cropping area of 4,584 ha (the gross area is 6,181 ha) and the actual irrigation application of $33m^3$/day /ha (3.3 mm/day) which was drived by the sample farm survey made by the team and other previous experiments and other conditions.

A further discrepancy in both the studies was the methodology of study as well. IWACO applied a method in the conventional equation filling necessary components drived by a number of assumptions. As previously stated, the JICA team adopted a mathematical simulation model.

The parameters of model were verified and defined by the actually investigated aquifer structure and the hydrologic behavior in the time-series observatory records of daily rainfall, groundwater hydrographs, floods and so forth.

4.6.5. Simulation

(1) Condition of Simulation

For the purpose of evaluation of groundwater resources, the following four cases were applied to the present Study:

Case	Amount, Strength and Location of wells of Groundwater Draft	Marginal Groundwater Head on Basin Management	Groundwater Augment Facility
Case 1	1. Maintain amount (1995) of current groundwater draft. 2. Maintain current pumping strength and well location.	1. Economical marginal depth of pumping: set on 300 m as pumping depth.	Out of consideration.
Case 2	1. Maximum amount of groundwater draft on marginal Groundwater head. 2. Optimum strength and well location to obtain the maximum.	1. Maintain groundwater head in the current dynamic condition: set on 100 m as a pumping depth.	- ditto -
Case 3	- ditto -	- ditto -	Groundwater recharge trench.
Case 4	- ditto -	- ditto -	Groundwater recharge trench and detention dam.

The target aquifers in this simulation were set on both the Upper and Lower Aquifers, and the extraction from an aquifer was controlled by a marginal head defined by the above conditions. This is called a "controlled head ", and the groundwater extraction automatically stops when this head is reached. Consequently, it resumes when the head has recovered up to this level.

In this simulation, "the control head" was determined based on economic conditions. If the pumping needs to be deeper than 300 m, the costs will be very high. The estimate for this situation is a cost of Dh. per $7.9/m^3$, which is nearly equal to that of the alternative water resources as mentioned below. On the contrary, Dh. per $2.0/m^3$ was the cost arrived at from the results of Case 2, when water is pumped from a depth greater than 100 m. This cost also bears comparison with that of tap water to as much as Dh. 1.7 per 6.7/m³. When pumping is carried out at a depth of less than 100 m, it becomes economically viable.

(2) Evaluation of Groundwater Resources

The evaluation of groundwater resources in the Study Area was made by means of the aforementioned simulation study which comprises Case 1 to Case 4. Case 1 was performed to forecast the timing of drying up of the groundwater resources and the evaluation of mining yield from the basin as well. Case 2 was conducted to obtain an indication of the sustainable yield in the Study Area. Cases 3 and 4 were completed to evaluate the artificial facilities needed to augment the groundwater recharge designed in the Study. The results obtained under the above cases are described in the following paragraph:

a) Mining Yield (Case 1)

The forecast was completed using the 100 years from 1996 to 2095. The simulation supposed a mining yield that is as large as 54 MCM/a of the present level and with a control depth of 300 m. The parameters related to rainfall and the evaporation potential to be input into the model were repeatedly diverted by the data from 1977 to 1995.

The results drawn in Figure 4.6.6. indicate a serious water shortage. At the Upper Aquifer, the time for drying-up is coming very quickly. It begins in 2003, and by 2010, this shortage covers all the Lower Aquifer even to a depth of 300 m. Finally, it influences all the Study Area and passes into a balanced state at 2040. At the same time, the potential of groundwater draft which can be pumped will have dropped to 22 MCM/a, which is considered to be the same amount as the potential groundwater recharge.

As a result, the groundwater basin has dried up (that is, it reaches the economic margin at a pumping depth of 300 m) within 45 years unless some measures, such as cutting down the amount of groundwater withdrawal, is enforced immediately.

b) Sustained Yield (Case 2)

The simulation was completed over the 38 year-period from 1996 to 2033. The amount of withdrawal was given by values ranging from the current level to the sustained yield. A control level of 100 m, to give an economic pumpage cost, was also applied. By means of a trial run to process the parameters, the amount of withdrawal for each year was determined as the maximum amount that could be extracted without any shortage occuring in the sub-basins. If the pumping exceeds this maximum amount, the groundwater head decreases down to the control level at some part of the simulated basin. As another parameter, the actual record of rainfall, the evaporation potential Dated 1977 to 1995 was repeatedly used. The results are shown in Figure 4.6.7.

From 1995 to 2015, the amount of groundwater withdrawal shows a gradual decrease. Also from this period, a constant extraction was maintained. The groundwater balance also became stable in this period. The hydrological balance, based on budget and expense, including 21.7 MCM/a of groundwater recharge, 2.2 MCM/a of groundwater runoff and 19.5 MCM/a of groundwater withdrawal, were preserved for the long term. Simultaneously, the "Sustainable Yield" was also introduced as the amount which could be sustained at this level of pumping. A groundwater withdrawal of 19.5 MCM/a was considered to be "Sustainable Yield" in the Study Area.

This Case concluded that a serious lowering of the groundwater which exceeds 100 m will arise if a cut in groundwater withdrawal, is not enforced within the 20 years from 1996 to 2015. Furthermore, the cut would need to remain in force until the level of Sustainable Yield was reached.

c) Recharge Trench (Case 3)

This Case was performed to evaluate the effect of the groundwater recharge trench. Using the current model, it devised its parameters from the results of infiltration experiments. The effectiveness obtained from the designed trench was then simulated. In reality, the degree of this effect was assumed by the difference between the calculation in Case 3 and that of the current model. The facility configuration adopted in this case was three sites located at the three wadis of Siji, Wadi Khadrah and Wadi Shoukah, each 1 km in length. For other input parameters such as rainfall and evapotranspiration, the actual observation data from 1977 to 1995 were applied. The result is shown in Figure 4.6.8.

A groundwater recharge of 22.01 MCM/a was calculated from Case 3 whereas a recharge of 21.67 MCM was calculated using the current model. Accordingly, the balance between both cases was obtained as being 0.3 MCM/a, which was deemed to be the effectiveness of the groundwater recharge trench.

d) Recharge Trench and Detention Dam (Case 4)

An evaluation of a groundwater augment facility was also conducted. A combination plan composed of the groundwater trench and the detention dam was planned in this case. The current model was modified by setting the parameters related to this combination plan to analyze their effectiveness. These dams were designed at the three sites of Wadi Siji with a capacity of 2.46 MCM, Wadi Khadrah with 3.28 MCM and Wadi Shoukah with 2.46 MCM. The capacity of outlet was assumed to be one tenth of the dam capacity. Furthermore, the scale of the recharge trench was set at 1 km in length, the same size that of Case 3. The actual observation data for rainfall and evaporation potential from 1977 to 1995 were used as the model parameters. The result is shown in Figure 4.6.9.

For all the Study Area, the total amount from this case was calculated as 23.64 MCM/a. On the other hand, 21.67 MCM/a was taken from the current model. Hence, the discrepancy between both cases, 1.97 MCM/a, is the effective benefit should these facilities be constructed.

e) Conclusion

The groundwater recharge was estimated as being 21.67 MCM/a in the Study Area, and the sustainable yield was evaluated as being 19.5 MCM/a. Moreover, the timing of drying-up was estimated as being 2040, within 45 years from the present, when the mining yield was set as 54 MCM/a and assuming no construction takes place. The effect of the groundwater trench was held to be 0.3 MCM/a when three facilities were constructed at major wadis. Furthermore, in the case of the combination plan of detention dams and groundwater trenches, the increase in groundwater recharge planned was estimated to be 1.97 MCM/a for the whole of the Study Area.

Thus, the groundwater resource leading to a sustainable development in the Study Area is evaluated as being 21.47 MCM/a in the case that the proposed groundwater augmenting scheme is implemented.

4.7. Soil and Land Use

4.7.1. Soil Survey

(1) Methodology

The main purposes of the soil survey are to investigate the soil conditions of existing farms and to identify the future development potential of agricultural development in the Study Area. Consequently, the survey points were selected not only in existing farms but also on virgin land in the Study Area. Areas which have no possibility of agricultural development, such as base rock outcrops, gravel quarries and moving sand dunes were not surveyed in the Study. The location of points which were surveyed are shown in Figure 4.7.1.

The soil survey in the Study Area was broken down into the following two stages:

1) Reconnaissance survey to determine the type of soils and their distribution in the Area;
2) Detailed observation and sampling for laboratory analysis by test pits.

The laboratory analysis was conducted by a local consultant.

(2) Reconnaissance Survey

After the collection and review of existing data and information, such as aerial photographs, topographic maps, and previous investigation reports, a reconnaissance soil survey was conducted at 65 test pits.

The observations made as to soil profiles were: characteristics of each layers on thickness, texture, color, gravel contents, size of gravel, moisture conditions, and hardness, as well as depth of crop/vegetation root penetration.

Through the reconnaissance survey the following points were identified:

- Morphologically, the Study Area can be divided in to 3 zones : 1) moving sand dune or rather stable desert zone spreading along western and northern edges of the Study Area, 2) Rock outcrop zone mainly extending from the base of the eastern mountain area and, 3) gravel plain which lies between the above two zones.
- Gravel plain soil can be divided by its gravel content.
- Gravel plain soils on the calcareous basement: Occasionally a shallow layer of hard pan forms, and salt accumulation caused by rainfall or irrigation water appears in the gravel layer on it.
- Except for the area near to the sand dunes, the gravel plain soil covers the fluvial gravel layer which usually appears within 70 cm of the surface.
- Gravel plain cultivation : There are many farms on the gravel plain in the Study Area. It is normally not used for cultivation, but these are cultivated tree crops which can exist in thin topsoil. Cobbles and gravel on the ground surface were removed and used as a flood dike, and sometimes silty sand from the sand dunes was spread on the gravel layer. Therefore, it was difficult for the survey to distinguish the original soil conditions. These could, however, by determined sometimes in the wadi flood course where they have not been disturbed.
- Salt accumulating in the coarse sand and gravel layers : In two areas of cultivation, a citrus farm in An Nasim and a forage farm in Suhelah, where the groundwater extracted for irrigation had a high level of salinity, and an excess of water was used for irrigation, salt accumulations were uncovered. Also, non-cultivated areas had salt crystals in the gravel/coarse sand layers, especially in the eastern toe of Jabal Al Fayah. Most of the accumulated salt crystal is $CaCo_3$ or $Ca\ SO_4$, and the longest crystal is about 2 cm. An accumulation of sodium chloride was found in the area of the Wishah gravel plain, where the extracted groundwater shows high electrical conductivity (EC: 8,000 μS/cm).

(3) Test Pit Survey and Soil Sampling

Based on the reconnaissance survey, detailed surveys and soil samplings were made at 66 pits to obtain more detailed information of each type of soil and the area it occupies, as distinguished by the reconnaissance survey.

The location of test pits and samplings were selected at:

- Sand dunes, including inland sabkha, occupying the north and east area of the Study Area where there are few farms,
- Wadi fluvial plain covered by sand dunes and which cover the Study Area widely,
- Gravel plain underlined by weathered limestone, which is located near the base of mountains and rock outcrops in the Study Area; and
- Gravel plain covered by silty sand in the Study Area.

In addition to the above classifications, the area uncovered by the salt accumulation during the reconnaissance survey period was also made part of the detailed soil survey to identify its extent. The location of test pits at which the samples were collected for laboratory analysis are shown in Figure 4.7.1.

4.7.2. Laboratory Analysis

(1) Laboratory Analysis

In order to determine the chemical and physical properties of soil by soil type, 65 collected samples were sent to the laboratory. The analysis covered the following items:

Physical properties;	apparent/specific gravity (bulk density), specific gravity, grain size distribution, pF - moisture contents, and clay mineral structure,
Chemical properties;	pH (1:5 water and 1:5 KCl extracted), conductivity (Ec), cation exchange capacity (Ca, Mg, K and Na), cation (Ca, Mg, K and Na), anion (Cl, SO_4, HCO_3, CO_3), phosphoric acid, nitrogen, carbon, contents, and rear metals (Cu, Zn, Mn).

(2) Analysis Results

The results of the soil laboratory tests are shown in Volume II: Sector Report Chapter Two and summarized as follows:

- Average sand content of the soil is 87% and average clay content is 4.2%.

- The clay mineralogy analysis reveals that most clay is composed of palygorskite or illaite.
- Soil pH (1:5 water and 1:5 KCl extracted) ranges between 7.6 and 9.3.
- Electric conductivity (1:5 water) reveals an average of 650 μS/cm and a maximum of 4,400 μS/cm, in the case of accumulated salt.
- Exchangeable Ca^{++} content is high, with an average of 61.6 meq/100g
- $SO4^{++}$ (1:5 in water) content is high, with an average of 888 mg/kg
- Organic carbon content is very small, with an average of 0.29%.

4.7.3. Soil Classification and Map

(1) Soil Classification

Based on the Soil pit survey and the laboratory analysis, the soil classification in the Study Area is divided into the following groups:

Order	Sub-group	Great Group	Sub-group
Entisols	Fluvents	Torrifluvents	
	Orthents	Torriorthents	
	Psamments	Torripsaments	Torripsaments-2
Aridsols	Orthids	Calciothids	
		Gypsiorthids	
Wadi Riverbed			
Rock Outcrop			

(2) Soil Map Units

a) Calciothids

Loamy-skeletal, deep soils, slightly to moderately dissected, slop 0 to 3%.

b) Gypsiorthids

Sandy to loamy-skeletal saline soils, gypsum pan, on moderately dissected high alluvial terraces and fans, 0 to 3% slope.

c) Torripsaments

Sand dunes less than 10 m high and plains of sandy, deep soils, 0 to 30% slopes.

d) Torriorthents

Extremely gravelly sand, deep soil on young flooded alluvial terrace and fans, 0 to 5% slopes.

e) Wadi Bed

Sandy-sketal, shallow to deep soils, strongly flooded, 0 to 1% slopes.

f) Rock Outcrops - Torriorthents

Mountains, hills and strongly dissected rocky plateaus, and loamy-skeletal to sandy skeletal, shallow soils, with gradients ranging from 0 to more than 100%. Mainly located on the eastern and south-western corner of the Study Area.

(3) Soil Map

Based on the soil classifications mentioned above, a soil map of the Study Area was prepared with reference to test pit logs and the result of physical and chemical analysis in the laboratory. The map is attached to Appendix-4.

4.7.4. Land Use

Present land use in the Study Area was studied by interpreting aerial photographs and topographic maps (orthphoto maps) prepared by the Study. They were confirmed on-site by the Study Team. The summary the present land use is as follows:

Categories	Area (ha)	Share (%)
Cultivation Area	5,800	6.6
Non-cultivation Area	2,300	2.6
Residence and Public Facilities	600	0.7
Quarry sites	6,200	7.1
Sand Dunes	65,600	75.0
Rock Outcrops	5,800	6.6
Others such as roads	1,200	1.4
Total	87,500	100.0

4.8. Agriculture

4.8.1. General

The present condition of agriculture of the Study Area in 1994 was clarified by the data obtained through the Farm Inventory Survey and MAF Statistics. The analysis of the Farm Inventory Survey is shown in the previous Section, 4.2.2. The MAF statistics used were for five districts (extension units : Dhaid-1, Dhaid-2, Falaj Al Mualla, Mileiha, Khadrah) in 1994.

The present conditions of the Study Area estimated as based on MAF Statistics is shown in Table 4.8.1. A comparison between MAF statistics and the Farm Inventory Survey is summarized in Table 4.8.2.

4.8.2. Agriculture in the Study Area

(1) Number of Farms and Cultivation Area

The number of farms and areas of cultivation in the Study Area in 1994 were 2,018 farms and 4,584 ha with an average cultivation area as 3.1 ha per farm, as shown in Table 4.8.2. The Farm Inventory Survey shows a higher average of 4.1 ha.

(2) Main Crops Cultivated

Tree crops occupy 40% of the cultivation area, followed by field crops (35%) and Vegetables (25%). Meanwhile, the Farm Inventory Survey results show tree crops occupy 60% of the cultivation area, followed by field crops (30%) and vegetables (10%). It is possible to say that the main crops in the Study Area are tree and field crops. The main tree crop is Date palms. The main field crop is alfalfa (Table 4.8.2.).

(3) Greenhouse Cultivation

The Agricultural Research Center of the Northern Agricultural Region was the first to introduce greenhouses into UAE. Recently, greenhouses with drip irrigation were installed in the Study Area. Some of them have a cooling system, for the following reasons:

1) effective management of crop production, including irrigation, fertilizer and pesticides,
2) possible reduction in manpower, and
3) to keep air moisture in the house for water saving.

According to observations by JICA experts at UAE University, the cooling system of the greenhouses, which uses the water filter pad method, reduces the internal temperature at the middle of the greenhouse by a minimum of 2°C in winter and maximum 15°C in Summer [Dr. Miyoshi, 1995 unpublished].

A normal greenhouse covered with plastic sheets and with internal dimensions of 8 m width and 36 to 40 m length, without cooling system, costs Dh. 3,000 to Dh. 8,500. The installation cost of standard greenhouses with a cooling system costs about Dh. 23,000 to Dh. 45,000.

(4) Net Income by Crop

Net income from agricultural products in the Study Area is estimated as being 79% from field crops, followed by tree crops at 11% and vegetables at 10%, according to MAF statistics. Moreover, the Farm Inventory Survey shows at the net income from field crops to be 91%, tree crops to be 14% and vegetables to be 10% by each crop. Both results show the same tendencies as regards the net income for each crop.

(5) Water Consumption

Based on the each cropping pattern, the water consumption were estimated at 80% of the net water requirement which is calculated by Penman-FAO method. It is estimated that the total water consumption in the Study Area was 51.4 MCM in 1994. 48% of total water consumption was by field crops, followed by tree crops (46%) and vegetables (6%), while the Farm Inventory Survey results showed 62% for field crops, 36% for tree crops, and 2% for vegetables (Table 4.8.2.). For a comparison of these results, the water consumption amounts were estimated on the experimental cultivation test results, both in the open field and greenhouse, conducted by UNDP/FAO in UAE during 1982 to 1983 (see Tables 4.8.3. and 4.8.4.)

(6) Net Income per Water Consumption (NI/WC)

In order to identify those crops which are water saving and highly profitable, the indicator of net income per unit water consumption (NI/WC) was applied to each crop. The indicator of showed that field crops were the highest at Dh. 7.2/m^3, followed by vegetables at Dh. 7.2/m^3, and tree crops at Dh. 1.1/m^3 (Table 4.8.2.). The Farm Inventory Survey results show Dh. 2.6/m^3 for field crops, 4.4/m^3 for vegetables, and 1.1/m^3 for tree crops.

(7) Livestock

The cost benefit analysis on livestock in the Study Area based on the Farm Inventory Survey was made as shown in Table 4.8.5. The potential profits are estimated based on the type of animal raised, and the milk and eggs yield in 1994. The costs are estimated breeding costs, including cost for feed, health care and labor, but exclude the cost for home-made feed. As shown in Table 4.8.5., the livestock in the Study Area is, in general, not economical, except for Antelopes and poultry, in which case it is possible to conclude that livestock bred in the Study Area is intended only for home consumption and financial investment.

(8) Summary

Based on the above-mentioned analysis, it is possible to conclude that the agriculture in the Study Area is for home consumption and unprofitable, depending mainly on high water-consumptive field and tree crops, as shown in Figure 4.8.1. This is caused by absentee farm owners who have another main source of income, and who leaves cultivation of the farm entirely to foreign workers. Farm owners do not pay much attention to profitable farming, but aim for those crops, such as perennial tree crops and semi-perennial forage crops, which can be easily managed in their absence.

However, recent degradation of the groundwater in the Study Area cannot allow this extensive agriculture to continue. A few devoted farmers in the Study Area have started the installation of a water-saving modern irrigation system and highly profitable vegetable crop and greenhouse cultivation.

4.9. Irrigation

4.9.1. Present Conditions of Irrigation

(1) Water Quality for Irrigation

The only source of water for irrigation in the Study Area is groundwater. Due to the over-development of agricultural land and over-extraction of irrigation water, the water table in the Study Area has dropped and the quality of the water has been degraded.

According to the groundwater quality analysis data from the Study Area, between 1977 and 1980 the groundwater quality for irrigation was classified as medium to high electric conductivity and low to medium SAR (C2-S1, C3-S1 and C3-S2 Classes,) as shown in Figure 4.9.1. and below:

Area	Electric Conductivity (μS/cm)	Sodium Absorption Ratio (SAR)
Dhaid	700	3.0
Mileiha	840 - 2,000	1.4 - 7.2
Fiji	600	1.2 - 2.0

Source : Water and Soil Yearbook No.2, 1977-1981, MAF

In the Study, the present groundwater quality was measured by the Study Team using portable EC and pH meters for the Well Inventory Survey. In addition to measuring the groundwater in the Well Inventory Survey, groundwater sampling was conducted by the Study Team for laboratory analysis in the MAF Central Laboratory.

The field measurement of groundwater at 1,250 wells in the Well Inventory Survey is summarized in Table 4.9.1. It shows the high salinity of groundwater in the Study Area. It varies widely, especially in the Dhaid Area, with an EC ranging from 200 to 37,700 μS/cm.

The results of the groundwater laboratory analysis at the MAF Central Laboratory show the irrigation water class to be from C3-S2 to C4-S3 (Figure 4.9.1.). Compared with data from 1977-1980, the groundwater quality in the Area has clearly deteriorated.

Based on the these results, it is necessary to select crops not only for their high tolerance to drought but also high tolerance to the salinity in the Study Area. Also, the irrigation methods used need to be revised to reduce salt accumulation. A method for "leaching" salt in the field needs to be carefully studied.

In this Study, irrigation water was classified according to electric conductivity - SAR method, which is applied globally.

(2) Groundwater Extraction for Irrigation

According to the irrigation water survey conducted in 1977 by UNDP/FAO/MAF, the average annual groundwater extraction per unit of irrigation area was 49,000 m^3 (Table 4.9.2.). In the survey, farms cultivated by drip irrigation showed a total usage of 21,000 m^3/ha/annum, and farms irrigated by lined canal showed a total of 34,000 m^3/ha/annum. These statistics show the efficiency of drip irrigation and canal lining.

Furthermore, the Study Team conducted a groundwater extraction survey in Summer 1995 (Table 4.9.3.). In the season of the survey, the farmers only irrigated fodder crops and Date palms. The average daily groundwater extraction amount for the net cultivation area was estimated to be 129 m^3/ha/day, and for farm areas as being 61 m^3/ha/day. Considering the evapotranspiration in July, the annual groundwater extraction amount is estimated to be 35,500 m^3/ha for perennial crops.

4.9.2. Present Irrigation Methods

(1) General Outline of Irrigation Facilities in The Study Area

Figures 4.9.2. and 4.9.3. show typical farm specifications. Farm-A has irrigated three quarters of its area with a bubbler and a quarter with a basin. Farm-B has irrigated most of its area with sprinklers, and less than 10% with a basin. The material for water distribution is PVC pipes, and the most popular diameter is between 110 mm and 25 mm. Non-built-in type drip tubes are commonly used along with emitters. These are the most popular and are sold in agricultural retail stores in the area. It seems that the non-built-in type is more popular than built-in type. Both high and low pressure sprinklers are used in the Study area. Many different types and makes of sprinkler were found.

The estimated cost of a facility is Dh. 122,000, with well construction and submersible pumps taking the majority share of 75% of the estimated cost. The question of which type of irrigation is used is not major factor in the cost structure.

(2) Present Irrigation Methods

Under the government support and subsidy system, water-saving irrigation facilities are installed in some farms in the Study Area.

Most of the farms which cultivate vegetables have installed the drip irrigation system. Related facilities such as sand filter and chemical injection systems , however, are incomplete because of the financial capabilities of the farmers. Most of the installed emitters have a capacity of 4 lit/sec. They are operated 15 to 20 minutes every morning and afternoon. Salt accumulation is found near the emitters on many farms. The drip irrigation system is applied in the greenhouses.

The basin irrigation method is the most popular for forage cultivation in the Study Area. Furrow irrigation for Rhodes grass is also to be seen. Most of the farms run their distribution canal from the water tank to the basin or furrow irrigation plot. Earth canals which are still unlined, however, remain in the Study Area. Salt covers are found on the slopes of these unlined earth canals. Some farms have buried the PVC pipes which run from water tank to the basin to reduce the conveyance losses of irrigation water. They are operated by buttons at the outlet pipe. The fixed type sprinkler irrigation system is installed on some alfalfa cultivation farms.

The bubbler irrigation system has also been introduced for tree crops. In most cases, the stakes and bubbler are removed and only plastic tubes are left, bound at the foot of the tree basin. The traditional irrigation method for a Date palm is individual tree basin irrigation using open canal (sometimes not lined), and is a common sight in the Study Area. Irrigation for tree crops is carried out at 3 to 7 day intervals with water to a depth of 5 cm in the tree basin.

(3) Evapotranspiration

According to MAF Hydrological Report No.3 1992, the potential evapotranspiration was estimated by using various methods. The estimated potential evapotranspiration (Eto) in the case of open pan evaporation proves largest in winter (Oct. to April), but the Eto as judged by the Thornthwaite method shows highest in Summer. Eto estimated by Penman method, which is recommended by FAO, shows medium values of Eto as compared with other methods. The irrigation Study conducted by UNDP/FAO in 1984, and many other institutes world-wide, have proven that the Penman method is highly reliable.

Based on the Penman method and climatological data from Falaj Al Mualla, the potential evapotranspiration was estimated as shown in Table 4.8.3. Here, Eto shows the highest in July at 8.7 mm/day and the lowest at in December and January at 3.0 mm/day. Based on these results, and assuming the crop coefficient of alfalfa to be 0.95 and that of Date palm to be 0.9), the annual net irrigation requirement is estimated at 2,076 mm for alfalfa and 1,967 mm for Date palms.

(4) Irrigation Efficiency and Irrigation Water Requirement

As shown in Table 4.9.3., the irrigation efficiency for perennial crops (Date palm and alfalfa) is estimated based on the field investigation results of the Study. The gross irrigation amount per unit cultivation area varies between 12 and 314 m^3/ha/day. Based on the data from Mileiha-east and Mileiha which show nearly average values among surveyed farms, the irrigation efficiency is estimated at 47% for Mileiha-east and 63% for Milheila.

The net irrigation area which is estimated by reducing the area of working passes and open canal area and other area with consideration of shaded area of crop, spacing of trees, lateral spacing and wetted width for drip irrigation from gross crop cultivation area. They were estimated based on the field survey in the Study Area as shown in the following table.

Crops	Net Irrigation Area Ratio	Irrigation Efficiency
Vegetable	0.4	0.75
Tree Crops	0.3	0.60
Field Crops	0.7	0.60

Based on the irrigation water requirement of each crop and cultivation patterns in the present Study Area, the gross irrigation water requirement including vegetable, tree and field crops, is estimated to be 12,000 m^3/ha/annum as shown in the table below.

Present Irrigation in the Study Area (Cropping Area based on MAF statistic), 1994

Crops	Gross Cultivation Area(ha)	Water Consumption (m^3/year)	Net Water Consumption (m^3/year)	Rate of Net Irrigation Area	Net Irrigation Area(ha)	Irrigation Efficiency	Gross Water Consumption* (m^3/year)	Water Consumption (m^3/ha/year)	Water Consumption (m^3/ha/day)
Vegetable	1,157.8	3,099,918	3,874,898	0.40	463.1	0.75	2,066,612	1,785	4.9
Tree Crops	1,825.3	23,622,695	29,528,369	0.30	547.6	0.60	14,764,184	8,089	22.2
Forage Crops	1,601.1	24,675,322	30,844,153	0.70	1,120.8	0.60	35,984,845	22,475	61.6
Total	4,584.2	51,397,935	64,247,419		2,131.5		52,815,641	32,349	31.6

Notes: Present Condition of irrigation in the Study Area can be referred to Table 4.8.1 (page 4-59) of Main Report, Water Consumption was estimated 80% of Net Water Consumption for the comparison of net income per unit water consumption* gross water consumption means groundwater extraction amount.

4.9.3. Intake Rate Test

In order to determine the irrigation water application discharge, the basic intake rate was measured on the field. The cylinder intake rate test method was applied in the Study.

The intake rate tests were made at 19 points in the Study Area. They were selected based on the type of soil which was identified in the initial soil investigation by the Study Team.

The basic intake rate varies from 4.4 and 211.5 mm/hr. The basic intake rate in the gravel plain depends on the thickness of the top soil as shown at points No. 15-A and 15-B. The result at No. 8 shows typically that gravel soil mixed with fine particles has a low basic intake rate.

4.10. Environment and Women

4.10.1. Environment

(1) Natural Conditions

a) Geological Conditions

Geologically speaking, the Study Area can be divided into the Al Dhaid Alluvial Plain and the Central Desert.

The Al Dhaid Alluvial Plain was formed by the alluvial sediment of intermittent streams, and is mainly covered by fluvial deposits consisting of gravel, sand and silt. Soil in the area is mainly torrifluvents, which is characterized as mostly deep, non-saline to moderately saline soils.

The Central Desert is formed from poorly graded sand dunes other sandy deposits. Soils in the area are Torripsamments and their characteristics are mostly saline to strongly saline. They also have a calcareous composition and small areas of loam.

b) Flora and Fauna

The Arabian peninsula is the zone of contact between three of the world's major zoogeographical regions. It is at the center of the Eremic desert zone. Consequently, a great variety of flora and fauna can be found in the UAE. Reptiles, especially, are quite common because the prevailing arid conditions provide an ideal environment for their proliferation, and the appropriate heat level required to maintain their body temperatures. These reptiles survive on little food as they have low metabolic rates. Human activity, however, such as overgrazing and hunting, has recently brought about many changes in the natural flora and fauna. The lowering water table has also had a damaging impact on them.

Main endemic species of flora and fauna found in the Study Area are shown in Tables 4.10.1. and 4.10 2.

(2) Environmental Organizations

Before 1993, environmental management in UAE was the responsibility of the Higher Environment Committee, which belonged to the Ministry of Health. In 1993, based on a recommendation by the Committee, the Federal Environment Agency (FEA) was constituted with the passing of Federal Law No. 7. This Agency is an independent entity, both financially and administratively, and annexed to the Cabinet. Its headquarters is in Abu Dhabi.

It is stipulated in the law that the Agency is managed by a Board of Directors chaired by the Minister of Health. This Board has nine members who are responsible for environmental development issues within the different instances of the government. The Minister nominates the members; their nominations are sanctioned by a cabinet resolution.

The objectives for creating the Authority are as follows:

- To protect and develop the environment within the State.
- To determine any necessary plans and policies to safeguard the environment from those activities which cause pollution, particularly those affecting human health, agricultural crops, wildlife, marine life, other natural resources and atmosphere.
- To implement such plans and policies.
- To take all suitable measures and actions to prevent deterioration of the environment.
- To fight environmental pollution of all kinds.
- To minimize the effects of pollution for the welfare of present and future generations.

As of 1995, the Agency had six staff who are working on the preparation of a definitive environmental law. A proposal for such a law is under discussion within the different state organizations who are concerned with environmental issues.

There is an Environmental Division in the Ministry of Health in Dubai. A tentative organization plan of the FEA is shown in Figure 4.10.1. It must be noted that the lower echelon has not yet been decided.

(3) Environmental Law and Regulation

Up to now, there has been no environmental law or regulations in UAE. However, a federal law concerning the preservation and development of the environment is now being elaborated under the guidance of the Federal Environmental Agency.

Among other regulations related to the Study, there is a MAF decree which bans the application of highly toxic and residual agricultural chemicals for farming. The banned substances are shown in Table 4.10.3.

(4) International Conventions

The UAE has ratified the convention on International Trade in Endangered Species of Wild Fauna and Flora, and signed the United Nations Convention on the Law of the Sea, the Basel Convention, and the Convention on Biological Diversity. Of the animals inhabiting the Study Area, the only species listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora are *Uromasyx spp*, and there are no fauna listed by the conventions on Biological Diversity in the Study Area. There are no areas for the conservation of natural resources and no sites registered under Conservation for the Protection of the World Cultural and Natural Heritage.

4.10.2 WID (Women in Development)

Almost all the agricultural field works in the Study Area are carried out by foreign workers; local women take practically no part in them. Due to diverse factors, this situation is not expected to change in the future. In other sectors, on the contrary, women's participation in the labor force and the number of female students has been increasing remarkably in recent years. For example, at the UAE University women students are now in the majority. Since the government has embarked on a policy which encourages female participation in the labor force, the number of women personnel working in the government has increased, particularly in the ministries of health, education, and labor and social affairs.

The history of women's participation in the public sector Dates back to 1964, before the formation of UAE, when the Kuwait office hired two women to teach at schools in Sharjah. These two women were among the four secondary school graduates of Sharjah's first female graduating class. As of 1977, out of a total of 2,357 female instructors employed by the Ministry of Education, 199 or 8.4 % were UAE national women. Employment in government ministries is considered to be most acceptable for UAE women. However, outside of the Ministries of Health, Education, and Labor and Social Affairs, the number of female UAE nationals employed was extremely limited. Since the government embarked on a policy which encourages female participation in the labor force, the number of women staff has been increasing in the government.

As shown in Table 4.10.5., there is a strong preference for national women to take on the top position in many divisions.

4.11. Transfer of Technology

4.11.1. Introduction

The transfer of technology to UAE counterpart personnel was carried out on many occasions during the Study. During the field survey, many discussions were held with UAE personnel as to how the technology will be applied. Workshops regarding the latest technology used in the Study have been held by both the Study Team and MAF. They include lectures concerning the methodology and applied principles of the technology, and discussion about the application of technology to MAF projects. Furthermore, transfer of technology which requires a high level of understanding (that is, analytical technology) was entrusted to JICA's Training Program in Japan during the course of the Study.

4.11.2. Hydrogeology and Groundwater Sector

As mentioned above, the transfer of technology was made using various methods during the Study period. As per the field discussion, technical discussion with UAE National counterparts took place at each stage of TEM Survey, Natural Gamma Ray Survey, Core Drilling, Test-Well Drilling, Infiltration Experiment, Geophysical Logging, Groundwater Sampling Survey, Groundwater Draft Survey and GPS positioning. The Workshops were held with the aim of introducing the following latest transfer of technology:

(1) Electrical and Electromagnetic Surveys for Groundwater Resources;

(2) An Introduction to GIS System, and

(3) An Introduction to Underground Dam.

For item (1) above, Electrical and Electromagnetic Surveys for Groundwater Resources, the Workshop dealt with Electrical, Electromagnetic and Natural Gamma-Ray methods. The lecture was well attended by MAF personnel who were directly involved with the Study. The lecture, composed of two parts and including theory and equipment set-up, was organized by a Geophysicist from the Study Team. Each UAE delegate was given a Pre-Information Text consisting of an introduction, history and applications of the Time Domain Electromagnetic Method (TDEM) and the Gamma-Ray Method. Concluding the lecture an open question and answer forum was held which drew a considerable amount of interest from attendants.

For item (2), An Introduction to GIS System, the prime objectives of this lecture were to introduce the initial results from the aerial geographical mapping of the Study Area, as well as to utilize the geographical data obtained by the GIS system. The lecture was made with actual demonstrations and was well received by MAF participants. The discussion with a MAF engineer went into significant detail on the configuration of the system structure, introductory methods of the system and applications to MAF Projects.

The workshop relating to item (3), An Introduction to Underground Dam, was conducted with the aim of introducing the relevant technology and to determine the feasibility of an underground system in UAE. The contents consisted of the following:

- Feasibility of an Underground Dam;
- Hydrogeological Condition (necessary conditions for constructing an underground dam);
- Hydrological Condition (necessary conditions for constructing an underground dam);
- Condition of Engineering Aspects, and
- Feasibility of Cost by Storage Capacity.

During the Counterpart Training in Japan, the practical session, consisting of the groundwater analysis and the groundwater modeling, was prepared by MAF engineers. The aim was learn more about analysis, and subsequently use this knowledge in applying the technology to management of the basin through utilization of the groundwater monitoring system and the database system.

The training, inclusive of lectures on the basic groundwater model, groundwater balance as a result of the model, and the simulation study for future management, is given as follows:

- An Introduction to Groundwater Analysis (groundwater flow analyzed by FEM, introduction of groundwater quality interpretation);
- Concept of Synthetic Storage Model and Construction Procedure;
- Analysis of Hydrological Balance estimated by Synthetic Storage Model;
- Analytical Forecasting used by Synthetic Storage Model (operation as management model), and
- Case Study in Japan and other countries.

For other items of the training in Japan, the objectives were the same as above. The results of the Study should be utilized more effectively in the future. For instance, with regard to inspections, field surveys to the underground dam sites, and groundwater irrigation farms which are closely related to the subject discussed in the Workshop. Other items of training, the inspection of the monitoring system and practice using GIS system was helpful in understanding the technology of the monitoring system and database plan to be proposed in the Study Area in the future.

4.11.3. Agriculture and Irrigation Sector

Transfer of technology relating to agriculture and irrigation to UAE counterparts was basically done on an on-the-job basis by the Study Team. They were invited into the field during