The water consumption in the coastal area was observed at 16 selected sample farms with cumulative flow meters attached to pumps for checking amount of discharge once or twice a month.

The water sources for the villages in the mountainous area depend on limestone springs, aflaj and wadi flows. Six aflaj were selected and staff gauges were installed to regularly observe the water level together with the current speed and EC value.

Change in water used was studied for the period from March, 1983 to August, 1985. The observation records show clearly the specific features of the current water use in the Area. The details of the observations are described in Supporting Report E.

4.6.2 Water Sources Available in the Batinah Coast

The water sources available in the Batinah Coast for irrigation and domestic use can be classified as follows:

Water Sources in the Batinah Coast

Names of Water Sources	Location
Springs	Such villages in piedmont as Nakhal and Al-Rustaq
Falaj	Villages along Wadi in the mountain area and gravel plain
Diversion Weir	" "
Well and Pump	Villages in farming area along coast and mountainous area as supplemental sources

The features of these sources serving suitable scale farming land in the lower reaches to their own capacity of sources are described below.

Springs

The springs can be mainly found in the piedmont of the limestone mountainous area and most of them discharge water in a relatively small range from 1 to 77 l/sec. The spring water temperature is comparatively high ranging from 29°C to 51°C with EC values in a range from 800 through 2,000μs/cm.

Falaj

Aflaj are those collecting channels which are artificially provided at wadi beds and function to take the underground wadi-bed flow. The yield of aflaj varies with amount and distribution of rainfall in the upper reach of the wadi, the scale of the wadi catchment area, and the scale of the collecting channel. The amount of water taken in has a wide range from 1 to 360 l/s.

Ordinarily, a village has one or two aflaj in its village area, except for large scale villages like Nakhal, Al-Rustaq and Houqain. The temperature of aflaj water varies in a range from 25°C to 35°C and shows EC values below 1,000μs/cm in many cases. The yield of the aflaj fluctuates from the wet season to the drought season, and the yield in the drought season sometimes falls to less than 10 percent of that in the wet season.

Diversion Weir

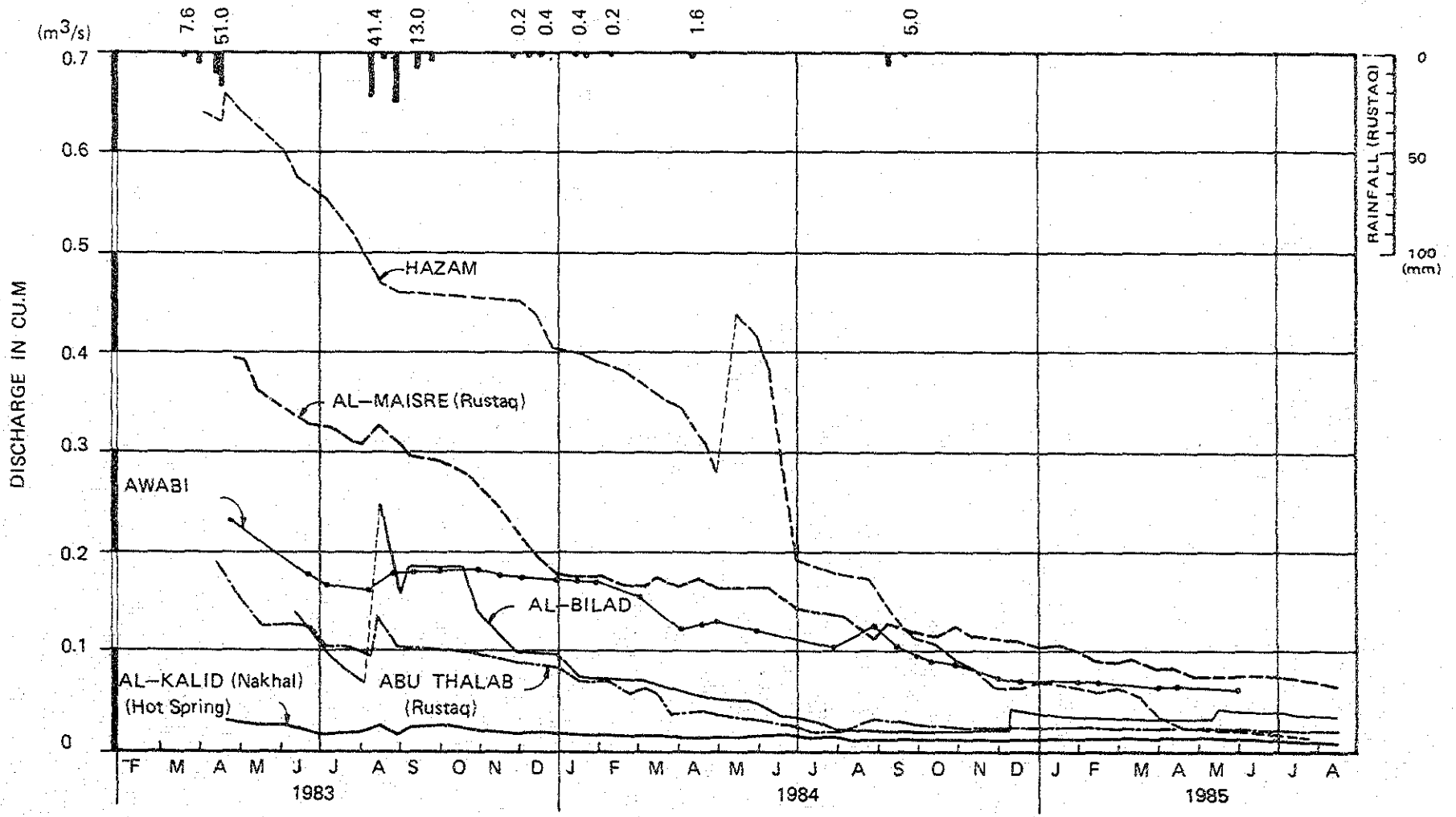
The diversions in the area are constructed across the wadi at the narrow part with the rock outcrop. since weirs are the low diversion type with masonry and concrete structures, they function to divert wadi water by daming. The amount of water available for diverting is almost the same as the yield of the falaj. The specific features of the water are similar to those of the flaj.water with temperatures of 25°C through 35°C and EC values ranging from 500 to 1,000μs/cm. The amount of water available, however, is easily affected by rainfall (wadi flow) and is greatly reduced from the wet season to the drought season.

Well and Pump

The arable land in the coastal area is irrigated by groundwater by the pumping up of the well water. One plot of cropping field provides one or two wells with pumping facilities, and one pump units irrigates about 1.82 ha on average. The Project Area, covering about 7,500 ha in total, would be irrigated by about 4,100 units of pumps. Many pumps used in the area are volute type with three inch (3") bore diameter for the total lift of 10 m.

The capacity of most pumps used is about 430 mm/month, which is estimated as 8 l/s of lifted water based on 9.0 hours of operation and 30 days per month with a command area of 1.8 ha. The amount of water used for irrigation is different from field to field depending on the pump operator. The water used by pumping has a temperature ranging from 22°C to 37°C with EC values 850 through 12,000μs/cm. These EC values are higher than those measured in the water in the mountainous area.

Fig. 4-6-1 Hydrograph of Falaj



4.6.3 Characteristic Features of Water Use in the Survey Area

(1) Water Use in the coastal Area

The water use in the coastal area presents different characteristic features from the water use in the mountainous area because the former employs the pumping facilities for obtaining the groundwater. The actual water use in the coastal area can be described as follows:

1. The amount of water used varies from crop to crop and month to month.

- The mixed farms of tree crops like dates, mango and lime with alfalfa and vegetable consume an average of about 2,260 mm water annually, whereas date mono-culture farms use about 1,320 mm. The difference is about 1,000 mm between the aforesaid two types of the water use. Both mixed farms and date mono-culture farms have the peak water use in the months of June and July, with the least use in the month of January. The monthly average water use is shown in Table 4.6.2, which shows that mixed farms use about 188 mm. Mixed farms use a minimum of abut 135 mm of water while date mono-culture farms use about 73 mm in average.

- It is assumed that the difference in the amount by crop and by month results from the difference in cropping conditions and the evapotranspiration of crops grown.

2. There are many farms overdrafting.

- The water use in the coastal area varies widely by farm. The annual overdrafting amount by some farms is estimated at 33 percent for date farms and 92 percent for mixed farms in excess of their actual requirements. Seven farms out of 13 farms where water use observation was carried out have overdrafted by about 21 percent of the annual total water use (780 mm/year/farm).

- The characteristic features of the farms which have been overdrafting are as follows:

a. The farms have been practicing traditional flood irrigation in spite of the fact that the farms have sandy soils with high permeability. This is an improper irrigation method.

b. The farms use pumping units with ordinary capacity for relatively small irrigation area (excessive installation of pumping facilities for the unit service area), and such facilities easily cause overdrafting. This represents a comparatively low level of irrigation technique.

Table 4-6-1 Monthly Average Water Use in the Coastal Area

(Unit: mm)

Cropping Month	'83 /'84 New Mixed	'83 /'84 Mixed	'83 /'84 Mean	'83 /'84 Dates	'84 /'85 New Mixed	'84 /'85 Mixed	'84 /'85 Mean	'84 /'85 Dates	Average Mixed	Average Dates
Apr.	155	185	170	84	225	186	206	138	188	111
May	160	214	187	146	230	250	240	137	214	142
Jun.	210	218	214	116	200	264	232	203	223	160
Jul.	203	245	224	135	165	264	215	133	220	134
Aug.	175	233	204	125	205	232	219	83	212	104
Sep.	170	196	183	110	225	200	213	127	198	119
Oct.	195	161	178	110	215	167	191	95	185	103
Nov.	150	161	156	80	208	197	203	140	180	110
Dec.	170	159	163	77	160	220	190	95	177	86
Jan.	155	159	157	90	128	97	113	55	135	73
Feb.	165	143	154	117	170	140	155	45	155	81
Mar.	180	171	176	128	158	174	166	70	171	99
Total	2,088	2,245	2,166	1,318	2,289	2,391	2,343	1,321	2,258	1,322
(Average)	(174)	(187)	(181)	(110)	(191)	(199)	(195)	(110)	(188)	(110)

Note: . New Mixed: New mixed farm

· Mixed : Mixed farm

. Refer Table E-2-7 in Supporting Report E.

Fig. 4-6-2(1) Monthly Average Water Use (1/2)

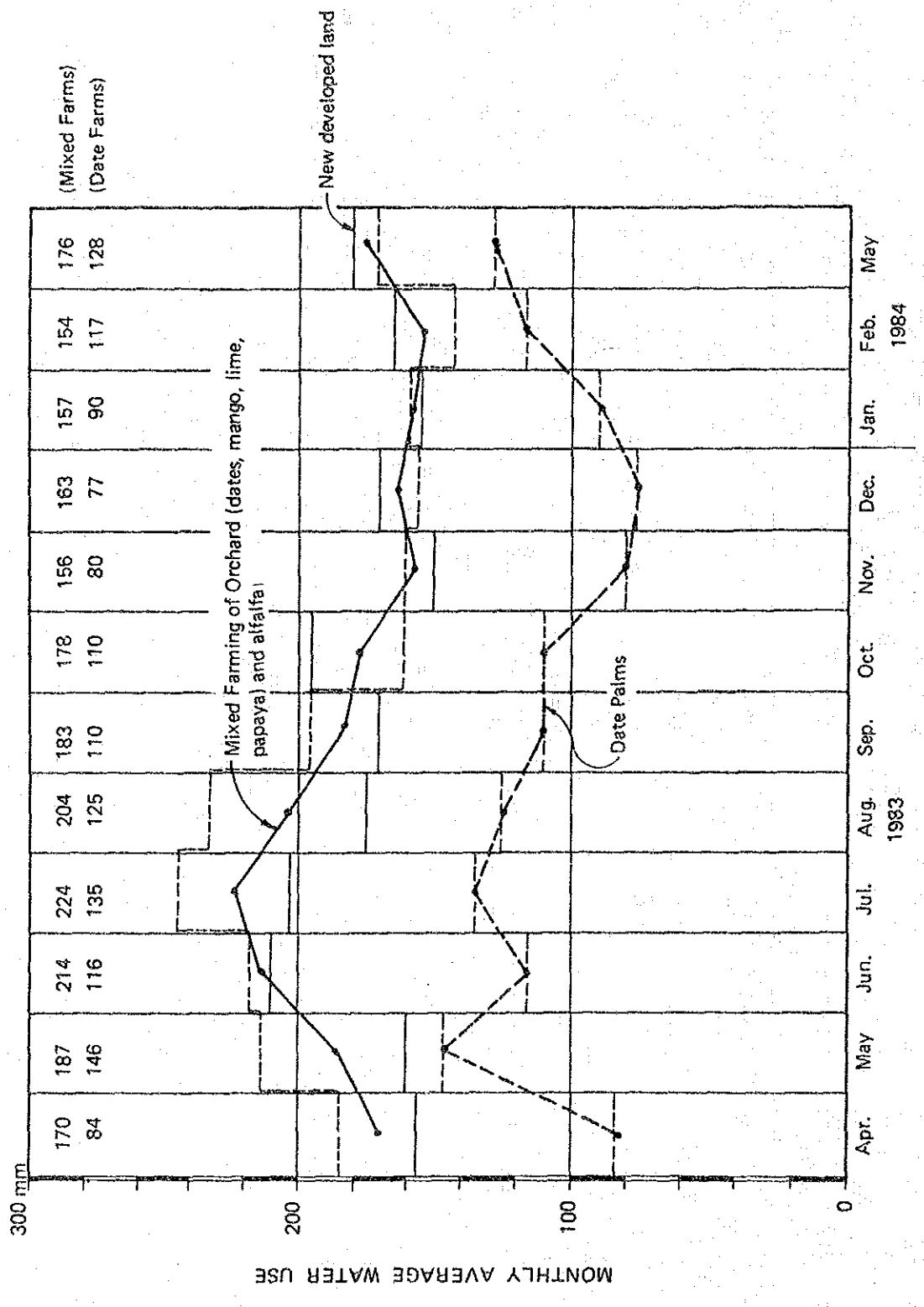
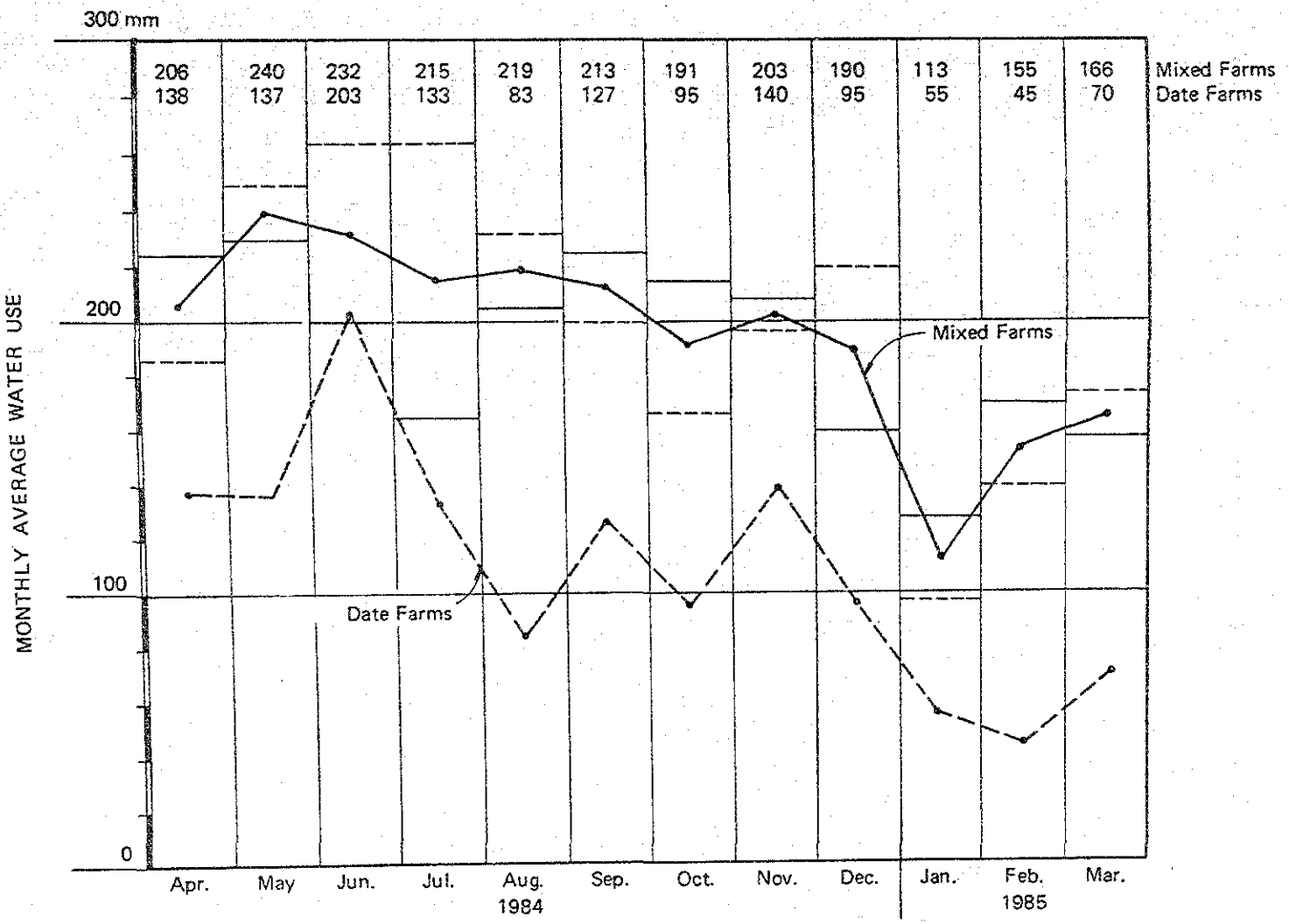


Fig. 4-6-2 (2) Monthly Average Water Use (2/2)



(2) Water Use in the Mountainous Area

In the villages of the mountainous area, all the water for irrigation for the mixed farms and villagers' domestic water is taken from springs and aflaj. Under the circumstances, the amount of intake water is equivalent to the water yield of the relevant water sources, and therefore the water use is quite different from that in the coastal area. The water use in the mountainous area has the following characteristic features.

1. The amount of intake water in the mountainous area is as much as 3,100 to 7,100 mm of water per year for the unit acreage (Table 4-6-3).

- The scale of the villages or arable land is determined by the amount of water sources available in drought. This means that in the ordinary years and the wet years, the yield of aflaj is commonly more than the water requirements by the villages, and this is used almost exclusively for irrigation of the mixed farms.

- The water amount of the sources depends upon the kinds of relevant water sources. The hydrograph reveals that the yield in drought season decreases by 1/3 to 1/4 of that in wet season or 600 mm to 800 mm per month. In general, the yield of springs fluctuates very little as compared with that of aflaj.

2. The other special features of the water use in the mountainous area are the water management system. In the mountainous area, the villagers should provide a water distribution system that allows parity allocation of the water instead of depending upon the artificial control of water sources for collective use by the villagers. However, at present, the distribution system is called "Athar", which is the right to use the terminal irrigation channels for 30 minutes. The "Athar" is exercised as a distribution unit following the communally decided order of the users.

Fig. 4-6-3 Monthly Water Use (Discharge) of Sample Falaj

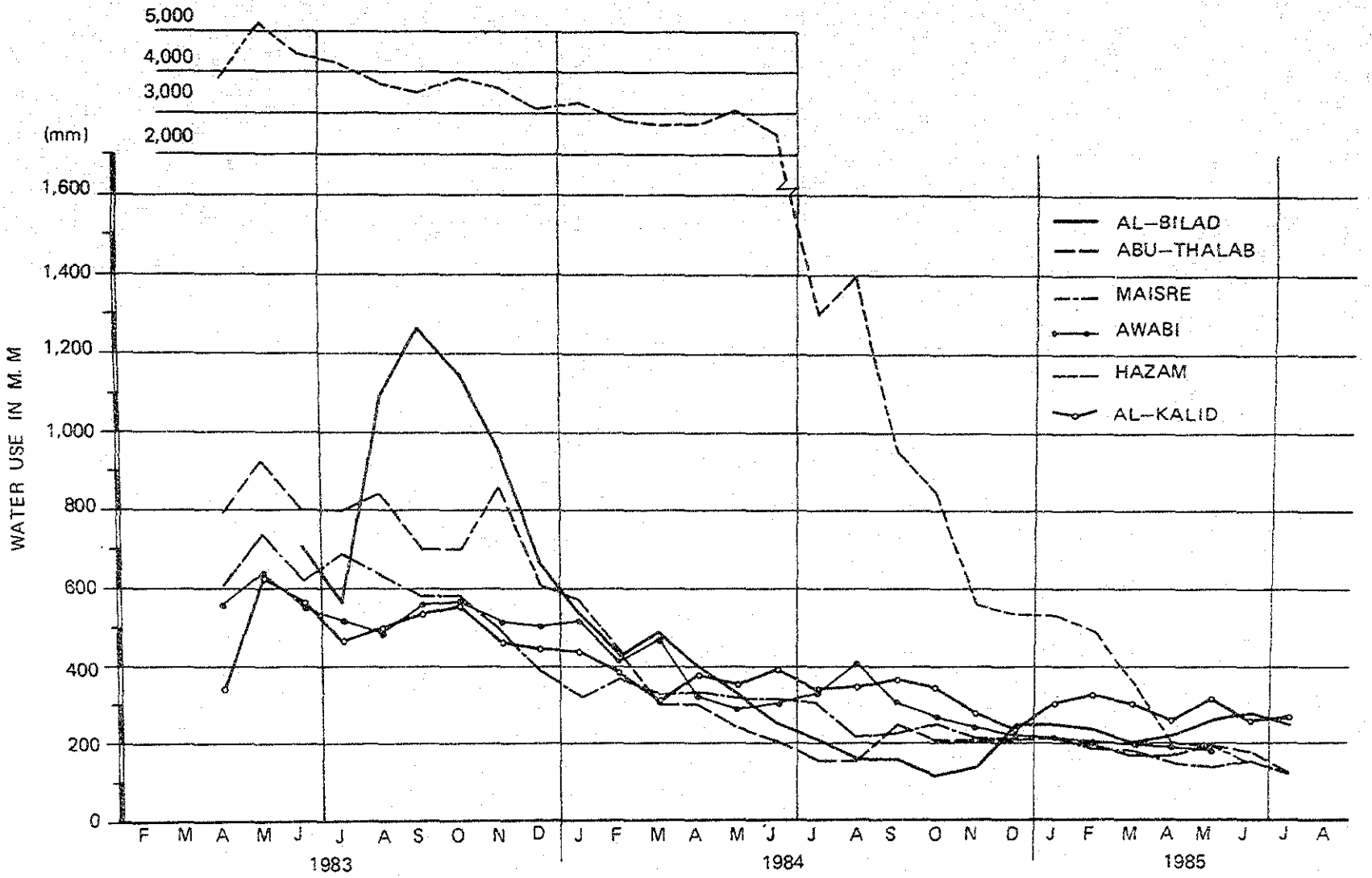


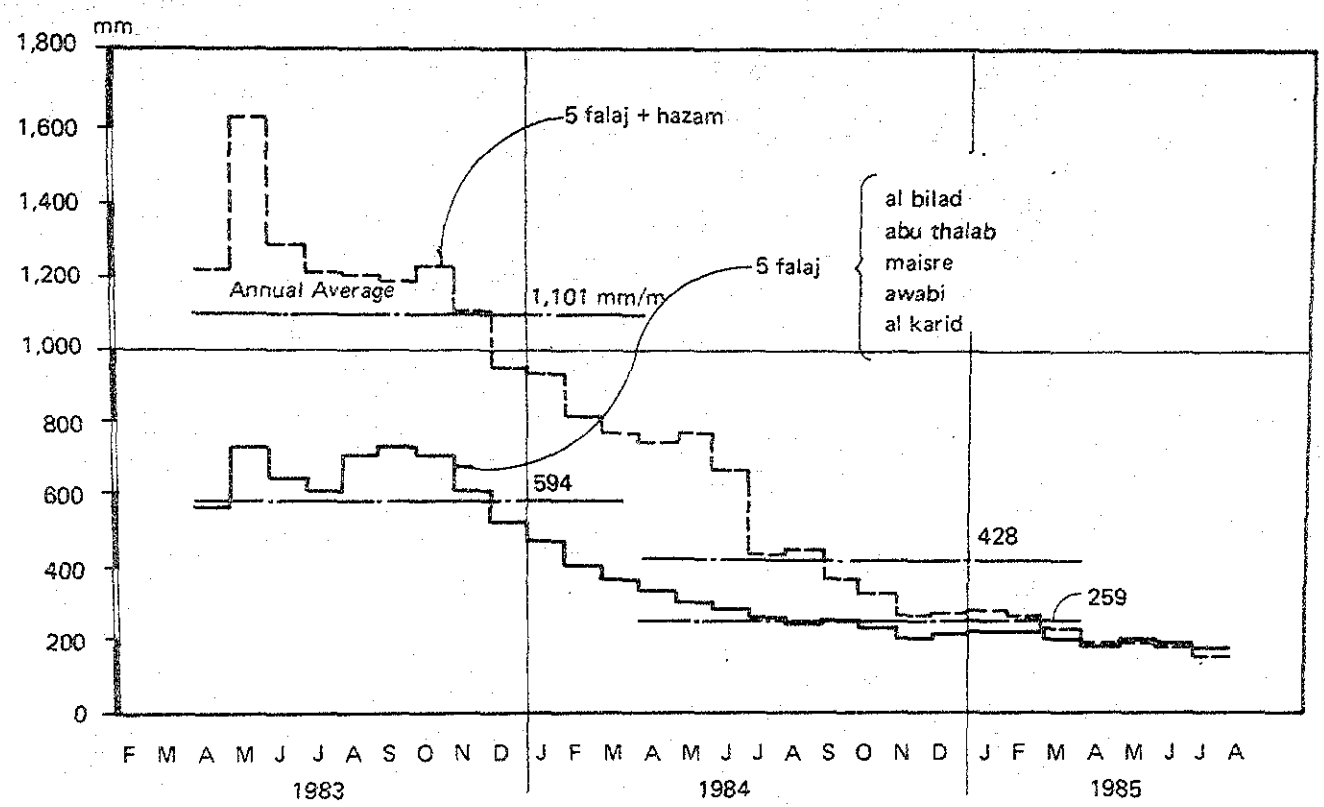
Table 4-6-2 Average Intake Water in Mountain Area

(Units; mm/month)

Area / Month	Mountain (Aflaj) *1		
	1983/84	1984/85	Mean (A)
Apr.	575	348	462
May	735	308	522
Jun.	648	296	472
Jul.	610	270	440
Aug.	712	260	486
Sep.	730	264	497
Oct.	712	240	476
Nov.	616	216	416
Dec.	524	224	374
Jan.	478	238	358
Feb.	408	232	320
Mar.	378	212	295
Total	7,126	3,108	5,118
(Mean)	(594)	(259)	(428)

Note: *1; Monthly Average Water Use in the Mountain Area is calculated based on discharge data of five afalaj except Falaj Hazam.

Fig 4-6-4 Monthly Average Intake Water of Falaj



(3) Some Considerations on Water Use

Some characteristic features of water use in the Batinah coast area are as follows:

1. The Minimum Water Requirement in the Mountainous Area

   Due to a long drought since August, 1983, the discharges of aflaj decreased gradually to the level that the falaj keepers made reports about water shortage.

   The discharges of aflaj just before the falaj keepers reported the water shortages is considered as the minimum water amount necessary for the village life.

   The total water intake for one year from April, 1984 to March, 1985 averaged about 250 mm/month, this can be evaluated as almost equivalent to the annual minimum amount necessary for the village life. This amount is also almost equivalent to about 1.0 l/s per hectare.

2. The amount of water use in the coastal area is estimated at 188 mm per month on average for mixed farms (135 mm - 223 mm/month), or 2,258 mm on the annual average, whereas 110 mm on the monthly average is used for date mono-culture farm (73 mm - 160 mm/month) or 1,322 mm on the annual average.

3. There are many farms overdrafting the groundwater in the coastal area. Such overdrafting has resulted from improper irrigation methods since water distribution and irrigation is carried out simultaneously at all the farms and fallow irrigation is practiced from the source to the terminal fields. This consumes a great deal of water. The current irrigation system is deemed as inappropriate to introduce water-saving farming due to large conveyance loss.

4.6.4 The Amount of Water Used in the Batinah Coast

The amount of water used at present in the Batinah Coast is estimated based on the village arable land acreages obtained by actual water measurement at sample farms and aflaj together with the aerial photos (MAF, 1981).

Unit Water Use

(Units; mm/month)

Croping / Month	1983 / 84			1984 / 85		
	Coastal		Mountain 1/	Coastal		Mountain 1/
	Mixed	Dates	Mixed	Mixed	Dates	Mixed
Apr.	170	84	575	206	138	348
May	187	146	735	240	137	308
Jun.	214	116	648	232	203	296
Jul.	224	135	610	215	133	270
Aug.	204	125	712	219	83	260
Sep.	183	110	730	213	127	264
Oct.	178	110	712	191	95	240
Nov.	156	80	616	203	140	216
Dec.	163	77	524	190	95	224
Jan.	157	90	478	113	55	238
Feb.	154	117	408	155	45	232
Mar.	176	128	378	166	70	212

Note: 1/ The data are based on the falaj head discharge.

Irrigation Area

Year	Area (ha)		
	Coastal	Mountain	Total
1983/84	7,580	2,425	10,005
1984/85	"	"	"

Annual Water Consumption

Item		Irrigation Area (ha)			Water Used (10^3 m^3/year)		
		Coastal	Mountain	Total	Coastal	Mountain	Total
Ahin	83/84	540	73	613	7,708	4,901	12,609
	84/85	"	"	"	8,205	2,140	10,345
	mean	"	"	"	7,956	3,521	11,477
Bani-Ghafir	83/84	1,830	298	2,128	26,121	20,212	46,333
	84/85	"	"	"	27,808	8,814	36,622
	mean	"	"	"	26,965	14,513	41,478
Fara	83/84	1,680	1,084	2,764	23,980	76,175	100,155
	84/85	"	"	"	25,529	33,224	58,753
	mean	"	"	"	24,754	54,700	79,454
Bani-Kharus	83/84	1,440	269	1,709	20,556	18,614	39,170
	84/85	"	"	"	21,882	8,118	30,000
	mean	"	"	"	21,219	13,366	34,585
Ma'awill	83/84	2,090	701	2,791	29,831	49,554	79,385
	84/85	"	"	"	31,760	21,613	53,373
	mean	"	"	"	30,796	35,584	66,379
Total	83/84	7,580	2,425	10,005	108,196	169,455	277,651
	84/85	"	"	"	115,184	73,909	189,093
	mean	"	"	"	111,690	121,682	233,372

In summary, an annual average (1983-1985) of about 233 MCM of water was used for irrigation and domestic use in the Batinah Coast. In the drought year of 1984/85 an annual average of above 189 MCM was consumed. This is deemed as the minimum water amount necessary for a year based on present irrigation methods. Consequently, the difference of about 89 MCM in water amount between 278 MCM in the wet year of 1983/84 and 189 MCM in the drought year of 1984/85 would include the water returned to recharge the groundwater around the aflaj and evaporated and transpirated ineffectively.

This fact suggests that water use in the mountain area is estimated as about 74 MCM and that water intake control is required around the aflaj to promote the groundwater recharging.

On the other hand, land reclamation has been encouraged in the area along the highway. The newly authorized land acreage is estimated at about 10,000 ha for the period of 1981 to 1984. When these new reclamation areas become water consumers, the water demand is expected to increase by about 169 MCM per year in the near future.

$$V = q \times A \times f = 2{,}258 \text{ mm} \times 10{,}000 \text{ ha} \times 0.75 = 169 \text{ MCM}$$

where, q ; Annual average water used by mixed farms
= 2,258 mm/year
A ; Reclaimed acreage = 10,000 ha
f ; Cropping Ratio = 75%

The water amount to be increased is almost equivalent to the current consumption, and it is expected that the annual water consumption will be doubled from the present level. These figures indicate that effective water resources control and introduction of water-saving farming techniques are required, although their implementation may involve some difficulties.

CHAPTER 5. HYDROLOGIC WATER BALANCE AND WATER RESOURCE DEVELOPMENT POTENTIAL

CHAPTER 5
HYDROLOGIC WATER BALANCE AND WATER RESOURCE DEVELOPMENT POTENTIAL

5.1 Hydrologic Water Balance

5.1.1 Hydrologic Balance Concept

The concept of water balance is based on the law of conservation of mass. The following equation explains the concept.

(Flow-in) - (Flow-out)=Storage change .....(5.1)

Fig.5-1-1 is a diagram of the hydrologic balance concept. Actual cycle is more confused and contains a large number of balance terms. With only observed terms through this project, the water balance equation for one wadi basin would be as follow:

$$P=D+R+E$$
$$R=W+A+I+G \quad \text{.....} (5.2)$$

where
- P: Rainfall
- D: Surface discharge to sea
- R: Groundwater recharge
- E: Evapotranspiration from wadi basin
- W: Water Use
- A: Water movement to/from alien basin
- I: Groundwater discharge to sea
- G: Groundwater storage change

Equation 5.2 contains the terms which should be established through continuous observation. Evapotranspiration (E) and Water movement to/from alien basin (A) are the terms.

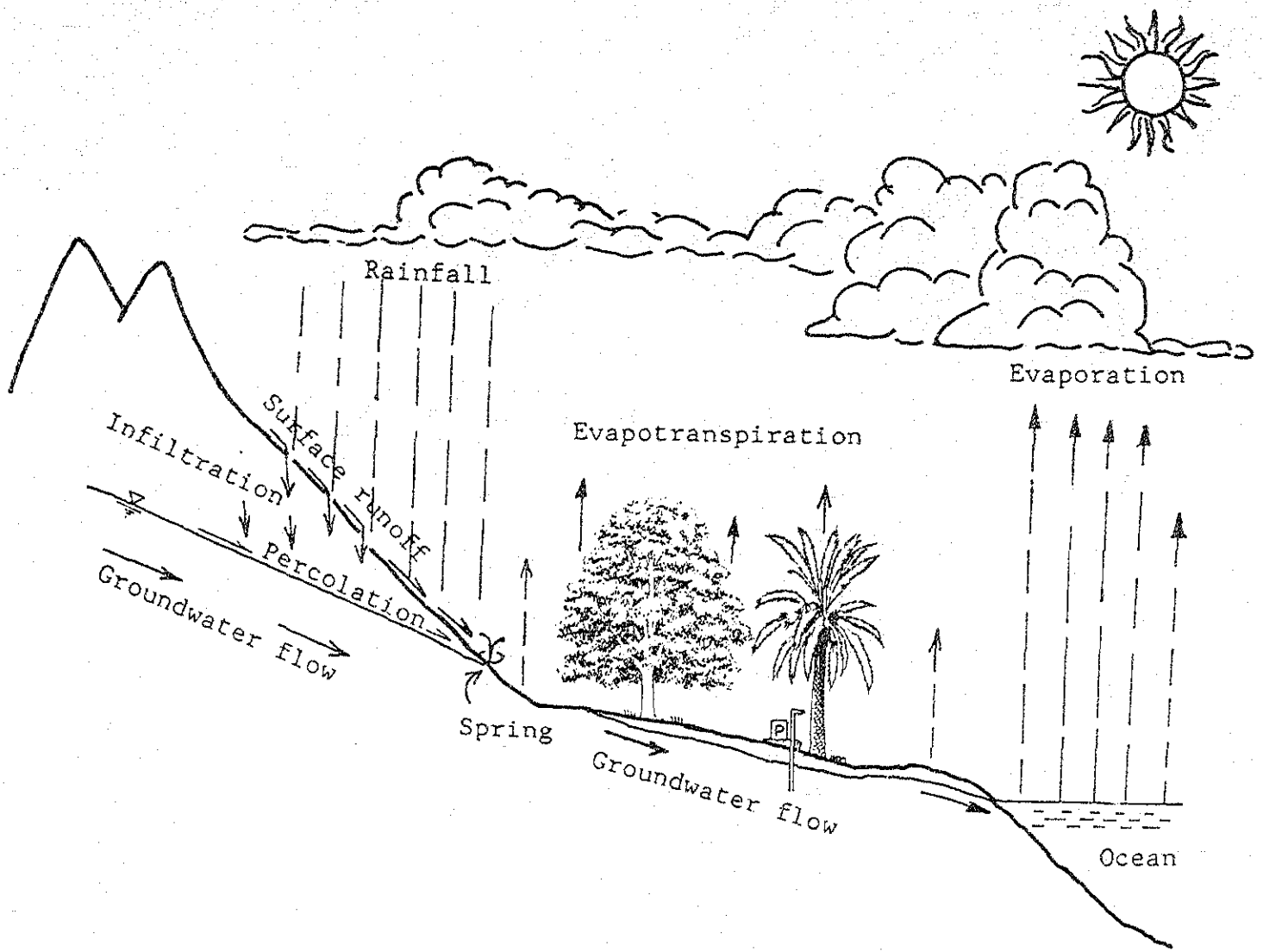
Water balance terms were estimated depending on devided two streams in a basin, upper stream (mountain area) and lower stream (coastal area) in this project. Because the project area seems to be devided into two areas from the point of topology and meteorology. In addition, the location of wadi gauges which were installed through this project were decided on that idea as shown Fig. 5-1-2. Table 5-1-1 lists such water balance terms.

Table 5-1-1 Terms of the Hydrologic Cycle

Symbol	Terms	Remarks
Pi	rainfall	
Di	surface discharge to sea	i = 2 only
Ri	groundwater recharge	
Ei	evapotranspiration from wadi basin	
Wi	water use	
Ai	groundwater movement to/from alien basin	
Ii	Groundwater discharge to sea	i = 2 only
ΔGi	groundwater storage change	i = 2 only

Note: Sufix i indicates the district in one wadi basin.
i = 1; upper stream. i=2; lower stream

Fig. 5-1-1 Schematic Diagram of Hydrologic Balance Model



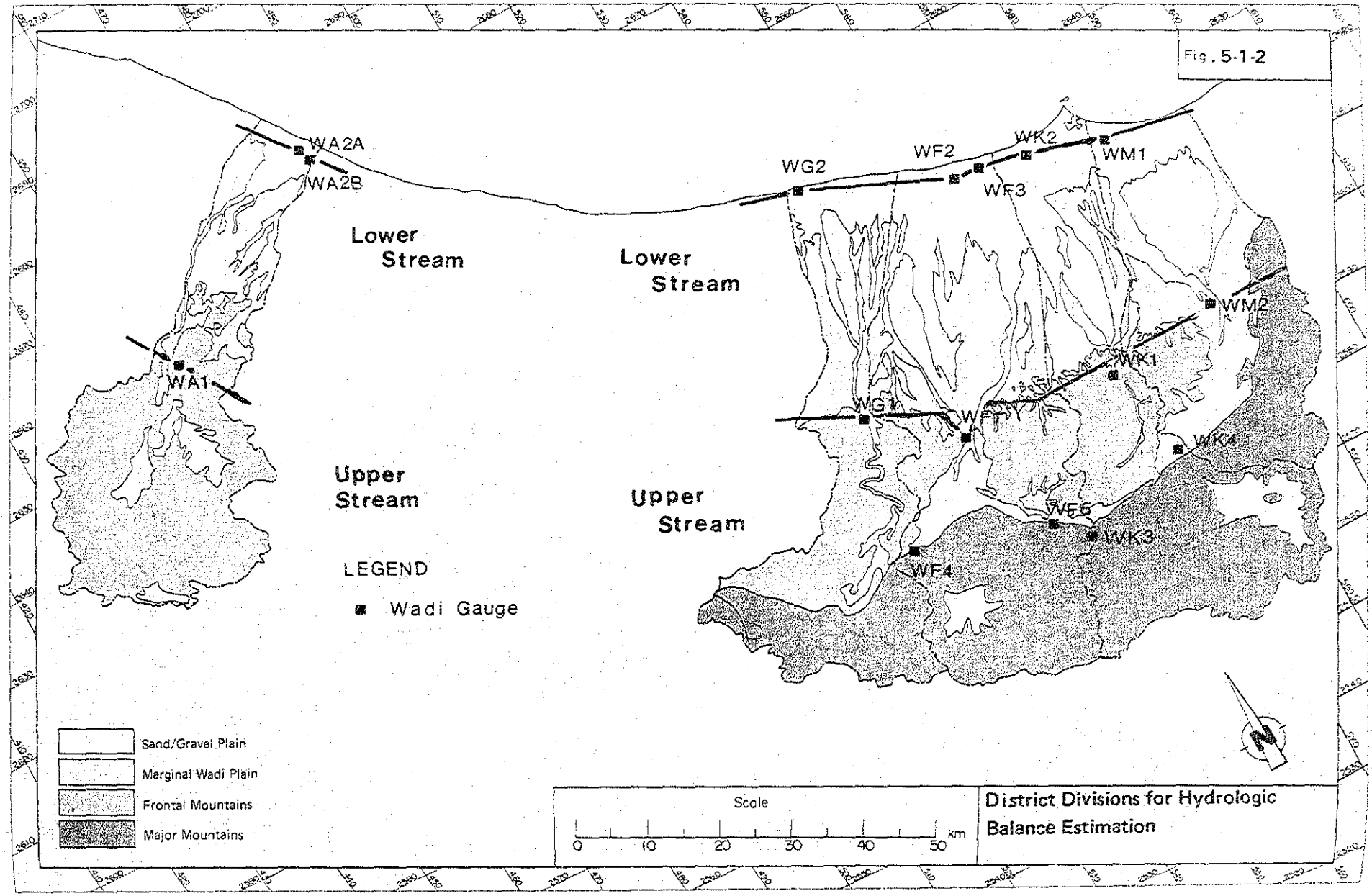


Fig. 5-1-2
WA2A
WA2B
WA1
WG2
WF2
WK2
WM1
WF3
WM2
WK1
WG1
WF1
WK4
WF5
WK3
WF4
Lower Stream
Lower Stream
Upper Stream
Upper Stream
LEGEND
Wadi Gauge
Sand/Gravel Plain
Marginal Wadi Plain
Frontal Mountains
Major Mountains
Scale
0 10 20 30 40 50 km
District Divisions for Hydrologic Balance Estimation

5.1.2 Terms of Hydrologic Balance and Their Computation

Observed terms are enumerated and their computation methods explained in this section.

(1) Rainfall ..... Pi

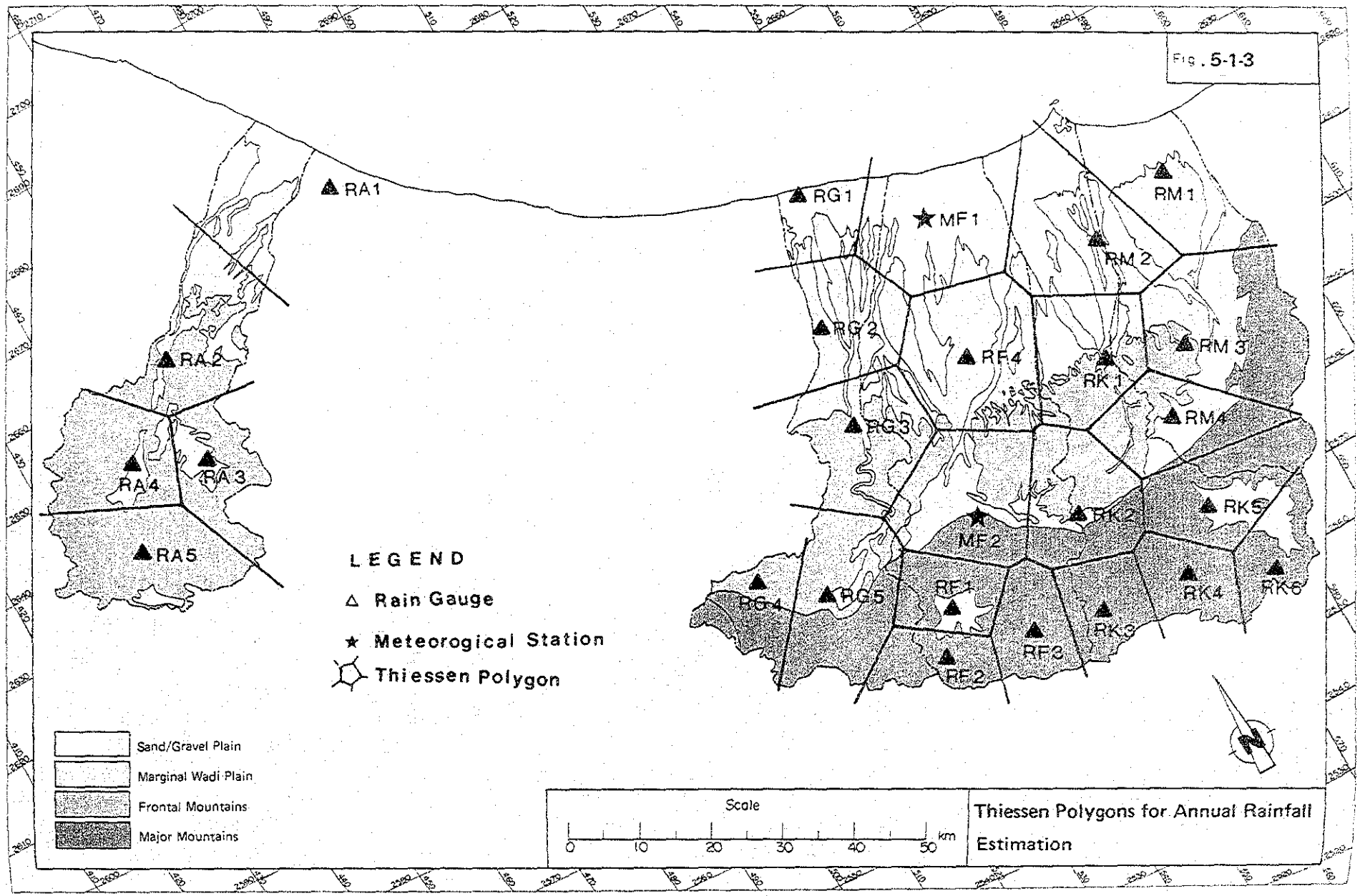
In order to obtain the annual rainfall of the survey area, daily rainfalls from Jan. 1977 to Jul. 1983, have been estimated on the previously observed rainfall data. The method of estimation is explained in Supporting Report B. Fig. 5-1-3 shows the Thiessen Polygon and Table 5-1-2 gives the rainfall volume (MCM/year).

(2) Water use ..... Wi

Observed water use amounts are presented in Main Report 4.6. and Supporting Report E. In this survey, observation was done in terms of intake volume itself and unit water consumptions for water balance were assumed as follows: 3000mm/year (monthly average 250mm/month) with 100% cropping ratio for upper stream (mountain area), 2258mm/year (monthly average 188.2mm/month) with cropping ratio 75% for lower stream (coastal area).

Cropping area is based on Gibb(1976) data regarding the cropping area for 1976 for each wadi basin and the present cropping area as determined during this project. The value of each intervening years was determined by interporation. Table 5-1-4 shows the cropping area and Table 5-1-5 presents the estimation of water use volume in each wadi basin.

Fig. 5-1-3



Thiessen Polygons for Annual Rainfall Estimation

Table 5-1-2 Estimated Results of Annual Rainfall

W. Ahin (MCM/Year)

	77	78	79	80	81	82	83	84	Average
Upper	121.6	81.4	82.5	40.9	55.6	192.1	128.7	21.4	90.5
Lower	43.7	19.1	38.3	7.2	20.1	49.8	42.9	5.6	28.3
Basin	165.3	100.5	120.8	48.1	75.7	241.9	171.6	27.0	118.9

W.B.Ghafir (MCM/Year)

	77	78	79	80	81	82	83	84	Average
Upper	137.0	70.8	78.2	71.2	67.8	238.0	107.1	19.2	98.7
Lower	38.5	9.3	27.0	11.0	18.3	55.3	28.5	6.4	24.3
Basin	175.5	80.1	105.2	82.2	86.1	293.3	135.6	25.6	123.0

W. Al-Fara' (MCM/Year)

	77	78	79	80	81	82	83	84	Average
Upper	172.0	77.4	98.8	90.0	89.8	323.7	129.1	37.8	127.3
Lower	82.4	25.2	58.6	21.3	47.9	146.0	61.8	8.8	56.5
Basin	254.4	102.6	157.4	111.3	137.7	469.8	190.9	46.6	183.8

W.B.Kharus (MCM/Year)

	77	78	79	80	81	82	83	84	Average
Upper	201.6	100.6	94.9	76.2	119.9	322.0	149.9	42.9	138.5
Lower	57.8	26.0	32.0	5.6	34.5	93.0	43.7	6.1	37.3
Basin	259.4	126.6	126.9	81.8	154.4	415.0	193.6	49.0	175.8

W. Al-Ma'awil (MCM/Year)

	77	78	79	80	81	82	83	84	Average
Upper	82.0	38.4	37.7	13.9	49.4	130.4	58.7	3.7	51.8
Lower	75.4	31.9	39.6	6.9	49.0	126.9	63.3	13.2	50.8
Basin	157.5	70.2	77.4	20.4	98.4	257.3	122.0	16.9	102.6

Table 5-1-3 Estimated Unit Water Consumption and Cropping Ratio

	Unit Water Consumption	Cropping Ratio
Upper Stream Area (Mountain area)	3000mm/year 1/	100%
Lower Stream Area (Coastal area)	2258mm/year 2/	75%

Note:

1/ Unit water consumption in upper stream (mountain area) was estimated 3000mm/year (monthly average 250mm/month) based on the observed value 3108mm/year. (1984/1985).

2/ Unit water consumption in lower stream (coastal area) was defined as 2258 mm/year (month average 188.2mm/month).

Table 5-1-4 Estimated Cropping Area

W. Ahin 1/ 2/ (ha)

	76	77	78	79	80	81	82	83	84	Average 3/
Upper	(73.0)	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
Lower	(376.0)	356.6	387.1	417.7	448.3	478.9	509.4	540.0	540.0	49.8
Basin	(399.0)	429.6	460.1	490.7	521.3	551.9	582.4	613.0	613.0	532.8

W.B. Ghafir (ha)

	76	77	78	79	80	81	82	83	84	Average
Upper	(295.7)	296.0	296.4	296.7	297.0	297.3	297.6	298.0	298.0	297.1
Lower	(1509.0)	1554.9	1600.7	1646.6	1692.4	1738.3	1784.1	1830.0	1830.0	1709.6
Basin	(1804.7)	1850.9	1897.4	1943.3	1989.4	2035.6	2081.7	2128.0	2128.0	2006.7

W. Al-Fara' (ha)

	76	77	78	79	80	81	82	83	84	Average
Upper	(754.5)	802.3	850.1	897.9	945.6	993.4	1041.2	1084.0	1084.0	963.6
Lower	(1507.0)	1531.7	1556.4	1581.1	1606.9	1630.6	1655.3	1680.0	1680.0	1615.3
Basin	(2361.5)	2334.0	2406.5	2479.0	2552.5	2624.0	2696.5	2764.0	2764.0	2578.9

W.B.Kharus (ha)

	76	77	78	79	80	81	82	83	84	Average
Upper	(381.4)	365.3	349.3	333.2	317.2	301.1	285.1	269.0	269.0	311.2
Lower	(834.0)	920.6	1007.1	1093.7	1180.3	1266.9	1353.4	1440.0	1440.0	1212.8
Basin	(1215.4)	1285.9	1356.4	1426.9	1497.5	1568.0	1638.5	1709.0	1709.0	1524.0

W. Al-Ma'awil (ha)

	76	77	78	79	80	81	82	83	84	Average
Upper	(499.9)	528.6	557.4	586.1	614.8	643.5	672.3	701.0	701.0	625.6
Lower	(1573.0)	1595.4	1677.9	1760.3	1842.7	1925.1	2007.6	2090.0	2090.0	1873.6
Basin	(2072.9)	2124.0	2235.3	2346.4	2457.5	2568.6	2679.9	2791.0	2791.0	2499.2

1/ Cropping Area in 1976 from Gibb (1976)
2/ Cf. Supporting Table E-2-11
3/ Averaged Cropping Area from 1977 to 1984

Table 5-1-5 Water Use at Each Basin

(Unit; MCM/year)

	Wadi Ahin	Wadi Bani Ghafir	Wadi Al-Fara'	Wadi Bani Kharus	Wadi Al-Ma'awil	Total
Upper 1/ Stream Area	2.2	8.9	28.9	9.3	18.8	68.1
Lower 2/ Stream Area	7.8	29.0	27.4	20.5	31.7	116.4
T O T A L	10.0	37.9	56.3	29.8	50.5	184.5

1/ Water use was estimated as the unit water consumption of 3,000mm/year. cropping ratio is 100%.

2/ Cropping ratio is 75%. Unit water consumption is 2,258mm year.

(3) Groundwater Storage Change ..... ΔG_i

Annual variation of groundwater storage change during the last nine years (from Dec. 1975 to Dec. 1984) in the sand/gravel plain and coastal area were estimated from the hydrographs of observation wells except Wadi Al-Ahin because any long term well hydrographs were not available. Further explanation is explained in Supporting G. Groundwater storage change are presented in Table 5-1-6.

(4) Surface discharge to lower stream ..... D_i

Five surface discharge events to the lower stream area(D_1) were observed from Dec. 1983 to Dec. 1984. However there is no available data for the period from Jan. 1977 to Nov. 1983, nor is there data on discharge to the sea(D_2). Eventually as mentioned in Main Report 4.2 estimation by Horn (1979) was adopted.

(5) Subsurface discharge to lower stream .... I_i

Subsurface discharge to the lower stream area (I_1) was not estimated. Surface discharge to the sea (I_2) of wadi were estimated from the hydraulic gradient along the wadi bed surveyed in 1985. Subsurface discharge was confirmed only in Wadi Ahin as in Table 5-1-7.

Table 5-1-6 Estimated Results of Annual Groundwater Storage Change

W.Ahin (MCM/Year)

	76	77	78	79	80	81	82	83	84	Average
Upper	-	-	-	-	-	-	-	-	-	--
Lower	-	-	-	-	-	-	-	-	1.07	1.07

W.B. Ghafir (MCM/Year)

	76	77	78	79	80	81	82	83	84	Average
Upper	-	-	-	-	-	-	-	-	-	-
Lower	-1.49	-1.06	0.78	0.88	-0.44	1.38	-0.25	-2.93	0.69	-0.23

W.Al-Fara' (MCM/Year)

	76	77	78	79	80	81	82	83	84	Average
Upper	-	-	-	-	-	-	-	-	-	-
Lower	-0.92	-0.98	1.23	0.28	-0.88	0.86	-0.56	-8.55	0.77	-1.05

W.B.Kharus (MCM/Year)

	76	77	78	79	80	81	82	83	84	Average
Upper	-	-	-	-	-	-	-	-	-	-
Lower	0.66	-0.26	-0.56	0.39	0.81	-0.12	-1.25	-1.80	-0.93	-0.41

W.Al-Ma'awil (MCM/Year)

	76	77	78	79	80	81	82	83	84	Average
Upper	-	-	-	-	-	-	-	-	-	-
Lower	-1.18	-1.29	-1.22	1.54	1.68	0.30	-1.20	-2.93	4.02	-0.03

Table 5-1-7 Subsurface Discharge to the Sea

Unit:MCM/year

	Wadi Ahin	Wadi Bani Ghafir	Wadi Al-Fara'	Wadi Bani Kharus	Wadi Al-Ma'awil
Subsurface Discharge to sea	5.1	0.0	0.0	0.0	0.0

Calculation of the discharge can be explained as following:

$D = IxTxBx365 \text{ days}/10^6$

where D = Subsurface discharge to sea (MCM/Year)
I = Hydraulic gradient
T = Transmissibility (m^2/day)
B = Width of the coastal aquifer (m)

$D = 5.4 \times 10^{-4*} \times 2600 \text{ m}^{2*}/\text{day} \times 10000 \text{ m} \times 365 \times 10^{-6}$
$= 5.12$
$\doteq 5.1$ (MCM/Year)

* Refer to Main Report 4.3

5.1.3 Hydrologic Water Blance in the Survey Area.

Hydrologic water balance in the survey area was estimated as Table 5-1-8 with direct observed terms except surface discharge to the sea. Through this section, its further details would be explained.

(1) Rainfall

In previous studies, the most important term-rainfall-had never been precisely defined because of the lack of a rain gauge network. However, based on our newly installed observation network and estimation, the mean annual rainfall seems to be almost 120mm/year over the Survey area. The wadi basin with the most plentiful rainfall volume is Wadi Al-Fara', Wadi Bani Kharus, Wadi Bani Ghafir, Wadi Ahin, and Wadi Al-Ma'awil follow in that order.

(2) Water use

Estimation of water use volumes for each wadi basin were calculated based on the unit water consumption, 3000mm/year for upper stream (mountain area) and 2258mm/year for lower stream (coastal area). This volume is defined as part of the evapotranspiration in the hydrologic cycle. The ratio of this volume to rainfall is highest in Wadi Al-Ma'awil (49.3%) followed by Wadi Bani Ghafir and Wadi Al-Fara' (almost 30%) for each. All of the origin for water use depends on the groundwater although the different intake method Falaj and pump. This means, the ratio of groundwater recharge to rainfall should be more than 30% of maintain the input/out water balance. Water resources in this area will be exhausted if the actual ratio is less than 30%. The exact ratio should be analyzed for effective long term water resources planning.

(3) Groundwater storage change

Groundwater storage in 4 wadis, excluding Wadi Ahin, is tending to decrease. All of the observation wells, locate only in the sand/gravel plain and coastal area. For four wadis, the volume of sea water coming into subsurface water has never been analyzed.

(4) Surface water discharge to sea.

This term quoted the estimations by Horn. Wadi Al-Ma'awil has the lowest ratio to rainfall (0.4%). Others belong the range of 2% $\sim$ 5%.

(5) Remainder

Main water balance terms belonging to remainder are as follows: evapotranspiration from wadi basin, groundwater movement to/from alien basin, sea water into subsurface groundwater and so on. The ratio of the remaining terms to rainfall is from 50% to 80% over the five wadis. Hydrologic observation has just started and these terms should be studied through continuous observation.

Table 5-1-8 Hydrologic Cycle in the Survey Area

Unit: upper; MCM/year
lower; (%)

Wadi Basin	Wadi Ahin	Wadi Bani Ghafir	Wadi Al-Fara'	Wadi Bani Kharus	Wadi Al-Ma'awil	Total
Rainfall P	118.9 (100.0)	123.0 (100.0)	183.8 (100.0)	175.8 (100.0)	102.5 (100.0)	704.0 (100.0)
Water Use * W	10.0 (8.4)	37.9 (30.8)	56.3 (30.6)	29.8 (17.0)	50.5 (49.3)	184.5 (26.2)
Groundwater Storage Change ΔG	+1.07 (+0.9)	-0.23 (-0.2)	-1.05 (-0.6)	-0.41 (-0.2)	-0.03 (-0.03)	-0.65 (-0.09)
Surface Water discharge to sea D	5.5 (4.6)	4.5 (3.7)	4.1 (2.2)	5.4 (3.1)	0.4 (0.4)	19.9 (2.8)
Groundwater discharge to sea I	5.1 (4.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Remainder **	97.23 (81.8)	80.83 (65.7)	124.45 (67.7)	141.01 (80.2)	51.63 (50.4)	495.15 (70.3)

Note:

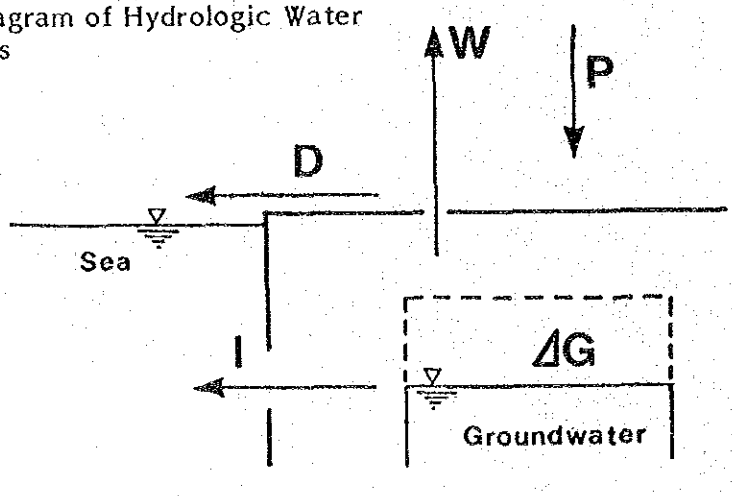
* Unit water consumption for the water use calculation:

Upper stream (Mountain area) ; 3000 mm/year

Lower stream (Coastal area) ; 2258 mm/year

** Remainder contains terms such as natural evapotranspiration from wadi basin, groundwater to/from alien basin and sea water into subsurface water.

Schematic Diagram of Hydrologic Water Balance Terms



5.2 Water Resources Development Potential

5.2.1 Available Water Resources

The available water resources for development will be the flood waters and subsurface outflows to the sea. The amount of possible water resources which are estimated from the hydrologic water balance of nine years (from 1976 to 1984) in the Project area are as follows:

(1) Flood Water

Floods large enough to flow the sea are expected several times in an ordinary year; however, none were observed during the Project period.

Several estimations for the amount of flood outflow to the sea were made by Gibb (1976), ILACO (1976), Horn (1979) and others. However they contain many assumptions because of the lack of hydrologic data.

During the Project, data on the annual basin rainfalls for eight years (from 1977 to 1984) were prepared. The flood outflows calculated by Horn which was used in the hydrologic water balance, was 19.9 MCM/year in the Project area, and 2.83% of the average annual rainfall amount (704.1 MCM/year).

Regarding flood water runoff to the sea, further surveys and studies are required since such data is indispensable for long range planning.

Estimation of Surface Discharge to the Sea
(Assumed with 2.83% of Rainfall)

Unit: MCM/year

Wadi Basin	Wadi Ahin	Wadi Bani Ghafir	Wadi Al-Fara'	Wadi Bani Kharus	Wadi Al-Ma'awil	Total
Rainfall	118.9	123.0	183.8	175.8	102.5	704.0
Discharge to the sea	3.4	3.5	5.2	5.0	2.9	19.9
Estimation by Horn	5.5	4.5	4.1	5.4	0.4	19.9

(2) Groundwater

The groundwater outflow of Wadi Ahin is estimated as 5.1 MCM/year and supposed to have potential for groundwater resources development.

The other four wadi basins are not believed to have further development potential since they show a deficit balance of groundwater storage during nine years (from 1976 to 1984).

5.2.2 Rationalization of Water Use

The amount of current water use in the coastal area was estimated 115.2 MCM/year and it seems already overuse. The demand for new developing area (10,070 ha) is estimated 170.6 MCM/year (with the unit water consumption 2258 mm/year, cropping ratio 75%). The amount of water use in the project area will be 285.8 MCM/year, exceeding by far the available water resources in the Project area.

Considering the limited available water resources, it is indispensable to rationalize the current water use methods. By rationalization of irrigation methods, water use efficiency should be increased to near the maximum, from 40% efficiency level to 80% efficiency levels.

Relationship between Water Use Efficiency and the Water Demand

	Water Demand		
Water use Efficiency	40%	60%	80%
Current Farm (7,580 ha)	115.2 MCM	76.8 MCM	57.6 MCM
New Farm (10,070 ha)	170.6	113.7	85.3
Total	285.8	190.5	142.9

It is indispensable to carry out the study for the relation between unit duty water and irrigation methods in the Project area. The relationship between irrigation methods and their irrigation efficiency from FAO reports are shown in the following table:

Irrigation Method and its efficiency

Irrigation Method	Efficiency (%)
Spray irrigation method	60 - 80
Basin method	45 - 75
Furrow irrigation method	40 - 65

SOURCE: FAO Irrigation and drainage Paper 38 (1980). Drainage design factors.

5.2.3 Development Order

The development prioreity order should be decided based on the results of further studies of flood runoff data and aquifer structures in order to be most accurate.

Wadi drainage basin characteristics are summarized in Table 5.2.1. Regarding development priority, the following points are mentioned:

- Wadi Al-Fara' and Wadi Bani Kharus have a large potential annual rainfalls and so a larger scale of flood is expected.

- Wadi Al-Ma'awil has a relatively large non-infiltration area in the gravel plain. Due to this high runoff coefficient, a bigger runoff in the coastal area is expected.

- Wadi Ahin still has surplus groundwater development potential because of its estimated subsurface runoff (5.1 MCM/year).

Table 5-2-1 Summary of Wadi Basins

ITEMS \ WADI BASIN		Wadi Ahin	Wadi Bani Ghafir	Wadi Al-Fara'	Wadi Bani Kharus	Wadi Al-Ma'awil	Total
Drainage Area	(km^2)	1127.5	951.9	1,546.8	1,292.3	1,029.8	5,948.3
Mountenous Drainage Area	(Km^2)	7658.3	591.1	698.2	750.6	319.1	3,127.3
Sound/Gravel Plain Drainage Area	(Km^2)	359.2	360.8	848.6	541.7	710.7	2,821.0
Mean Annual Rainfall	mm/year MCM/year	106.3 (118.9)	132.0 (123.0)	121.0 (184.8)	141.0 (175.8)	102.6 (102.5)	121.1 (704.0)
" in Mountain Area	mm/year MCM/year	118.4 (90.5)	151.9 (98.7)	151.3 (127.3)	164.4 (138.5)	121.5 (51.8)	143.8 (506.8)
" in Sand/Gravel Plain	mm/year MCM/year	80.1 (28.3)	86.3 (24.3)	83.4 (56.5)	92.6 (37.3)	88.5 (50.8)	86.1 (197.2)
Annual Sunface Discharge to Sea (by HORN)	MCM/year	5.5	4.5	4.1	5.4	0.4	19.9
Groundwater Discharge to Sea	MCM/year	5.1	0.0	0.0	0.0	0.0	5.1
Groundwater Storage Change	MCM/year	+1.07	-0.23	-1.05	-0.41	-0.03	-0.65
Current Farm Area (Total)	(ha)	613	2,128	2,764	1,709	2,791	10,005
Current Farm Area (Mountain Area)	(ha)	73	298	1,084	269	701	2,425
Current Farm Area (Coastal Area)	(ha)	540	1,830	1,680	1,440	2,090	7,580
Estimated Water Use	mm/year	9.1	38.4	37.9	23.2	51.9	31.8
(TOTAL)	MCM/year	(10.3)	(36.6)	(58.7	(30.0	(53.4)	(189.1)
Estimated Water Use	mm/year	1.9	9.2	21.5	6.3	21.0	12.4
(Mountain Area)	MCM/year	(2.1)	(8.8)	33.2)	(8.1)	(21.6)	(73.9)
Estimated Water Use	mm/year	7.2	29.2	16.4	16.9	30.9	19.4
(Coastal Area)	MCM/year	(8.2)	(27.8)	(25.5)	(21.9)	(31.8)	(115.2)
Current Source of Irrigation Water in Mountain Area		Falaj	Falaj	Falaj	Falaj	Falaj	—
Current Source of Irrigation Water in Coastal Area		Pump-up	Pump-up	Pump-up	Pump-up	Pump-up	—
Newly Registered Farm	(ha)	1,240	1,540	2,970	1,700	2,620	10,070
Water Demand for * New Farm	MCM/year	21.0	26.1	50.3	28.8	44.4	170.6
Water Demand for Future	mm/year	27.8	65.9	70.5	45.5	95.0	60.5
Irrigation	MCM/year	(31.3)	(62.7)	(109)	58.8)	(97.8)	(359.7)

Note: *Unit Water Consumption 2258 mm/year, cropping ratio 75%

CHAPTER 6. CONCLUSION AND RECOMMENDATION

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Reclamation of new farm land is increasing in the Batinah coast area. It is remarkable that the continuation of the current progress rate of water use will cause the development of salinity problems in the coastal area.

The four wadi basins: W.B. Ghafir, W. Al-Fara', W.B. Kharus and W. Al-Ma'awil, are not supposed to have further development potential in groundwater, considering the deficit balance of groundwater storage during nine years (from 1976 to 1984), and the increase in EC values in some coastal areas.

For increasing groundwater resources in the Batinah coast, it is recommended to make effective use of flood water which flow into the sea, using dam-type structure which will recharge the flood water into the wadi alluvium and increase groundwater resources.

The location of recharging structures should be planned based on the results of runoff analysis and hydrogeological survey.

In order to cope with the regional scarcity of water resources and the development of salinity problems, it is indispensable to economize water use for irrigation, in addition to develop the surface water runoff to the sea into recharging water for groundwater.

Before implementation of any water resources development scheme, it is indispensable to evaluate the technical and economic feasibility of it. For evaluating any project, a new agricultural census should be prepared in line with hydrological data.

6.2 Recommendations

Based on the conclusions, it is recommended for the Government of Oman to undertake the followings:

1. Continuation of hydrologic observation and improvement of hydrological observation networks.

2. Execution of water resources development scheme

3. Groundwater conservation and rationalization of water use

4. Others

The items and flow for further studies are summarized in Fig. 6.2.1

6.2.1 Continuation of Hydrologic Observation and Improvement of Hydrological Observation Networks

For future water resources development and groundwater conservation, it is indispensable to continue of perform hydrological observation. Since hydrological conditions fluctuate yearly, 10 years are the minimum conventional planning term adopted widely for formulating a dependable water resources development scheme. For carrying out the proper observations, the following recommendations are made:

1) To increase necessary staff and to strengthen the organization for the observation and maintenance of the hydrologic observation network.

In order to continue properly the observation and maintenance of the hydrologic observation network, at least following number of staff should be increased.

	Current Staff	Required Increase
1. Overall supervisor	1	-
2. Field operation personnel	4	2 (junior staff)
3. Office operation personnel	-	3 (Senior technical staff)
4. Administration personnel	-	1
Total	5	6

2) To have the staff follow the observation and maintenance manual properly.

To the observation works, it is important to have the staff follow the proper method of the observation and maintenance. It is indispensable to follow the observation and maintenance manual which was prepared by the survey team.

It is also recommended to make use of the checklists of observation and maintenance which were prepared by the Project for the purpose of accurate data collection. The checklists have to be filled the record of the conditions of each observation.

3) To continue on-the-job training

It is necessary for the staff to improve observation skills and to expand their scientific knowledge for hydrological observation. Specific advisors or experts might participate periodically in the training for the time being.

The technical staff should be educated in accordance with particular responsibilities expected, and sent for higher education.

4) To compile yearbooks of hydrological data

Yearbook should be compiled to keep data properly and to contribute not only to the development of water resources but also other fields.

5) To improve the hydrologic network

The meteorology, rain gauge and wadi gauge networks installed by the Project should be maintained properly. However observation networks for conservation of water resources and water use rationalization in the coastal should be improved during the next stage.

The density of rain gauges should be reviewed after several years observation for water resources development purposes.

For monitoring salinization in the coastal area, at least 4 monitoring wells are required at each wadi. As for rationalization of water use, cumulative flow meters for approx. 10% of the production wells are recommended to be installed.

The old observation wells which have been deteriorated and lost their original depth, should be repaired at some suitable occasion in the future

The mid-plain contains a hydrogeologic structure which still has not been probed into detail. Two (or three) observation wells should be drilled at each wadi basin.

6.2.2 Execution of Water Resources Development Scheme

Before starting a water resources development scheme, it is necessary to prepare such basic long-term hydrological data including numbers of floods, hydrogeological conditions and topographic map (1:5,000 or 1:10,000).

In order to promote groundwater recharging schemes at each wadi basin, the following recommendations are made:

1) To carry out supplementary hydrogeological surveys

Hydrogeological survey for obtaining supplementary hydrogeological conditions, hydraulic properties of aquifers and supplementary aquifer stratigraphy drilling works with pumping tests should be carried out.

2) To set up study for flood data and groundwater recharging schemes

Hydrological analysis of floods flowing into the sea, and the scale of groundwater recharging schemes and their locations should be studied.

The Lower reach of each wadi likely has a good possibility for the location of groundwater recharging scheme, because the area with a comparatively high infiltration capacity is most limited to the area along wadi beds and the young deposits along the coastal strip.

3) To carry out sediment discharge survey

Judging from topographic and land cover conditions, a large sediment discharge is presumed to occur during large floods. Therefore, the potential of sediment discharge should be studied.

4) To carry out the study for water resources development schemes including the following:

1. Basic survey for recharging scheme structure plan

- Topographic survey for structure plan (1/1,000 - 1/2,000)
- Geological survey
- Structure planning survey
- Socio-economic survey

2. Project evaluation

3. Implementation program

6.2.3 Groundwater Conservation and Rationalization of Water Use

It is an urgent task to formulate effective use of the existing water resources to cope with the increasing demand for irrigation water and the salinity problems in the coastal area.

Rationalization of water use should be carried out for stopping the increase of salinity problems and economizing the current agricultural water use.

For demonstration of feasibility, establishment of farm practices and management practices, it is recommended to undertake pilot schemes on

selected areas.

For execution of rationalization of water use, the following recommendations are made:

1) To carry out more intensive water use survey

1. To improve the observation network

- Improvement of groundwater salinization monitoring system in the coastal area.
  (4 monitoring wells in one wadi basin)

- Improvement of water use observation in the pilot scheme area.
  (Fixation of cumulative flow meter on 10% production well)

2. To carry out the survey for drawing up well location map (1/5,000 - 1/10,000)

3. To install cumulative flow meters to pumps (approx. 10% of the total number) sampled in pilot scheme areas, and to carry out water use survey (irrigation area, used amount and quality of water).

4. To carry out the questionnaire survey for current salinity problems in the coastal area.

2) To carry out water use rationalization scheme

1. To study on water use efficiency

For rationalization of water use, it is necessary to improve current irrigation methods in order to minimize loss in the system or to introduce more efficient and more productive irrigation methods such as localized system, which will enable production of vegetables plus tree-crops, as major crops.

Before introducing any improvement or different irrigation methods, both technical and socio-economic considerations should be assessed based on the quality and quantity of the basic resouces: water, land, labour, investment capital and their inter-relationship with the desired level of agricultural production.

2. To study on farm water management for application of rationalized water use.

   In the coastal area, management of wells belongs to individuals, however in the mountain area, management of a falaj system is usually done by a community (one village or a group of villagers).

   For adjusting demand and supply of irrigation water and conserving water quality, a suitable collective or cooperative management system in parallel with an effective use of the water resources should be studied.

3. To carry out the study for rationalization of water use.

   Based on the survey results, necessary improvement of irrigation system and facilities should be planned. For the purposes the following surveys are required:

   - Topographic survey for structure plan (1/1,000 - 1/2,000)
   - Soil survey
   - Agro-economic survey
   - Socio-economic survey

4. To evaluate the Project

   The economic and social impacts by the pilot scheme should be analyzed to determine the feasibility of the plan.

5. Impelementation program in line with preparation of implementation program for detailed design and construction stages.

The technical and administration organization of the project needs to be considered to demonstrate management practices and farm practices.

Essential services in the organization will be as follows:

1. Administration
2. Facility management
3. Laboratory facilities

3) To carry out the study for groundwater conservation

It is remarkable that the continuation of the current progress rate of water use will cause the salinity problems in the coastal area. It will be indispensable to establish the comprehensive water management. As the counterplans, the studies are to be carried out as follows:

1. To study the groundwater simulation model.

2. To study the water management organization for the groundwater conservation.

6.2.4 Others

1) To carry out rationalization of water use in falaj area and survey for rehabilitation of falaj systems including the following:

The amount of water taken from the falaj in the mountain areas and gravel plains has a large seasonal fluctuation. It is necessary to establish some measures for efficient water use to meet minimum requirements and to increase the water sources so as to secure the necessary water amount during a drought season. The survey for falaj systems should be carried out at selected area. The following recommendations are made:

1. Survey for falaj system location map (1/5,000 - 1/10,000)

2. Survey for the current water use

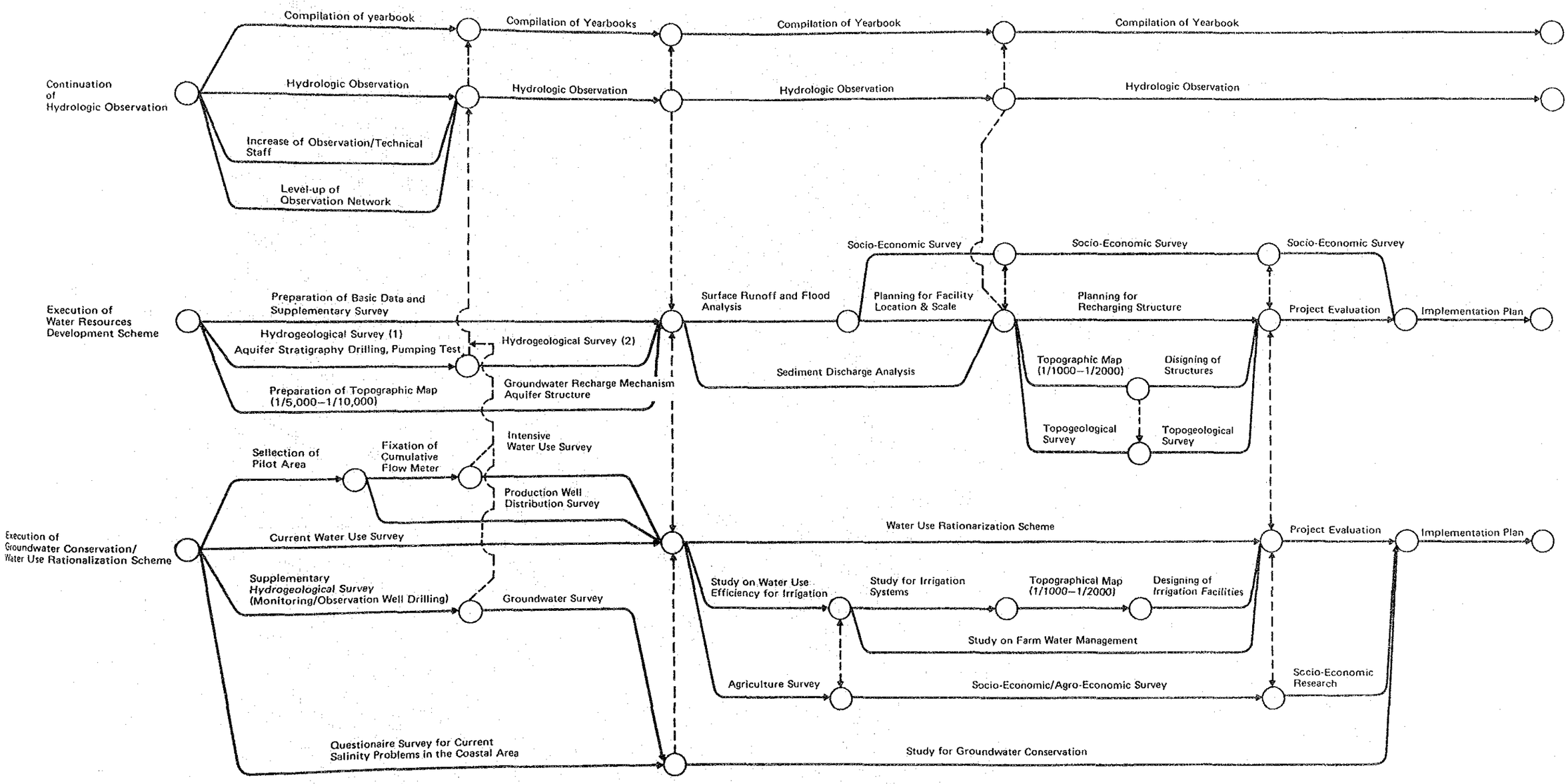
   - Irrigation area
   - Distribution canal discharge
   - Surplus water at falaj tails

3. Questionnaire survey for the problems in falaj systems.

2) To prepare a new agricultural census

The last agricultural census was published in 1979. New agricultural census will be indispensable to evaluate any agricultural development projects. The early publication of a new agricultural census is recommended.

Fig. 6-2-1 Flow Chart for Further Studies



APPENDICES

APPENDIX A List of Officials Concerned

"Member of the Project Team"
Member of Advisory Committee

NAME		1982/1983	1983/1984	1984/1985	1985/1986
(CHAIRMAN)					
Mr. SADAMICHI Shigemi	Ministry of Construction	o	o	o	
Dr. ISHIZAKI Katsuyoshi	Ministry of Construction			o	o
(MEMBER)					
Mr. FURUI Shigehiro	Ministry of Construction	o	o	o	
Mr. TADA Toshikazu	Ministry of Construction	o	o	o	o
Mr. NAGAOKA Masatoshi	Ministry of Construction	o	o	o	o
Mr. MORITA Masashi	Ministry of Agriculture, Forestry and Fisheries	o	o		
Mr. TSUJI Seiichi	Ministry of Agriculture, Forestry and Fisheries			o	o
Mr. KUROKAWA Mutsuo	Ministry of Agriculture, Forestry and Fisheries	o	o		
Dr. SUGAWARA Toshio	Ministry of Agriculture, Forestry and Fisheries			o	o

Member of Survey Team

NAME	ASSIGNMENT	1982/ 1983	1983/ 1984	1984/ 1985	1985/ 1986
Dr. ITO Shosuke	Team Leader	o			
Mr. TANAKA Makoto	Team Leader		o	o	o
Mr. TANAKA Hajime	Acting Team Leader		o	o	o
Mr. YOSHIKAWA Mitsuru	Ground-Water Conservation Planning	o	o	o	
Mr. USHIKI Hisao	Hydro-geological/ Geo-chemical Survey	o	o	o	o
Dr. MATSUDA Masuyoshi	Hydro-meteorological Survey	o	o	o	o
Mr. SAKAMOTO Takao	Hydrological Survey		o	o	o
Mr. SHIONO Yutaka	Hydrological Survey		o		
Mr. SUZUKI Seishiro	Hydrological Survey			o	o
Mr. SUIZU Shigeo	Hydro-meteorological Survey		o	o	o
Mr. ISENO Daizo	Water-Use Survey	o	o	o	o
Mr. DOKIYA Tetsuo	Land-Use Survey		o	o	o
Mr. OHCHI Minoru	Geo-electric Sounding		o		
Mr. KATO Izumi	Geomorphologial Survey		o	o	o
Mr. OSHIKA Yusuke	Boring Supervision	o		o	
Mr. AMATSUJI Yasuhiro	Ground-Water Analysis			o	
Mr. UEDA Tsunehisa	Remote Sensing for Water/Land Use	o			
Mr. GOMI Yoshitaka	Remote Sensing for Environmental Assessment	o			
Dr. NASU Mitsuru	Remote Sensing Analysis		+	+	o
Mr. ISHII Kouichi	Administration		o	o	

Note: o Field and Domestic assignment
+ Domestic assignment

Project Counterparts

NAME	FUNCTION	1982/ 1983	1983/ 1984	1984/ 1985	1985/ 1986
Mr. Majid bin Bilarab Al-Batashi	Project Officer	o	o	o	o
Mr. Saeed bin Salim Al-Bady	Senior Counterpart	o	o	o	
Mr. Mohammed bin Ghalib Al-Kishiri	Senior Counterpart (Temporary)		o	o	
Mr. Hilal bin Malik Al-Batashi	Senior Counterpart (Temporary)				o
Mr. Ali bin Salim Rafeet	Junior Counterpart		o	o	
Mr. Habib bin Suleiman Al-Sharji	Junior Counterpart		o	o	o
Mr. Nasser bin Said Al-Rawahy	Junior Counterpart		o	o	o
Mr. Juma bin Hamood Al-Maskery	Junior Counterpart		o	o	o
Mr. Sultan bin Abdullah Al-Khanjari	Assistant			o	o
Mr. Hilal bin Salim Khalfan Al-Rahby	Junior Counterpart				o

"Government Officials and Others Concerned"

Ministry of Agriculture and Fisheries (MAF)

H.E. Abdul-Hafiz bin Salim bin Rajab	The Minister
H.E. Hassan bin Abdulla Al-Morazza	The Under-Secretary
Mr. Ahmed bin Salem Al-Shanfari	Director General of Planning Unit
Mr. Omar bin Saeed Al-Marhoon	Director General of Diwan
Dr. Alam Al-Huda Hammad	Advisor to MAF (resigned Apr. 1983)
Mr. Mohamed bin Reda bin Hasen	Director General of Agriculture
Mr. Abdullah bin Hamadan Al-Wahaibi	Director General of Water Resources and Irrigation
Mr. Abdullah Al-Ogeli	Director of Legal Dept.
Mr. Zakarya bin Yahya Al-Riyami	Director of Water Resources
Mr. Abdel Mohsen bin Saleh Reidan	Director of Irrigation
Mr. Ahnaf Al-Zubeidi	Director of Agriculture Affairs
Mr. Ali Al-Amri	Director of Statistics
Mr. Abdul-Hakim bin Ali Al-Zedgali	Director General of General Service
Mr. Mohammed bin Mukhtar bin Mohammed	Director of Transportation
Dr. Wafai T. Saleh	Financial Expert/JICA Project Co-ordinator
Mr. Hassan Shehatta	Economic Expert, Planning Unit, MAF
Mr. Wazir Hassan	Agriculture Expert, Planning Unit, MAF
Mr. Hamed bin Zaki	Admin. Co-ordinator, Planning Unit, MAF
Mr. Ali bin Shehadad Al-Baluchi	Technical Assistant, DGWRI
Mr. Salim bin Said Al-Hadrami	Technical Assistant, DGWRI
Mr. Hilal bin Malik Al-Batashi	Technical Assistant, DGWRI
Dr. Naim Abdul-Rahman	Senior Expert, DGWRI
Mr. Othman Mukhtar	Senior Expert, DGWRI
Mr. Rifat Abu-Al-Magd Abu-Saya	Hydrologist, DGWRI

Mr. Kattepur Narayana Rao Krishna Murthy	Engineer/Hydrologist, DGWRI
Mr. Aziz Abbas	Hydrogeologist, DGWRI
Mr. Bernard Blasco	Hydrogeologist, DGWRI
Mr. Ezzedin Mohammed	Geologist, DGWRI
Mr. Said Hamdi Besiso	" "
Mr. David Read	FAO Advisor, DGWRI (resigned Dec. 1982)
Mr. Ayadurai Somesan	FAO Advisor, DGWRI (resigned Dec. 1982)
Mr. Abu-Bakr Waziri	Minister's office
Mr. Salim bin Ali Al-Rawahy	In-Charge, Soil Water Laboratory Agriculture Research Center in Rumais
Mr. Mustafa Muradh	Soil Scientist, Soil Water Laboratory Agriculture Research Center in Rumais
Mr. Abdul-Rahman Ali	"

Rustaq

Mr. Masoud bin Abdullah bin Saleh	In-Charge of Rustaq Agricultural Extention Center

Musana'ah

Mr. Mohammed Fathi Mustafa	Agriculture Extension Engineer Musana'ah Agriculture Extension Center

Sohar

Mr. Ali bin Salim bin Rashid	Director, Agriculture Office in Sohar
Mr. Hussain bin Abdul-Rahim	Technical Assistant, DGWRI
Mr. Mohammed bin Nasser	Technical Assistant, DGWRI

Public Authority for Water Resources (PAWR)

Dr. Robert H. Dale	Technical Secretary (resigned Sep. 1983)
Mr. William Doyel	Manager, Surface Water Dept.
Mr. Richard P. Thomas	Surface Water Department

Mr. Benjamin R. Hudson	Manager, Groundwater Exploration Department
Mr. Donald Davison Jr.	Chief, Groundwater Exploration Dept. Seeb (field) Office
Mr. Richard Anderson	Groundwater Exploration Dept. Seeb (field) Office
Mr. Charles G. Graf	Groundwater Exploration Dept. Sohar Office
Mr. Roger MacClafin	Manager, Aerial Phot Department
Mr. Steve Luxton	Contracts Manager

Ministry of Electricity and Water

H.E. Seif bin Salim Al-Maamary	The Under-Secretary (At post in 1982)
Mr. Abdul-Aziz bin Hashem bin Abd	Director, Directorate of Rural Water Supply
Mr. N. P. Subramanian	Chief Engineer, Directorate of Planning and Project
Mr. Aminul-Islam	Acting Director of Technical Affairs, Directorate General of Water
Mr. Osman El-Amin Ahmed	Deputy Director of Technical Affairs, Directorate General of Water