No. 2

ISLAMIC REPUBLIC OF PAKISTAN
GOVERNMENT OF SINDH

FEASIBILITY STUDY ON WATER RESOURCES DEVELOPMENT PROJECT IN MALIR BASIN

VOLUME I

MAIN REPORT

NOVEMBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

ISLAMIC REPUBLIC OF PAKISTAN
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PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct a feasibility study on the Water Resources Development Project in Malir Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Pakistan a survey team headed by Mr. Kunio IRIE, Nippon Koei Co., Ltd., and composed of members from the same company and Nippon Giken Inc., three times between August 1989 and August 1990.

The team held discussions with the officials concerned of the Government of Pakistan, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

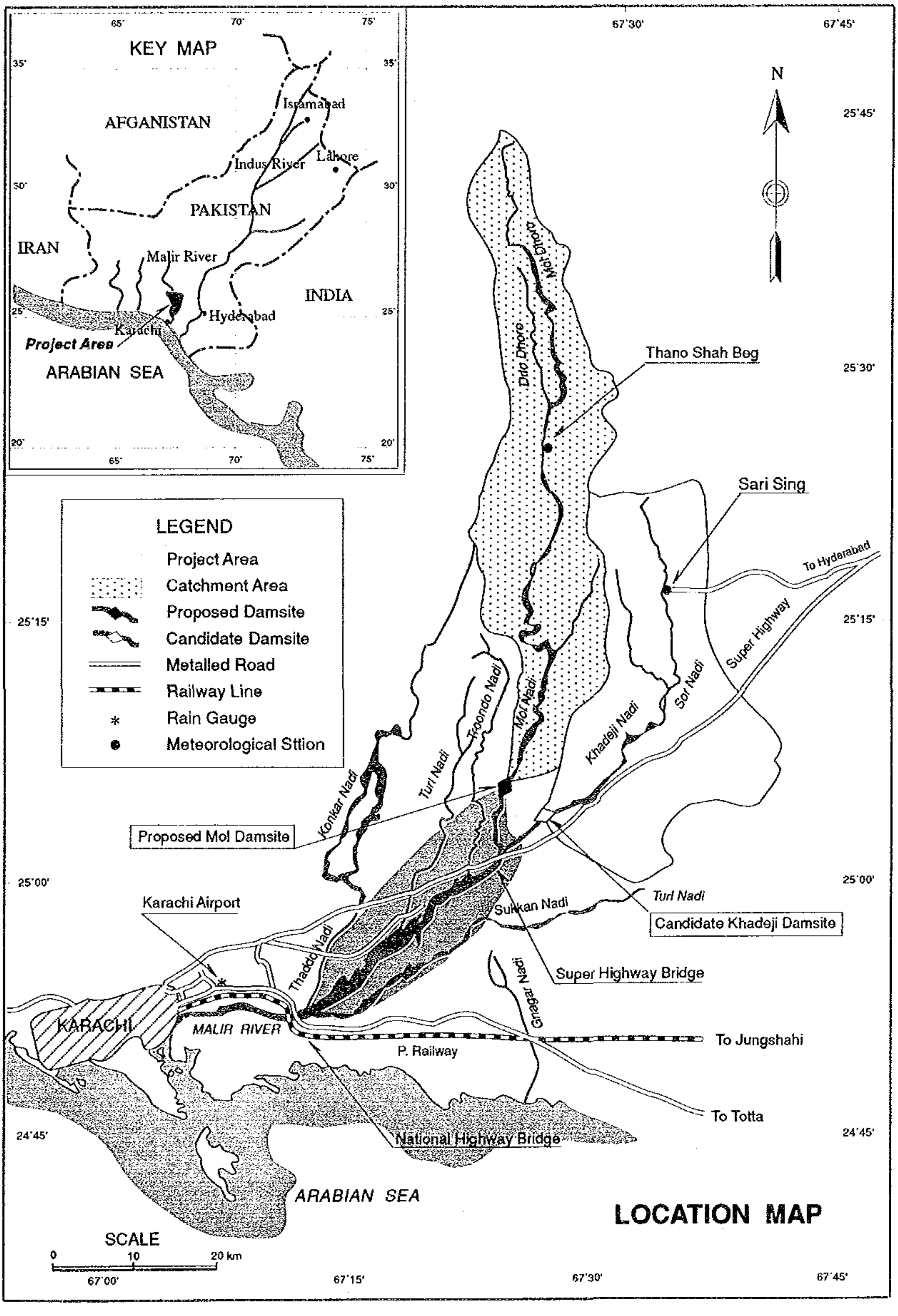
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincerest appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the team.

November 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency



KEY MAP
AFGANISTAN
IRAN
PAKISTAN
INDIA
Islamabad
Lahore
Indus River
Malir River
Hyderabad
Karachi
Project Area
ARABIAN SEA
LEGEND
Project Area
Catchment Area
Proposed Damsite
Candidate Damsite
Metalled Road
Railway Line
Rain Gauge
Meteorological Sttion
Thano Shah Beg
Sari Sing
To Hyderabad
Super Highway
Dido Dhoro
Mol Dhoro
Mol Nadi
Khadeji Nadi
Sol Nadi
Thoondo Nadi
Turi Nadi
Konkar Nadi
Proposed Mol Damsite
Karachi Airport
Candidate Khadeji Damsite
Sukkan Nadi
Super Highway Bridge
Thaddo Nadi
Gnagar Nadi
KARACHI
MALIR RIVER
P. Railway
To Jungshahi
To Totta
National Highway Bridge
ARABIAN SEA
LOCATION MAP
SCALE
0
10
20 km
67°00'
67°15'
67°30'
67°45'
25°45'
25°30'
25°15'
25°00'
24°45'

SUMMARY AND RECOMMENDATIONS

1. INTRODUCTION

01. This Report is prepared in accordance with the Scope of Work for the Feasibility Study on the Water Resources Development Project in Malir Basin agreed upon between the Government of Sindh (GOS), Islamic Republic of Pakistan, and the Japan International Cooperation Agency (JICA) in February 1989. The objectives of the study are to formulate the water resources and agricultural development plan in the Malir river basin by augmenting irrigation water through artificial recharge to groundwater through construction of storage dam(s) on the Khadeji and/or Mol tributaries of the Malir river, and also to verify the feasibility of the project.

02. Due to excessive extraction of groundwater, which has resulted in a drop in groundwater table year by year, a critical shortage has developed in both irrigation and potable water supply, combined with sea water intrusion into the basin aquifer. In 1967, a preliminary study on water resources development in the basin was carried out and a reconnaissance report was prepared. In 1979, a study on the project was carried out and a feasibility report on Water Resources Development in the Malir Basin was prepared by WAPDA. In 1984, a project document on Water Resources Development in the Malir Basin was prepared by National Engineering Services Limited, Pakistan (NESPAK) for the purpose of recasting the summary and recommendations of the feasibility report on the basis of information and data incorporated in the feasibility report.

03. GOS has had a keen interest in developing the water resources of the Malir river basin for a long time. In 1988, GOS therefore requested GOJ to carry out a feasibility study on Water Resources Development Project in the Malir Basin including agricultural development. In response to the GOS's request, GOJ decided to conduct the feasibility study and entrusted the study to JICA. JICA sent a Preliminary Survey Team in January 1989. The Scope of Work and Minutes of Meeting were agreed upon and signed on 6th February 1989.

2. BACKGROUND

04. Pakistan extends from 23° to 37° north latitude and from 61° to 76° east longitude. The total land area of the country is 79.6 x 10^6 ha comprising 44.7 x 10^6 ha for non-cultivation area, 3.2 x 10^6 ha for forest area, 11.1 x 10^6 ha for cultivated waste area, and 20.6 x 10^6 ha for cultivated area or about 26% of total area. The irrigated area is 15.8 x 10^6 ha or 76% of the cultivated area. In Sindh Province, the total land area is 14.1 x 10^6 ha. Cultivated land of about 5.6 x 10^6 ha is located on the Sindh plain which extends along the Indus river and its tributaries.

05. Total population of Pakistan was 84.2 million in 1981. The projected population was 105.4 million in 1988 based on the average growth rate (1972 - 1981) of 3.1% per annum. If the population growth continues at the above rate, it will reach 150 million by 2000. The Gross Domestic Product (GDP) in 1988/89 at constant prices of 1980/81 amounted to Rs. 404,140 x 10^6 among which the agricultural sector shared about 26%. The annual growth rate in GDP was 5.1%, and the per capita income at constant prices was Rs. 3,910.

06. According to the Seventh Five Year Plan (1988-93), agriculture remains the mainstay of Pakistan's economy accounting for over 23% of GDP and employing about 50% of the labour force. The agricultural production growth rate in Pakistan for the years 1988 - 89 was about 6% per year. The growth rate in major crops was 7.8%, 3.2% for minor crops, 5.9% in livestock, 3.9% in forestry and 0.5% in fishing. Major and minor crops, livestock and fishing lagged behind the plan targets, and only forestry achieved the plan target. However, the average annual growth rate of the agriculture sector during period of the Sixth Five Year Plan (1983-87) was 3.8% against a target of 4.9%. Although the growth target was not achieved, Pakistan has become self-sufficient in food grains. The production of rice and wheat was below the targets set in the plan. In case of the rice, a shortage of water at the transplanting stage, less rainfall, pest damages and lack of high-yielding variety seeds resulted in a decrease in production. Wheat production was also affected by adverse weather conditions in 1986-88.

3. THE STUDY AREA

07. The study area is located in the Malir river basin which is situated about 20 km north-east of Karachi city, the provincial capital of Sindh. The Malir river is formed by the confluence of the Khadeji and Mol rivers near the Super Highway bridge with a catchment area of 1,205 km^2 at the confluence. After the confluence, it runs about 48 km towards southwest and drains into the Arabian Sea near Karachi. The study area extends on both sides of the Malir river between the proposed Mol damsite located at about 7.2 km upstream of the confluence of the Mol and Khadeji rivers and National Highway, and covers a flood plain of 24,230 ha in gross.

08. The annual average rainfall at Karachi airport (1929-1988) is 219 mm, of which about 78% occurs during the three months from July to September in the monsoon season. The hottest month is May and the mean daily maximum and minimum temperatures are 35.2°C and 25.8°C at Karachi airport. The coolest month is January and the mean daily maximum and minimum temperatures are 25.7°C and 10.1°C respectively. Mean relative humidity varies from 79% in August to 51% in January. Mean pan evaporation reaches 14.7 mm/day in May, and an annual average of 10.4 mm/day at Super Highway bridge. The average monthly wind speed at Karachi airport varies between 4.7 m/sec in June and 1.4 m/sec in December.

09. The total population in the study area was 30,100 persons in 1961 and increased to 65,600 persons in 1981. The population is estimated to have been increased to 90,400 by 1989 based on the overall growth rate of 5.3% from 1972 to 1981 for Karachi East District. It is estimated that about 53% of the population is male and 47% female. Population density is estimated at 373 persons/km which is about three times the average for Sindh Province of 135 persons/km, but considerably lower than that for Karachi East District as a whole, which is 783 persons/km. The total number of households is estimated at 16,270 with an average household size of 5.6 persons.

10. Land capability was assessed for the soils of the WAPDA area in order to classify the suitability of soils for general agricultural purposes including grazing and forestation. Land capability was classified into four (4) and summarized as follows:

Land Capability Class	Area (ha)	(%)
Class I	6,210	21
Class II	9,570	33
Class III	11,190	38
Class IV	2,240	8
Total	29,210	100

11. The hydrogeological profile of the area is classified mainly into three zones, namely, permeable, slightly permeable and impermeable zone. The phreatic aquifer of the Quaternary deposits is the main aquifer in the study area. The phreatic aquifers mainly comprise alluvial deposits distributed along the Malir river, and consisting of layers of sand and gravels with silty sand layers. The dimensions of alluvial deposits in various stretches are as follows:

River Stretch	Width (km)	Thickness (m)
Upper reaches	3 (2.5)	20 (10)
Middle reaches	7 (5.5)	30 (10)
Lower reaches	6 (2.5)	40 (40)

12. For last 12 years from 1977 to 1989, the groundwater table has been lowered due to overdraft of groundwater. Groundwater depression below mean sea level (EL. 0 m) was observed in 1977 in the southern (lower) part of the project area, and its area in 1989 was expanded. The annual net withdrawal from the aquifer from 1977 to 1988 is estimated at about 8.0 MCM and accordingly the average annual drawdown is 0.43 m, which shows a more rapid drawdown than projected by WAPDA. The total groundwater volume in the phreatic aquifer in 1977 and 1989 is estimated as summarized below:

Stretch	Aquifer Area (km^2)	Groundwater Potential 1977 (MCM)	Groundwater Potential 1989 (MCM)	Net Withdrawal 1977-1989 (MCM)
Upper	54	57.9	24.7	33.2
Middle	55	96.3	56.8	39.5
Lower	76	62.8	39.4	23.4
Total	185	217.0	120.9	96.1
Average annual net withdrawal				8.0 MCM
Average annual drawdown of groundwater table				0.43 m

13. Well construction was accelerated in the 1960's and it was continued in the 1970's and 1980's. Due to excessive withdrawal of groundwater, the depth of dugwells became deeper and deeper every decade, and this fact shows that the groundwater table is declining at the rate of about 5 - 7 m per decade. Especially in the areas of Thano and Laundhi Union Councils, drawdown of groundwater table is remarkable, and abandaned wells are increasing sharply. In the project area which is delineated based on the hydrogeological condition and its recharge mechanism in the study area, there are 466 production wells, and a summary of the production wells is shown below:

Diameter of Discharge Pipe mm (inch)	Nos. of Production Wells				
		Upper R. Stretch	Middle R. Stretch	Lower R. Stretch	
	Project Area	Darsano Chano U.C.	Konkar U.C.	Laundhi U.C.	Thano U.C.
50 (2.0)	92	-	76	11	5
75 (3.0)	246	44	97	89	16
100 (4.0)	121	52	28	16	25
125 (5.0 -)	7	6	-	-	1
Total	466	102	201	116	47

14. In the project area, there are 2,600 ha of net irrigation area which are irrigated by 466 production wells. Based on the agricultural electric consumer's record in 1987/88 (KESC), pumped water from the production wells was estimated to be about 35.5 MCM in 1987/88. Actual irrigation water supply in 1987/88 was limited to about 80% of the necessary irrigation water requirement. This means that crops and plants in the project area are used to facing shortage of irrigation water supply, due to long droughts over the last 20 years.

Item	Unit	River Stretch			Whole Project Area	Necessary Diversion Water Requirement
		Upper	Middle	Lower		
1. Nos. of Production Well	Nos.	102	201	163	466	-
2. Pumped Volume	MCM	11.5	15.2	8.8	35.5	44.3
3. Unit Pumping Volume	1,000 m^3	113	76	54	76	-

4. POTENTIAL WATER RESOURCES DEVELOPMENT

15. Natural recharge into the basin phreatic aquifers is estimated to have been 46.5 MCM/yr from 1929 to 1988 and 38.8 MCM/yr from 1977 to 1988. A comprehensive water balance in the basin aquifer as a whole is shown in the following table. Annual net withdrawal from the aquifer from 1977 to 1988 is estimated at 8.2 MCM/yr, which is nearly equal to the measured net withdrawal of 8.0 MCM/yr (refer to Paragraph No.12).

Unit: MCM/yr

Simulation Period : 1977-1988				
A. Recharge			B. Withdrawal	
1. Natural recharge	38.8		1. Irrigation water	48.7
2. Deep percolation (irrigation)	7.3		2. Potable water supply to Karachi	2.7
3. Deep percolation (domestic water)	0.3		3. Domestic water	1.9
4. Total (A)	46.4		4. Groundwater discharge to sea	1.3
			5. Total (B)	54.6
C. Balance (A - B)		-8.2		
D. Measure net withdrawal from the aquifer		-8.0		

16. Several important projects were executed during the decade, which will be affected by implementation of this project, especially by the Khadeji dam. A part of the existing two lanes and other two lanes under construction of the Super Highway from Karachi to the north will be submerged under the Khadeji reservoir, requiring relocation costs. Moreover, the Khadeji dam axis touches the Precision Engineering Complex (PEC) of Pakistan International Airline (PIA) belonging to the Ministry of Defence, and clearance between the proposed surcharge water level in the previous study and the lowest ground elevation of the Complex is only 2.7 m. Therefore, in order to avoid submergence of the Super Highway, to minimize the costs, as well as to give more clearance to the PEC, the maximum surcharge elevation of the Khadeji dam would be fixed at EL. 163 m. The maximum allowable surcharge elevation of the Mol reservoir is about EL. 175 m which shows the allowable topographic limitation as also studied by WAPDA. The following table summarises the implications:

Item	Unit	Khadeji Dam	Mol Dam
1. Maximum Allowable Surcharge Level	EL. m	163.0	175.2
2. Surcharge Depth	m	3.9	3.4
3. Normal Full Water Level (Max. NFWL)	EL. m	159.1	171.8
4. Maximum Gross Storage Capacity	MCM	45.7	54.5
5. Dead Storage Capacity	MCM	10.2	10.7
6. Minimum Water Level	EL. m	149.0	156.5
7. Maximum Live Storage Capacity	MCM	35.5	43.8

17. Recharge to the phreatic aquifer in the upper and lower stretches should be kept equal as far as possible. If discharge from the dam is small, most of the water will be recharged to groundwater but only in the upper river stretch. On the other hand, if the discharge is more than recharge capacity, excess water will be wasted into the sea without being utilized. Therefore, allowable discharge from the dam will be an important factor for the dam operation. Allowable discharge from the dam(s) is estimated at 8 m^3/sec (21 MCM/month).

18. The dam(s) operation rule is set to release water from the dam(s), which corresponds to the balance between the allowable discharge of 8 m^3/sec and the runoff from the remaining catchment area. If the runoff from the remaining catchment area exceeds the allowable discharge, no water will be released from the dam(s). Only the balance of water is released, when runoff is less than the allowable discharge. Artificial recharge is calculated for various alternative cases, and the total volume combining the natural and artificial recharge is summarized as follows:

Unit: MCM

	JICA Study							WAPDA
Combination of Dams	Khadeji+Mol	Khadeji+Mol	Mol Only			Khadeji Only		Khadeji + Mol
	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	
Live Storage Capacity	35.5+43.8	35.5+35.0	43.8	35.0	30.0	35.5	30.0	54.6 50.9
Natural Recharge from the Remaining Basin and Dam Spillout	26.1	26.9	39.6	41.1	41.6	43.1	43.8	26.8
Recharge by Dams	44.5	42.4	25.8	23.6	22.3	19.6	18.3	46.6
Total Recharge	70.6	69.3	65.4	64.7	63.9	62.7	62.1	73.4

19. The area which could be irrigated by groundwater augmented by construction of the project dam(s) is estimated at 4,100 to 4,860 ha depending on the combination of dams and live storage capacity as summarized in the following table. Comparison of the seven (7) alternatives is made based on the Economic Internal Rate of Return (EIRR), Benefit Cost Ratio (B/C), and Net Present Value (B-C). The results are summarized below:

Item		Case-1 Khadeji + Mol	Case-2 Khadeji + Mol	Case-3 Mol Only	Case-4 Mol Only	Case-5 Mol Only	Case-6 Khadeji Only	Case-7 Khadeji Only
Live Reservoir Capacity: (MCM)	Khadeji ;	35.5	35.5	-	-	-	35.5	30.0
	Mol ;	43.8	35.0	43.8	35.0	30.0	-	-
1. Possible irrigation area (ha)		4,860	4,760	4,450	4,350	4,270	4,160	4,100
2. Total economic project cost (10^6 Rs.)		1,451	1,426	659	633	621	793	784
3. Net incremental economic benefit (10^6 Rs.)		104.7	102.5	95.2	93.7	91.3	89.6	88.3
4. EIRR (%)		5.18	5.15	10.40	<u>10.60</u>	10.53	8.40	8.37
5. B/C *1		0.67	0.66	1.33	<u>1.36</u>	1.35	1.05	1.05
6. B-C *1 (10^6 Rs.)		-412	-408	188	<u>196</u>	187	36	33

Remarks: *1 Discount rate of 8% is applied.

As seen in the above table, the Mol dam with a live storage capacity of 35.0 MCM (Case-4) is the most economical of the seven, and the optimum scale of the Mol dam is determined as follows:

	Item	Unit	Mol Dam
1.	Dam Type		Rockfill (Zone Type)
2.	Crest Elevation	EL. m	175.3
3.	Maximum Water Level	EL. m	173.0
4.	Normal Full Water Level	EL. m	169.6
5.	Dead Water Level	EL. m	156.5
6.	Dam Height	m	48.8
7.	Gross Storage Capacity	MCM	45.7
8.	Dead Storage Capacity	MCM	10.7
9.	Live Storage Capacity	MCM	35.0
10.	Dam Volume	10^3m^3	1,730

5. THE PROJECT

20. The project is formulated to maximize the potential agricultural benefits through efficient use of land and water resources. The main concept of the project are:

- To increase groundwater recharge by construction of the dam(s),
- To expand irrigation area to maximum extent through augmentation of artificial groundwater recharge,
- To sustain groundwater resource through monitoring and management,
- To supply vegetables and fruit to the greater Karachi market,
- To increase crop yields through introduction of intensive farming practices,
- To improve the socio-economic situation and to increase employment opportunities in the area,
- To maintain a green belt located near the greater Karachi city, and
- To improve organization to ensure the above strategies.

21. Out of 24,200 ha of the study area, the project area to be benefited by augmentation of groundwater recharge is delineated based on the existence of the phreatic aquifer. The phreatic aquifer in the Malir river basin extends over on both sides of the river between the National Highway and the proposed Mol damsite. Finally based on an economic comparison of the development plans, the possible irrigation area is found to be 4,350 ha. The following table shows the present land use in the study and project areas, and the future without and with the project:

Unit: ha

Land Category	Study Area	Project Area		
	in 1989	in 1989	Without Project	With Project
Agricultural Land	3,220	2,700	2,500	4,450
- Orchard fields (irrigated)	1,200	1,180	1,000	1,000
- Upland fields (irrigated)	1,540	1,420	1,400	3,350
- Upland fields (rain-fed)	480	100	100	100
Fallow Land	2,920	2,800	3,000	1,050
Non Agricultural Land	18,090	8,400	8,400	8,400
Total	24,230	13,900	13,900	13,900

22. The climate in the project area, generally characterized by the summer and winter seasons having warm and relatively dry as well as sufficient sunshine hours, is very favorable for cultivation of fodder, vegetables and fruit crops throughout the year. No significant variation of yields for major crops is observed in the year-round cultivation which is now being practiced by the farmers in the project area. The proposed cropping pattern is finally determined in consideration of profitability, marketability, peak water requirements, labour requirement, etc. A summary is presented in the following table:

Unit: ha

Crops	WAPDA Study		JICA Study		
	Area in 1977	Proposed Project	Present Condition	Without Project	With Project
Summer season					
Fodder	590	700	150	150	150
Vegetables	2,100	2,280	1,270	1,250	3,200
Fruit	1,380	1,380	1,180	1,000	1,000
Sub-total	4,070	4,360	2,600	2,400	4,350
Winter season					
Fodder	370	450	50	40	50
Vegetables	1,520	1,740	310	290	2,100
Sub-total	1,890	2,190	360	330	2,150
Total	5,960	6,550	2,960	2,730	6,500
(Cropping intensity)	(1.46)	(1.50)	(1.14)	(1.14)	(1.50)

23. Based on the proposed cropping pattern, the cropped area, crop yields and total crop production under both "with project" and "without project" conditions are estimated summarized in the following table.

Unit: tons

Item	Without Project	With Project	Increment
Production			
Fodder crops	2,340	4,400	2,060
Vegetables	6,960	46,650	39,690
Fruit	4,760	7,250	2,490
Total production	14,060	58,300	44,240

24. The annual costs and income without project and with project at full development stage are summarized in the following table. Total income from crop production (at constant 1989 prices) is projected to increase from Rs. 18.4 million under without project to Rs. 112.0 million under with project at full development. Incremental annual income from crop production is projected to be Rs. 93.6 million at the full development stage.

Unit: 10^3 Rs.

Item	Without Project	With Project	Increment
Net Crop Income			
Fodder	282	754	472
Vegetable	9,810	96,375	86,565
Fruit	8,351	14,895	6,544
Total	18,443	112,024	93,581

25. The Mol dam is designed as a rockfill dam with an impervious center core. The maximum height of dam is 48.8 m above the foundation, the crest of elevation is designed at EL. 175.3 m with a freeboard of 2.3 m including crest road pavement of 0.5 m thick, and the dam has 10 m top width. The length of the dam crest is 2,347 m including 848 m of the main dam and 1,499 m of the saddle dam. The slopes of the dam faces are designed at 1:2.5 for the upstream and 1:2.0 for the downstream. The total embankment volume of the dam will be about 1,730 x 10^3 m^3.

26. A pilot demonstration farm will play an important role in the project to achieve the project target by demonstrating advanced irrigation and farming techniques. It is proposed that the pilot demonstration farm be sited within the Plant Introduction Center at Saleh Mohammed Goth, Laundhi Union Council, which is situated in the southern part of the project area. Out of 10 ha (25 acres), only 2.4 ha (6 acres) are at present used for orchard research and the remaining 7.6 ha (19 acres) are fallow due to the limited irrigation water supply. There is also a section of extension services which belongs to the Agriculture, Livestock and Fisheries Department of GOS. Therefore, most favorable circumstance are available in the center to establish a pilot demonstration farm.

27. The implementation period of the project is assumed to be four (4) years from 1991 to 1995. The whole of 1991 would be required for detailed design and mobilization. Actual construction works would be commenced in 1992, and be completed in March 1995. Total project cost is estimated to be Rs. 685.6 million (US$31.9 million equivalent) consisting of Rs. 531.0 million (US$24.7 million equivalent) for foreign currency portion and Rs. 154.6 million (US$7.2 million equivalent) for local currency portion, and summarized below:

Unit: Rs. 10^6

	Major Item	Foreign Currency	Local Currency	Total
1.	Preparatory works	27.0	5.9	32.9
2.	Mol dam	362.6	76.8	439.4
3.	Causeway	2.4	3.8	6.2
4.	Pilot demonstration farm	10.4	2.9	13.3
5.	Project office	0.4	0.8	1.2
6.	O&M equipment	10.3	0.0	10.3
7.	Physical contingency	58.2	12.8	71.0
8.	Administration cost	0.0	6.7	6.7
9.	Engineering services	59.6	16.4	76.0
10.	Price contingency	0.0	28.6	28.6
	Grand Total	530.9	154.7	685.6

6. PROJECT ORGANIZATION AND MANAGEMENT

28. Irrigation and Power Department (IPD) of GOS will be the executing agency for implementation of the project. IPD will appoint a project manager for the Malir Project Office to coordinate the execution of the project, which will be established near the Mol dam. Function of the office will include approval of construction methods and schedules, preparation of design revisions, construction progress, coordination of contracted works, monitoring of construction progress, work quantities and quality control, approval of payment, etc. as well as groundwater monitoring and establishment of a Groundwater Users Association of beneficiary farmers.

29. After completion of construction, the Malir project office will be re-organized into the Project O&M Office under IPD for operation and maintenance of the dam and groundwater monitoring in cooperation with the Groundwater Users Association. The dam O&M section will be responsible for operation of the dam to maximize recharge to the groundwater in the basin aquifers, and maintenance of the dam and the river course. Another groundwater management section will be totally responsible for management of groundwater to maintain suitable groundwater levels and to ensure the sustainable development and utilization of groundwater.

30. In order to maintain suitable groundwater levels, pumping of groundwater must be controlled and regulated. For this, it is recommended that a water extraction management system and the Groundwater Users Association should be established as discussed in the preceding section. The functions of the water management section of the Malir Project Office are firstly to monitor the groundwater table and pumping records in the project area periodically and to establish guidelines for water extraction from each well. The monitoring works should gradually be transferred from the Malir Project Office under IPD to the Association, and the Association will finally be responsible for all groundwater management works.

31. In order to demonstrate the proposed improved farming practices with high inputs and to introduce new irrigation technology, a demonstration farm is proposed. Demonstration of high yields of crops with improved farming practices will give farmers incentives to adopt the new technology. Further expansion of the cultivated area will be expected through the introduction of water-saving irrigation technology such as sprinkler and drip irrigation methods.

7. PROJECT EVALUATION

32. The project is evaluated from the economic, financial and socio-economic points of view. Firstly economic evaluation is made based on the following assumptions:

(1) The construction period of dam would be four (4) years including one (1) year of detailed design and preparatory works.
(2) Economic useful life of the project would be 50 years.
(3) All prices are expressed in constant late 1989 prices.
(4) The exchange rate of US$1.00 = Rs. 21.5 = ¥150.0 would be used throughout.

Economic agricultural benefit of the project at full development stage is estimated at Rs. 93.7×10^6, while economic cost of the project is estimated at Rs. 632.8×10^6. Considering other minor costs (annual O&M costs and replacement cost) and benefit (cost saving of further well deepening and electricity), EIRR, B/C and NPV are calculated. The results are as follows:

EIRR	=	10.6%	
B/C	=	1.36	(at a discount rate of 8%)
NPV	=	Rs. 196.4×10^6	(at a discount rate of 8%)

33. Financial evaluation of the project is made by the analysis of the typical farm budgets. With the implementation of the project, farm income will increase by 3 or 4 times of income in without project condition, irrespective of the type of land tenure. Incremental benefit per hectare between with and without project conditions will be Rs.4,920 for tenant farmer and Rs. 16,600 for owner operator. Assuming the per capita average annual national expenditure of Rs. 5,300 is target income, about 400 families or more than 50% of the total beneficiaries (owner, owner/tenant and tenant farmers) in the project area will reach to the target in with-project conditon. The project can be justified financially.

34. The major expected socio-economic impacts of the project is enumerated as below:

(1) Stable supply of water,
(2) Increase of employment opportunities,
(3) Increase of crop production and stable supply of the products to the Karachi city,
(4) Increase of farmers' income,
(5) Improvement of water quality,
(6) Flood mitigation effects,
(7) The use of fertilizer and agro-chemicals, and
(8) Demonstration effect of pilot farm.

8. RECOMMENDATIONS

35. Early Implementation of the Project

The Malir basin has played an important role for a long time in supplying agricultural products such as fruit, vegetables, etc. and in supplying potable water to Karachi city. Despite the fact that demand for such agricultural products is increasing due to rapid population growth of Karachi, agricultural land in the project area is decreasing year by year mainly due to overdraft of groundwater from the potential aquifers in the basin, which will further be accelerated unless appropriate countermeasures are provided for augmentation of recharge to and proper management of the aquifers. It is, therefore, recommended that the necessary arrangements for early implementation of the project be taken as soon as possible.

36. Establishment of Pilot Demonstration Farm

Fruit and vegetable crop yields achieved by producers in the project area are significantly lower than those generally achieved in Sindh and much below national averages. The restoration of a reliable and properly managed supply of water under the proposed project would create the conditions for development of more intensive fruit and vegetable production in the project area. The project itself, however, would make only a limited contribution to the intensification of crop production in the project area through augmentation of recharge to the aquifers. It is therefore essential to establish a pilot demonstration farm in order to achieve the desired increase in crop yields.

37. Groundwater Management

Proper groundwater management should be carried out strictly for sustainable groundwater use in order to prevent serious groundwater mining and deterioration of water quality, in coordination with implementation of the project. Otherwise, decrease of potential groundwater resources as seen at present in the project area may occur again in the future, even if increased recharge to the aquifers can be provided by the project. No legal framework for groundwater resources development exists in the Province or in the project area. It is strongly recommended that a section of IDP be established for proper groundwater management, including development of necessary regulations for groundwater resources development, and to monitor and maintain the aquifer level/status in the project area as well as to ensure proper utilization of potential groundwater resources, in collaboration with the proposed Groundwater Users Association.

FEASIBILITY STUDY ON
WATER RESOURCES DEVELOPMENT PROJECT
IN MALIR BASIN

MAIN REPORT

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ATTACHMENTS

ABBREVIATIONS

AFLFD	Agriculture, Food, Livestock and Fisheries Department, GOS
FAO	Food and Agriculture Organization, United Nations
GDP	Gross Domestic Product
GNP	Gross National Product
GOJ	Government of Japan
GOP	Federal Government of Pakistan
GOS	Government of Sindh, GOP
IPD	Irrigation and Power Department, GOS
JICA	Japan International Cooperation Agency
KESC	Karachi Electric Supply Corporation
UNDP	United Nation Development Programme
WAPDA	Water and Power Development Authority
DA	General Director of Agriculture
ADA	Assistant Director of Agriculture
EADA	Extra Assistant Director of Agriculture
APPO	Assistant Plant Protection Officer
AO	Agricultural Officer
FA	Field Assistant

ABBREVIATIONS OF MEASUREMENT

Length

cm = Centimeter
m = Meter
km = Kilometer
ft = Foot
yd = Yard

Area

cm^2 = sq.cm = Square centimeter
m^2 = sq.m = Square meter
ha = Hectare
km^2 = sq.km = Square kilometer

Volume

cm^3 = cu.cm = Cubic centimeter
l = lit = liter
kl = Kiloliter
m^3 = cu.m = Cubic meter
gal. = Gallon
MCM = Million Cubic Meters

Weight

mg = Milligram
g = Gram
kg = Kilogram
ton = Metric ton
lb = Pound

Time

sec = s = Second
min = Minute
hr = Hour
d = Day
yr = Year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = Percent
PS = Horsepower
° = Degree
' = Minute
" = Second
°C = Degree centigrade
10^3 = Thousand
10^6 = Million
10^9 = Billion (milliard)

Derived Measures

m^3/s = m^3/sec = Cubic meter per second
cusec = Cubic feet per second
mgd = Million gallon per day
kWh = Kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/yr = Kilowatt hour per year
kVA = Kilovolt ampere
BTU = British thermal unit

Money

Rs. = Pakistan Rupees
US$ = US dollar
Yen = Japanese Yen

CONVERSION FACTORS

	From Metric System			To Metric System		
Length	1 cm	=	0.394 inch	1 inch	=	2.54 cm
	1 m	=	3.28 ft = 1.094 yd	1 ft	=	30.48 cm
	1 km	=	0.621 mile	1 yd	=	91.44 cm
				1 mile	=	1.609 km
Area	1 cm^2	=	0.155 sq.in	1 sq.ft	=	0.0929 m^2
	1 m^2	=	10.76 sq.ft.	1 sq.yd	=	0.835 m^2
	1 ha	=	2.471 acres	1 acre	=	0.4047 ha
	1 km^2	=	0.386 sq.mile	1 sq.mile	=	2.59 km^2
Volume	1 cm^3	=	0.0610 cu.in	1 cu.ft	=	28.32 lit
	1 lit	=	0.220 gal. (imp.)	1 cu.yd	=	0.765 m^3
	1 kl	=	6.29 barrels	1 gal. (imp.)	=	4.55 lit
	1 m^3	=	35.3 cu.ft	1 gal. (US)	=	3.79 lit
	10^6 m^3	=	811 acre-ft	1 acre-ft	=	1,233.5 m^3
Energy	1 kWh	=	3,413 BTU	1 BTU	=	0.293 Wh
Temperature	°C	=	(°F-32) 5/9	°F	=	1.8°C + 32
Derived Measures						
	1 m^3/s	=	35.3 cusec	1 cusec	=	0.0283 m^3/s
	1 kg/cm^2	=	14.2 psi	1 psi	=	0.703 kg/cm^2
	1 ton/ha	=	891 lb/acre	1 lb/acre	=	1.12 kg/ha
	10^6 m^3	=	810.7 acre-ft	1 acre-ft	=	1,233.5 m^3
	1 m^3/s	=	19.0 mgd	1 mgd	=	0.0526 m^3/s

EXCHANGE RATE

US$1.0 = Rs. 21.5 = J. Yen 150.0

1. INTRODUCTION

1.1 Authorities

This Report is prepared in accordance with the Scope of Work for the Feasibility Study on the Water Resources Development Project in Malir Basin agreed upon between the Government of Sindh (GOS), Islamic Republic of Pakistan, and the Japan International Cooperation Agency (JICA) in February 1989.

The objectives of the study are to formulate the water resources and agricultural development plan in the Malir river basin by augmenting irrigation water through artificial recharge to groundwater, increase in city water supply to Karachi, and mitigation of flood damages through construction of storage dam(s) on the Khadeji and/or Mol tributaries of the Malir river, and also to verify the feasibility of the project.

This Report presents all the findings on present conditions in and around the study area, the development concept and plan, proposed major project features, project benefits and costs, and the project evaluation. The studies were performed first for review of the previous feasibility study by WAPDA (Ref. 01) and secondly for formulation of the project based on analyses of the newly available data.

1.2 Background of the Project

The Malir river basin with a catchment area of about 2,240 km^2 has played an important role in Karachi city for a long time in supplying agricultural products such as fruit, vegetables, etc. and in supplying potable water. In the 1960's, the demand for fruit and vegetables increased due to the rapid population growth of Karachi city. Such increase of market demand encouraged farmers to develop farm land and groundwater for achieving higher and stable agricultural production. In the 1960's and thereafter, intensive dug/tube well development has continued without restriction and regulation.

Due to excessive extraction of groundwater, which results in falling groundwater levels year by year, a critical situation has developed in shortage of both irrigation and potable water supply, and also sea water intrusion into the basin aquifer. In order to solve these constraints through artificial recharge to the aquifer in the basin, it is essential to exploit fully the water resources of the basin.

In 1967, a preliminary study on water resources development in the basin was carried out and a reconnaissance report was prepared by the Directorate of Planning and Investigation, Quetta Irrigation Zone of the erstwhile West Pakistan Irrigation and Power Department.

Twelve years later, a study on the project was carried out and a feasibility report on the Water Resources Development in Malir Basin was prepared by WAPDA in 1979. This report was finalized in 1982 by WAPDA, based on further field investigation and analysis.

In 1984, a project document on Water Resources Development in the Malir Basin was prepared by National Engineering Services Limited, Pakistan (NESPAK) for the purpose of recasting the summary and recommendations of the feasibility report on the basis of information and data incorporated in that report.

GOS has kept a keen interest in implementing the water resources development in the Malir river basin for a long time. In 1988, GOS therefore requested GOJ to carry out a feasibility study on water resources development project in the Malir basin including agricultural development in the basin. In response to the GOS's request, GOJ sent a JICA Preliminary Survey Team in January 1989. The Scope of Work and Minutes of Meeting were agreed upon and signed on 6th February 1989.

1.3 Works Performed

In accordance with the Scope of Work agreed upon between GOS and JICA, formulation of the water resources and agricultural development plan has been carried out by the JICA team in collaboration with experts assigned from the Irrigation and Power Department of GOS, University of Sindh, Mehran University. The Scope of Work is attached in the APPENDIX, and members of the counterpart and JICA team are listed in Table 1.

The study was carried out in two phases, i.e. Phase-I and Phase-II. The first field works of Phase-I Study, during the three (3) months from September to November 1989, included mainly collection of general information and meteo-hydrological data, hydrogeological survey, electric resistivity survey, geological and construction materials surveys, soils and land use survey, survey of the existing agricultural conditions, well inventory survey, irrigation and drainage survey, and data collection of dam planning. In December 1989, the JICA team submitted its Progress Report which outlines progress on the study and major findings of the field works.

The first office works in Tokyo, during one (1) month from December 1989 to January 1990, were carried out mainly to analyze the data and information collected during the first field works, to analyze high and low river flow, to analyze preliminarily the groundwater movement and recharge mechanism, and to make a preliminary assessment of the water resources development potential. All the results of Phase-I Study were compiled in the Interim Report and the Report was submitted to GOS in January 1990.

The second field works were performed during two (2) months from January to March 1990. The works included mainly supplemental data collection, agro-economic survey, survey of price of construction materials and construction costs, formulation of basic development concept, etc., the findings and results being compiled in Field Notes. In March 1990, the JICA team submitted the Notes.

The results of field surveys and studies were further elaborated in Tokyo and all the study results are compiled in this report. The supporting studies and basic data of the report are compiled in a volume of ANNEXES and a volume of DRAWINGS.

1.4 Acknowledgement

During the field works, the study team, i.e. both the JICA and counterpart teams, received generous assistance and cooperation from the authorities concerned in Karachi and Lahore, as well as at the site. The team takes this opportunity to express its heartfelt gratitude to all individuals, authorities, agencies, etc. concerned. The study team sincerely hopes that the joint effort and cooperation extended to the study will contribute to early implementation of the project and eventually to socio-economic development in the area.

2. BACKGROUND

2.1 Land and Population

Pakistan extends from 23° to 37° north latitude and from 61° to 76° east longitude. The total land area of the country is 79.6 x 10^6 ha comprising 44.7 x 10^6 ha for non-cultivation area, 3.2 x 10^6 ha for forest area and 11.1 x 10^6 ha for cultivated waste area. The cultivated area is 20.6 x 10^6 ha or about 26% of total area. The irrigated area is 15.8 x 10^6 ha or 76% of cultivated area.

In Sindh Province, the total land area is 14.1 x 10^6 ha. Cultivated land of about 5.6 x 10^6 ha is located on the Sindh plain which extends along the Indus river and its tributaries. The Sindh plain is an almost flat and featureless flood plain. The land is covered with alluvial soils which are formed of materials transported by the Indus river and its tributaries. The alluvial soils are medium to coarse in texture and immature, and are used for production of various crops. The land and land use in Pakistan and Sindh Province are summarized as follow:

Unit: 10^6 ha

Land Use	Pakistan		Sindh Province	
Total Area	79.6	100%	14.1	100%
Non-Cultivation Area	44.7	56%	5.3	37%
Forest Area	3.2	4 %	0.7	5%
Cultivated Waste Area	11.1	14%	2.5	18%
Cultivated Area	20.6	26%	5.6	40%
Irrigated Area	15.8	(76%)	3.3	(59%)

Source: Pakistan Statistical Yearbook, 1989

According of the Pakistan Statistical Yearbook 1989, the total population of Pakistan was 84.2 million in 1981, and the projected population was 105.4 million in 1988 based on an average growth rate (1972 - 1981) of 3.1% per annum. If the population continues to grow at the above rate, it will reach 150 million in 2000. As of 1981, 23.8 million people or 28% of the total population lived in urban areas, while the remainder or 72% were in rural areas. The demographic conditions of Pakistan and Sindh Province may be summarized as follows from the 1981 Population Census:

Items	Unit	Pakistan	Sindh Province
Total Area	10^3 km^2	796.1	140.9
Total Population in 1981	10^6 persons	84.3	19.0
Male	10^6 persons	44.2 (52%)	10.0 (53%)
Female	10^6 persons	40.1 (48%)	9.0 (47%)
Population Density	persons/km^2	106	135
Nos. of Household	10^3 Nos.	12,588	2,718
Household Size	persons	6.7	7.0
Average Annual Growth Rate 1972 - 1981	%	3.05	5.56

Source : Pakistan Statistical Yearbook, 1989

In Pakistan, population over 10 years of age and above is defined as productive-aged population accounting for 56.3 x 10^6 in 1981. The working population in 1981 was about 21.9 x 10^6 consisting of 21.2 x 10^6 of male and 0.77 x 10^6 of female. This corresponds to about 26% of the total population. The ratio between the working population and the productive-aged population was about 70% male, 3% female and 39% as a whole. More than 90% of female of these ages was engaged in the house-keeping work without economic activity. The working population in agricultural occupations shared 53% of the total working population. The agricultural sector provides with the largest employing opportunities in Pakistan. The working population by occupation in Pakistan may be summarized as below:

Unit: 10^3 persons

Occupation	Total	Male	Female
Productive-aged Population (10 years and above)	56,339	30,078	26,261
Working Population	21,925	21,152	773
- Agriculture, forestry, fishing, hunting	11,560	11,256	304
- Manufacturing	2,008	1,890	118
- Wholesale, retailer, restaurants, hotels	2,064	2,017	47
- Community, social, personal services	3,003	2,774	229
- Others	3,290	3,215	75
Looking for Work	702	639	63
House-keeping	24,064	-	24,064
Students	4,506	3,149	1,357
Others	5,142	5,138	4

Source : Pakistan Statistical Yearbook, 1989

2.2 National Economy

According to the Pakistan Statistical Yearbook 1989, Gross Domestic Product (GDP) in 1988/89 at constant prices of 1980/81 amounted to Rs. 404,140 x 10^6 of which agriculture sector accounted for about 26%. The annual growth rate of GDP was 5.1%, and the per capita income at constant prices was Rs. 3,910. GDP for 1987/88 and 1988/89 at constant prices of 1980/81 may be summarized as follows:

Items	1987/88 (Rs. 10^6)		1988/89 (Rs. 10^6)		Percentage
Agriculture	99,060	26%	105,140	26%	6.1%
- Major crops	48,330		52,100		7.8%
- Minor crops	16,820		17,360		3.2%
- Livestock	28,910		30,610		5.9%
- Fishing	3,780		3,800		0.5%
- Forestry	1,220		1,270		3.9%
Manufacturing	67,620	18%	69,700	17%	3.1%
Wholesale, Retailer	63,930	17%	67,160	17%	5.1%
Others	153,800	39%	162,140	40%	5.4%
Total GDP	384,410	100%	404,140	100%	5.1%
Population (million)	105		107		
Per Capita Income (Rs.)	3,870		3,910		

2.3 Agriculture in Pakistan and Sindh

According to the Seventh Five Year Plan (1988-93), agriculture remains the mainstay of Pakistan's economy accounting for over 23% of GDP and employing about 50% of the labour force.

Agricultural production growth rate in Pakistan for the year 1988 - 89 was about 6% per annum. The growth rate in major crops was 7.8%, 3.2% for minor crops, 5.9% in livestock, 3.9% in forestry and 0.5% in fishing. Major and minor crops, livestock and fishing lagged behind the plan targets, and only forestry achieved the target. However, the average annual growth rate of the agriculture sector during period of the Sixth Five Year Plan (1983-87) was 3.8% against a target of 4.9%. Although the growth target was not achieved, Pakistan is at present self-sufficient in food grains. The production of rice and wheat was below the targets set in the plan. In case of rice, a shortage of water at the transplanting stage, less than normal rainfall, pest damage and lack of high-yielding varieties of seeds resulted in decrease in production. Wheat production was also affected by adverse weather conditions in 1986-88.

Total cropping area and production of major crops in Pakistan and Sindh Province are summarized on the 2 years average basis of 1986/87 and 1987/88 as follows :

Crops	Pakistan*1			Sindh Province*2		
	Cropping Area (10^3 ha)	Production (10^3 tons)	Unit Yield (t/ha)	Cropping Area (10^3 ha)	Production (10^3 tons)	Unit Yield (t/ha)
Wheat	7,510	12,780	1.7	1,030	2,200	2.1
Rice	2,010	3,360	1.6	720	1,540	2.1
Cotton	2,540	1,390	0.5	660	1,340	2.0
Sugarcane	800	31,470	39.2	190	8,740	44.9
Maize	840	1,120	1.3	20	10	0.5
Millet	400	180	0.5	130	50	0.4
Sorghum	360	210	0.6	100	60	0.6
Pulses	1,220	610	0.5	110	80	0.7

Sources: *1 Pakistan Statistical Yearbook, 1989
*2 Agricultural Statistics of Sindh, 1989

3. THE STUDY AREA

3.1 Previous Study

In 1977-79, GOS carried out a feasibility study on the Water Resources Development in Malir Basin. It was found that in 1977, out of 514 tube/dugwells, 406 wells were utilized for irrigation and potable water supply in the basin and the remaining 108 wells were abandoned. In 1977, about 4,070 ha of agricultural land (cropped area of 5,960 ha) were irrigated by these wells. Due to excessive pumping of groundwater, it was observed that the groundwater table had been falling progressively at a rate of approximately 0.15 m per year, and thereby greatly decreasing the yields of these wells. The shortage of water adversely affected the area already developed.

In order to alleviate the above constraints, the study on water resources development in the Malir basin was carried out. Four alternative plans were identified, namely (1) a series of detention dams along the Malir river, (2) a single dam located at slightly upstream of the confluence of Mol and Khadeji rivers, (3) a single dam at about 3.2 km downstream of the confluence, and (4) the Mol and Khadeji dams. Based on preliminary investigations and the economic comparison of the four (4) alternative plans, it was concluded that water resources development by construction of the Mol and Khadeji dams would be the most economical and technically feasible. Accordingly a detailed feasibility study was carried out only for the provision of two dams at Khadeji and Mol sites.

Construction of dams on the Khadeji and Mol tributaries of the Malir river, and agricultural development of 4,360 ha being irrigated by groundwater (cropped area of 6,550 ha) were proposed in the 1977/79 study. The salient features of the proposed dams are attached in Table 2. The study concluded that the Economic Internal Rate of Return (EIRR) would be 12% for Mol and Khadeji dams, and the project would be economically and technically feasible.

3.2 Location

The study area is located in the Malir river basin which is situated about 30-60km north-east of Karachi city, the provincial capital of Sindh. The Malir river is formed by the confluence of the Khadeji and Mol rivers near the Super Highway bridge with a catchment area of 1,205 km^2 at the confluence. After the confluence, it runs about 48 km towards the southwest and drains into the Arabian Sea near Karachi.

The study area extends on both sides of the Malir river between the proposed Mol damsite located at about 7.2 km upstream of the confluence of the Mol and Khadeji rivers and National Highways, and covers a flood plain of 24,230 ha in gross as seen in Fig. 18.

3.3 Topography

The study area lies around 30-60 km northeast of Karachi city, the Provincial Capital of Sindh, lying along the northeasterly trending Malir river with its tributaries the Khadeji and Mol. Topographically, the downstream area appears relatively flat and plain with only a few low residual ridges and hills, having elevations of 20-100 m. Upstream from the confluence of Khadeji and Mol rivers at over 100 m in elevation there are steeper gradients of slopes in comparison with the downstream area. The downstream area is a very flat flood plain with a slope of 0.15% to 0.5% from the north-northeast to south-southwest direction, and the average slope is about 0.3%.

3.4 Population

The total population in the study area was 30,100 persons in 1961 and had increased to 65,600 persons by 1981. The population is estimated to have increased to 90,400 by 1989 based on the overall growth rate of 5.3% from 1972 to 1981 for Karachi East District. It is estimated that about 53% of the population is male and 47% female. Population density is estimated at 373 persons/km^2 which is about three times the average for Sindh Province of 135 persons/km^2, but considerably lower than that for Karachi East District as a whole, which is 783 persons/km^2. The total number of households is estimated at 16,270 with an average household size of 5.6 persons. The distribution of population, households and household size in the study area are summarized as follows:

Union Council	Study Area (km^2)	Total Population (person)	Population Density (person/km^2)	No. of Households	Household Size (person)
- Darsano Channo	105.8	12,629	119	2,468	5.1
- Kankar	94.4	40,154	425	7,282	5.5
- Laundhi	35.5	26,198	738	4,415	5.9
- Thano	6.6	11,391	1,726	2,109	5.4
Total	242.3	90,372	373	16,274	5.6

3.5 Regional Economy

The present economy of the study area is primary based upon agriculture that entirely depends on the availability of groundwater from potential aquifers in the area. The present agriculture is mostly concentrated on the production of high value vegetables, fruit and fodder crops, produced under relatively intensive conditions, to supply the Karachi city market. Despite the fact that the study area enjoys, in many respects, a significant advantage in the production of fruit and vegetables by virtue of its location very close to the city of Karachi, agricultural production in the area is reported to have been in decline for one to two decades whilst the population of the area has at least doubled. The major constraints to maintaining or increasing production are overall shortage of water in relation to the area of irrigable land and the farming population. This has resulted in continuous over pumping and depletion of the aquifers. Cropped area, production, crop income and employment have fallen by one half over the decade 1978-1988. Thus the study area which was once famous for its gardens and greenery is now facing problems for survival.

Traditional livestock is largely confined to satisfying domestic requirements for milk and poultry products. In recent years, a number of small and medium scale intensive poultry units have been established, often by persons from outside the study area, to supply the Karachi market. These units also have difficulty in meeting their fresh water, which is necessary to transport from outside of water tank carriers. It can be predicted under the project that development in the raising of livestock and livestock products along with the development of agriculture will gain momentum.

Karachi being a center of commerce and industry, labour force moves to the city and its industrial areas from the surroundings and even the far flung areas of the country. This will result in a high population growth in the Karachi city. The statistical data also show a high growth rate for the population in urban areas. It is anticipated under these circumstances that the consumption of commodities as well as of agricultural products such as fresh vegetables and fruit will increase in Karachi, the largest commercial city of Pakistan. In this view, there will be no major constraints in the marketing of agricultural products. In addition, all the necessary infrastructures like roads and transportation services are adequately available in the study area for the marketing.

3.6 Meteorology and Hydrology

The annual average rainfall at Karachi airport (1929-1988) is 219 mm, of which about 78% occurs during the three months from July to September in the monsoon season. The hottest month is May and the mean daily maximum and minimum temperatures are 35.2°C and 25.8°C at Karachi airport. The coolest month is January and the mean daily maximum and minimum temperatures are 25.7°C and 10.1°C respectively. The mean relative humidity varies from 79% in August to 51% in January. The mean pan evaporation reaches 14.7 mm/day in May, and the annual average of 10.4 mm/day at Super Highway bridge, however, these figures show very high values compared to the value at Karachi airport. The average monthly wind speed at Karachi airport varies between 4.7 m/sec in June and 1.4 m/sec in December. The mean meteorological data in the study area are illustrated in Fig. 1.

In and around the study area, there are two (2) meteorological stations, five (5) rainfall gauging stations and five (5) runoff gauging stations as shown in Fig. 2. Seasonal runoff coefficients at the major control points in the Malir river basin are summarized below (details in ANNEX-B):

Gauging Station	Catchment Area (km²)	Observation Period	Runoff Coefficient (%) July-Sep. (Monsoon)	Sep.-June (Winter & Spring)	Throughout the Year
1. Khadeji river at Super Highway	575	1976-1987	23.6	13.9	21.5
2. Malir Super Highway	1,205	1976-1987	24.5	7.4	20.7
3. Malir National Highway	1,985	1978-1984	15.0	0.0	11.9

The purpose of the long-term runoff analysis is to estimate the stream discharge during the period of missing discharge data by using the available data and a hydrological runoff model. The Tank Model method is selected to analyze especially long-term runoff among several hydrological runoff models. The Tank Model is used to estimate monthly discharge based on monthly rainfall. Coefficients of tank are determined through simulation until the nearest possible discharge is obtained to the observed discharge.

Since good correlation of monthly rainfall at respective stations is achieved, the relationship between Karachi airport and other rainfall stations is used to estimate long-term monthly rainfall in the study area. By using the above method and the long-term mouthly rainfall, runoffs at the proposed damsites and gauging stations are calculated and annual runoff in the basin is schematically shown in Fig. 3. In the previous feasibility study, runoff at the proposed damsites was calculated by a adopting runoff coefficient of 30% for monsoon season and 9% for winter and spring. Runoff estimated in present study shows a little higher runoff coefficient than the previous one. Runoff at the proposed damsites and major control points are summarized below:

	Damsites and Control Point	Catchment Area (km²)	Average Area Rainfall (mm)	Runoff Coefficient (%)	Ave. Annual Runoff (MCM)	WAPDA Report (MCM)
1.	Mol damsite	596	231	32.6	44.8	33.3
2.	Khadeji damsite	567	215	27.8	33.9	30.3
3.	Malir Super Highway	1,205	224	27.4	74.1	-
4.	Malir National Highway	1,985	225	13.4	60.0	-

The river runoff patterns and masscurves at the Mol and Khadeji damsites are shown in Fig. 4 and the average monthly discharges at the major control points are summarized below:

Unit: MCM

Site	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Mol Damsite	*0.4*	*0.4*	*0.5*	*0.3*	*0.3*	*0.5*	*23.8*	*11.6*	*5.5*	*0.7*	*0.4*	*0.4*	*44.8*
Khadeji Damsite	0.3	0.3	0.4	0.3	0.2	0.4	18.1	8.5	4.1	0.6	0.3	0.3	33.9
Super Highway	0.3	0.3	0.4	0.2	0.2	0.7	39.6	21.0	9.9	0.9	0.3	0.3	74.1
National Highway	0.0	0.0	0.0	0.0	0.0	0.1	33.1	18.4	8.1	0.3	0.0	0.0	60.0

The Probable Maximum Flood (PMF) at the proposed damsites are estimated based on the Probable Maximum Precipitation (PMP) which is calculated by adopting the 19-22 July 1913 storm and unit hydrograph. The PMF and probable floods are summarized below:

Description		Unit	Khadeji Damsite	Mol Damsite
1. Drainage Area		km^2	567	596
2. Peak Discharge				
- PMF		m^3/sec	5,120	4,280
- Return period	1/1,000	m^3/sec	3,870	3,240
	1/100	m^3/sec	2,240	1,870
	1/50	m^3/sec	1,820	1,520
	1/20	m^3/sec	1,300	1,090
	1/5	m^3/sec	600	390

Measurements of suspended loads were carried out from 1976 to 1988 by WAPDA (Ref. 04). Annual sediment yield for Khadeji and Mol dams is estimated at 570 $m^3/km^2/yr$ comprising suspended sediment of 460 $m^3/km^2/yr$ and bed load of 110 $m^3/km^2/yr$, respectively.

3.7 Geology and Hydrogeology

(1) Regional Geology

The study area is divided into three geological formations, i.e. Recent/Sub-recent formation, Manchar formation and Gaj formation. Quaternary deposits occupy most of the irrigated area and riverbed plains. Manchar formation consists of sandstones and conglomerates with strike of N60°W to N80°W and dip of 5° to 15° towards the south. Gaj formation is composed of sandstone and limestone having strike of N50°E to N60°E and dip of 5° to 45° toward the north-northwest.

Baserocks of the study area consist of Gaj formation of Miocene and Manchar formation of Pliocene. Gaj formation distributes in the north including the area of two damsites in exposed state underlying the Manchar formation, which exposes in the southern hills as well as moundrocks of the study area.

Quaternary deposits which are composed mainly of sand and gravels with boulders (some of them are compact due to cementing) are distributed along the present river bed. Thickness of this formation appears to be 50 m in downstream and 10-30 m in upstream reach.

Stratigraphy of the study area is as follows:

Age	Formation	Geological features
Recent to Pleistocene	Quaternary Deposits	Clay and Silt Fine to Coarse *Sand with Gravels and Boulders*
Pliocene	Manchar Formation	Sandstone, Shale, and Conglomerate
Miocene	Gaj Formation	Limestone, Sandstone, and Shale

(2) Hydrogeology

The distribution of unconsolidated layers is examined mainly through electric resistivity survey (see Fig. 5). On the basis of resistivity value, the geological profile *of the area is classified mainly into three zones, namely, permeable, slightly permeable* and impermeable zone.

The strata with resistivity values of more than 100 ohm.m are interpreted to indicate the probable existence of gravel or coarse sand. The strata of resistivity values from 20 to 100 ohm.m indicate the presence of arenaceous materials, namely sandy silt or fine to medium sand. The strata of resistivity values of less than 20 ohm.m indicate the presence of clay or shale, sandstone and conglomerates of the bedrock. They are summarized as follows:

Classification	Electric Resistivity (ohm.m)	Geological Features
Permeable	more than 100	Gravel, Coarse sand
Slightly Permeable	20 - 100	Sandy silt, Fine to medium sand
Impermeable	less than 20	Shale, Sandstone, Conglomerate

The phreatic aquifer of the Quaternary deposits is the main aquifer in the study area. The phreatic aquifers mainly comprise alluvial deposits along the Malir river, which consist of layers of sand and gravels with silty sand layers. The hydrogeological profile in the study area is illustrated in Fig. 6. The dimensions of alluvial deposits in respective stretches are as follows:

River Stretch	Width (km)	Thickness (m)
Upper reaches	3 (2.5)	20 (10)
Middle reaches	7 (5.5)	30 (10)
Lower reaches	6 (2.5)	40 (40)

Remarks: Parenthesis indicate figures for sand and gravel layer.

Geomorphology of the study area is classified into six (6) categories, such as alluvial plain, alluvial terraces of two different levels, hilly terrains, piedmont slope and hills. The groundwater development potential of the study area can be classified into the following three categories on the basis of the results of hydrogeological investigations and the geomorphology of the area:

Classification	Development Potential	Topography	Geology
Recent deposits (Unconsolidated)	Good	Alluvial Flood Plain	Quaternary Deposits
Old Terrace deposits (Unconsolidated)	Moderately good	Alluvial Terrace (Low and High)	Quaternary Deposits
Rocks with Quaternary deposits (Consolidated)	Poor	Hilly Terrains, Piedmont Slopes, Hills	Quaternary Deposits Manchar, Gaj Formation

According to results of pumping tests, measured transmissivities of the wells vary ranging from 4,100 m^2/day to 166,000 m^2/day. Low transmissivities of 4,100-5,900 m^2/day are observed in the southern (lower) part of the phreatic aquifer, and high values of 45,000-60,000 m^2/day in the northern (upper) part.

Since the aquifer in the study area is unconfined, the storativity (S) is equivalent to the effective porosity. Considering the hydrogeological conditions of the aquifer, which are reflected in the electric resistivity, it is probable that the average storativity is in the range from 0.03 to 0.20.

(3) Groundwater Table and Potential

The results of water table measurements carried out in October 1977 and 1989 are available as shown in Fig. 7. For last 12 years from 1977 to 1989, the water table was fell due to overdraft of groundwater. Groundwater depression being below mean sea level (EL. 0 m) was observed in 1977 in the southern (lower) part of the project area, and its area in 1989 was expanded. The annual notwithdrawal from the aquifer from 1977 to 1988 is estimated at about 8 MCM for last 12 years and accordingly the average annual drawdown is 0.43 m, which shows rapid drawdown compared to the projection made by WAPDA (Ref. 01). Total groundwater volume in the phreatic aquifer in 1977 and 1989 is estimated as summarized below:

Stretch	Aquifer Area (km^2)	Groundwater Potential 1977 (MCM)	1989 (MCM)	Net Withdrawal 1977-1989 (MCM)
Upper	54	57.9	24.7	33.2
Middle	55	96.3	56.8	39.5
Lower	76	62.8	39.4	23.4
Total	185	217.0	120.9	96.1
Average annual net withdrawal				8.0 MCM
Average annual drawdown of groundwater table				0.43 m

Net withdrawal from the basin phreatic aquifer is estimated at 96 MCM for last 12 years from 1977 to 1989. The remaining groundwater potential is only about 121 MCM in the project area.

(4) Water Quality and Sea Water Intrusion

Water quality of surface runoff in the Malir river is excellent and categorized as medium salinity and low alkalinity and (C_2S_1) according to the USDA standard of water classification. However, total dissolved salt (T.D.S), electric conductivity (EC) and Sodium Adsorption Rate (SAR) in the monsoon season show lower values than these during the winter and spring seasons. Excellent surface runoff water is the main source of recharge to the phreatic aquifer in the project area (see the details in ANNEX-D).

Little change of pH distributions has been recorded in 1989/1990 in comparison with data collected in 1977. pH values vary from 7.6 to 8.3 in general. According to the distribution of EC in the study area, EC of around 1,000 μS/cm occur along the Malir river and its value increases as the distance from the river increases. EC values of groundwater analyzed in 1989 show generally higher values than those recorded in 1977 at wells located in the downstream area.

Groundwater in the project area is classified generally into C_2S_1 and C_3S_1 according to the USDA standard except water sampled from the groundwater depression in Thano and Laundhi Union Councils. Groundwater in the project area shows a moderate to medium high salinity hazard but less sodium (alkalinity) hazard for irrigation purposes. However groundwater in the depression is classified as a high salinity hazard and medium alkalinity hazard (C_4S_2). SAR is low, ranging from 1.1 to 6.18. Taking these results into consideration, boron and other chemical contents are just permissible for irrigation water except in the southern part of the depression mentioned above.

According to the report entitled "Groundwater Potential Study" by the Ministry of Petroleum and Natural Resources in 1985, the pore waters in the bedrocks of Manchar and Gaj formations were originally saline. The movement of groundwater from the bedrock to the phreatic aquifer of the study area could also have occurred due to the cone depression formed in the downstream area. Hence, it is probably that some intruded saline water originates not only from the sea water but also from the bedrock, of which the chemical characteristics are similar.

As the previous studies indicated that there was sea water intrusion in the downstream area, the groundwater sampled from the downstream part of the project area is probably affected by sea water intrusion, judging from the results of simple pattern analysis (Stiff, 1955), the trilinear diagram analysis (Piper, 1944), tritium content analysis and hydrogeological information. As a result of sea water intrusion into the groundwater depression, EC values changed from about 2,000 μS/cm in 1977 to more than 3,000 μS/cm in 1989.

3.8 Soils and Land Capability

The Soil Survey of Pakistan was carried out in the WAPDA study area with a total extent of 29,210 ha which covers the flood plains formed by the Malir river and its surrounding highland. According to the previous study and field surveys, a high coincidence was recognized between distribution patterns of major soils and landforms. The landforms were classified into four (4) units for which seven (7) soil associations were identified as summarized below:

Landform	Geological Era	Soil Association	Extent (ha)
1. Sub-recent flood plain	Qurtenary	Meheb	6,460
2. Old piedmont plain less eroded	Late Pleistocene	Iddu, Mauripur and Mindiari	11,560
3. Old dissected piedmont plain	Late Pleistocene	Laundhi and Pipri	8,580
4. Very old dissected gravelly piedmont terrace	Middle Pleistocene	Monze	2,610
Total			29,210

The existing agricultural area is mainly located on sub-recent flood plains. This unit occurs on narrow river banks formed along the Malir river. Topography is generally level to nearly level. Soils in the existing agricultural area are classified into Mehab Association which can be characterized by fine silty to sandy textured topsoils with some gravel content underlain by sand at 100 cm or deeper. Soil fertility is rather higher than one of the other landforms. Electrical conductivity (EC) of saturation extract ranges from 0.8 to 8.0 mmho/cm, which are classified into non-saline to strongly saline classes. In cases, soils show non-saline to very slightly saline characteristics in surface soils, while moderately saline in subsoils. Soils pH range from 7.9 to 8.4 throughout profiles indicating slightly alkaline.

There is no severe alkalinity hazard in the area except for some crops, e.g. vegetables, with high susceptibility to saline soils.

Land capability was assessed for the soils of the WAPDA area in order to classify the suitability of soils for general agricultural purposes including grazing and forestation (Ref. 01). Land capability was classified into four (4) and summarized as follows:

Land Capability Class	Area (ha)	(%)
Class I	6,210	21
Class II	9,570	33
Class III	11,190	38
Class IV	2,240	8
Total	29,210	100

Source : Feasibility report, WAPDA in 1979

The total arable land in the WAPDA survey area from the above is estimated at about 15,800 ha. This area may be large enough for future agricultural development through utilizing the groundwater resource, considering the present cultivated area of 2,700 ha as discussed in Section 3.9. Most of the soils under Mehab Association were classified into Class I. By introducing irrigation and modern crop management techniques, high agricultural productivity can be expected in Class I.

3.9 Land Use and Agriculture

(1) Land Use

The present land use pattern is closely related to topographic conditions, soil conditions and availability of irrigation water. The land use is classified into five (5) categories i.e., (a) orchard fields, (b) irrigated upland fields, (c) rainfed upland fields, (d) fallow land and (e) non-agricultural land.

The orchard fields and irrigated upland fields extend over the alluvial plains where the soil condition is good and groundwater can easily be extracted. The rainfed upland fields are scattered in the hilly and sub-hilly lands where groundwater is not available. Villages are also scattered in the alluvial plains adjacent to the irrigated upland field. Uncultivated land consists of roads, rivers, and unutilized land in the hilly and sub-hilly area. Extensive poultry and livestock breeding are practised in the hilly area.

The irrigated fields have been developed to possible maximum extent depending on availability of groundwater in the Malir river basin. In resent years, however, irrigated fields have decreased due to less available irrigation water. Due to shortage of irrigation water, many mature mango trees are dying, and the fallow land area has increased. Present land use in the study area is shown in Table 3. Total agricultural land fell by about 20% over the period from 1978 to 1987/88, as summarized below:

Land Category	WAPDA Study 1978		JICA Study 1988/89	
	(ha)	(%)	(ha)	(%)
Agricultural Land	4,070	13.9	3,220	13.3
- Orchard fields (irrigated)	1,380	(4.7)	1,200	(5.0)
- Upland fields (irrigated)	2,690	(9.2)	1,540	(6.3)
- Upland fields (rain-fed)	(-)		480	(2.0)
Fallow Land	1,590	5.4	2,920	12.1
Non-agricultural Land				
- Villages, hills, rivers and others	23,550	80.7	18,090	74.6
Total	29,210	100	24,230	100

(2) Land Holdings and Land Tenure

In 1979, the WAPDA study reviewed the land holding and land tenure situation in the study area for 1978 on the basis of records maintained by the Karachi East District Revenue office for the purpose of collecting land tax. The WAPDA study indicated that a total of about 5,660 ha of land were registered which was owned and/or operated by 831 farmers, giving an average holding of 6.8 ha.

According to the updated estimate in 1988 by the Karachi East District Revenue office, it indicates that over the past decade the area registered has increased to 6,140 ha, and that the number of farmers has decreased to about 700. Therefore average holding size has increased to 8.8 ha. The overall situation in 1978 and 1988 is summarized in the table below:

Item	Under 5 ha		5-20 ha		Over 20 ha		Total	
	1978	1988	1978	1988	1978	1988	1978	1988
No. of Holdings	499	352	224	283	108	63	831	698
(%)	60	50	27	41	13	9	100	100
Area (ha)	1,360	847	1,982	2,836	2,323	2,457	5,665	6,140
(%)	24	14	35	46	41	40	100	100
Average Holding (ha)	2.7	2.4	8.9	10.0	21.5	39.0	6.8	8.8

Both the 1978 and 1988 estimates indicate that a high proportion of registered land, 41% and 40% in the respective years, is concentrated in large units of over 20 ha which are in the hands of a small number of farmers, 13% and 9% of the respective annual totals. In 1978 some 108 farmers in this group had an average holding of 21.5 ha, and in 1988, 63 farmers had holdings with an increase in average size to 39.0 ha. The estimates also indicate, on the other hand, that a high proportion of farmers, 60% in 1978 and 50% in 1988, operated units of under 5 ha, occupying only 24% and 14% of the registered area in the respective years. The average size of holding was 2.7 ha in 1978 and 2.4 ha in 1988. Data from 1988 indicate that almost 10% of farmers operated units with an average size of only 0.6 ha. A middle group of farmers operated holdings in the 5 to 20 ha size range. These farmers increased in number from 224 in 1978 to 283 in 1988 and operated farms occupying 35% of registered land in the earlier period and 46% in 1988. The average holding of the group was 8.9 ha in 1978 and 10.0 ha in 1988.

The 1979 WAPDA study presents a breakdown of the land tenure situation in the study area in 1978, also from Karachi East District Revenue office records. Present land tenure conditions are estimated based on the rate of the WAPDA study, 1978. Data for 1978 indicate that 53% of all farmers were tenants, whose farm land was owned by other persons, on a share cropping basis. The tenants operated on about 38% of the total area of land, with an average farm size of 6.1 ha. Owners, directly farming their own land, accounted for 27% of all farmers and 36% of the registered land area, with an average farm size of 12.1 ha. An intermediate category of owner-tenant (owning and farming part of the land and farming another part owned by other persons on a share-cropping basis) accounted for the remaining 20% of farmers and 26% of the registered land area. The average farm size of owner-tenants was 11.5 ha, similar to that of owner farmers.

Overall, therefore, 70% of all farmers are tenants operating a holding which is, on average, a little over half the size of that of owner farmers and owner-tenant farmers. Given that up to half the volume of production on tenant operated farms is paid to the owner, the actual and potential return to the tenant farmer is likely to be relatively small.

Under the existing tenancy system the land owner receives 50% to 60% of the gross output of the crop which is paid to him (generally in kind) by the tenant. The tenant receives 40% to 50% of the crop. The tenant and land owner each provide 50% of the cost of a range of production inputs, whilst the tenant meets all labour costs, and the land owner provides well operation and maintenance costs.

(3) Agricultural Production

In the absence of specific and reliable information for the study area, present unit yields of main crops are estimated based on the Agricultural Statistic Data of Karachi District on two years average (1986/87 - 1987/88). Most of crop yields in Karachi District averaged over two years 1986/87 - 1987/88 have not reached the level of comparable yields for Sindh Province as a whole due to poor soil fertility, shortage of irrigation water, low level of farm inputs and traditional farming practices. The unit yields of main crops are summarized as follows:

Unit: ton/ha

Crops	Sindh Province	Karachi District	Crops	Sindh Province	Karachi District
Vegetables :			Fodder Crops :		
Tomato	5.0	3.3	Sorghum	-	11.5
Eggplant	6.8	4.9	Maize	-	10.6
Chilli	3.5	1.0	Lucerne	-	13.9
Sponge Gourd	6.4	3.1	Fruit :		
Bottle Gourd	5.4	4.7	Mango	7.7	6.1
Cauliflower	5.8	13.3	Guava	6.0	3.8
Spinach	4.2	2.6	Coconut	-	2.7
Carrot	9.9	5.4	Chikoo	-	2.3
Radish	7.8	4.0	Papaya	-	7.3
Peas	4.1	2.6			

The volume of crop production in the study area has been estimated on the basis of the estimates of cropped area and crop yields as set out above. The study area is estimated to produce some 6,900 tons of fodder from a cropped area of 570 ha, some 8,600 tons of vegetables from 1,960 ha, and 5,980 tons of fruit from 1,200 ha. The volume of crop production is summarized in the following table and given in detail in Table 4:

Crop	Cropped Area ha	Volume ton	Yield ton/ha
Fodder	570	6,910	12.1
Vegetables	1,960	8,610	4.4
Fruit	1,200	5,980	5.0
All	3,730	21,500	-

The livestock population of the study area in 1989 was estimated at 4,800 cattle, 15,650 buffalo, 9,490 sheep and goats, and 1,130 other stock (mainly donkeys, mules and horses). Livestock are seldom used in crop cultivation, however it is mainly replaced by hired tractors. Animals, mainly donkeys, are used for carting farm inputs and harvested crop within the area. Cattle and buffalo are mainly kept for dairying and this accounts for the rather large proportion of cropped area which is allocated to fodder. Goats are kept for meat and milk.

Most farmers interviewed stated that they maintained one or two cows or buffaloes to meet their domestic requirements for milk. It is likely, therefore, that the majority of large stock is kept in dairy units at the edge of the study area in urban zones immediately adjoining Karachi. This milk production does not impact economically upon the majority of farmers or inhabitants of the study area. Similarly several large intensive poultry production units are located in the study area but obtain commercial feed and other inputs from Karachi, and sell their produce into Karachi. They create some employment in the study area, but are mainly owned by Karachi residents.

3.10 Agricultural Supporting Services

(1) Agricultural Extension

The Director of Agriculture (Extension) controls extension activities through two General Directors of Agriculture (DA), one in Hyderabad and one in Sukkan Division. At his headquarters, he is assisted by specialist staff officers, one Assistant Director of Agriculture (ADA for Administration) and one ADA (Economics and Marketing).

The two divisional ADAs supervise Extra Assistant Directors of Agriculture (EADA) in each district, who are in charge of all agricultural extension activities. Each divisional ADA has specialist staff officers for horticulture and plant protection. The district EADAs supervise about 200 Agricultural Officers (AO), who supervise about 700 Field Assistants (FA). Each EADA is assisted by an Assistant Plant Protection Officer (APPO) who acts as a district subject matter specialist in plant protection matters. In each district there is also an EADA (Economics and Marketing) who reports to the ADA (E&M) at Headquarters.

A Field Assistant (FA) is expected to contact over 1,000 farmers. Most FAs live on the farms of the larger landlords, to whom many eventually become obligated to provide various services. Each FA is supported by one or two trained laborers (beldars) who are recruited from the local farming community and usually live on their family farms or in the villages. The beldars' duties involve practical teaching and demonstration work under the supervision of the FAs. The FAs and the beldars are involved in the sale and application of pesticides, mainly for cotton and orchards.

Since May 1978, the Department of Agriculture has changed its method of operation to conform with the principles of the Training and Visits (T&V) System, for which it has received technical assistance from the World Bank. There are now clear job descriptions for all staff levels. Day-by-day work schedules for FAs and AOs have been prepared and are being followed.

The organization of agricultural extension in Karachi area is assigned to one EADA under the supervision of Director of Agriculture Extension, Hyderabad. Under the ADA Karachi Office, there is one Agriculture Office located at Malir, and one APPO assists and advise 5 AOs and 9 FAs. In the study area, the total number of AOs and FAs are 4 and 7, respectively, covering 4 Union Councils, 32 Dehs and about 1,000 farmers.

(2) Agricultural Research

Agricultural research is being conducted by six (6) organizations under separate authorities summarized below:

	Research Institute	Location in Sindh	Responsible Authorities
1.	Agricultural Research Institute	Tando Jam	Dept. of Agriculture, GOS
2.	Rice Research Institute	Dokri	Dept. of Agriculture, GOS
3.	Horticulture Research Institute	Mirpurkhas	Dept. of Agriculture, GOS
4.	Sindh Agricultural University	Tando Jam	Dept. of Education, GOS
5.	Cotton Research Institute	Sakrand	Federal Government, GOP
6.	Atomic Agricultural Research	Tando Jam	Federal Government, GOP

The institutes are reasonably well equipped, but their effectiveness suffers from a dearth of operating funds, insufficient adaptive field work and inadequate linkage with the extension service. Their field stations are too few for effective testing of research findings in all the various agro-climatic zones of the province; shortage of operating funds makes it necessary to reduce the scope of the field stations' work drastically, frequently below that required for efficient operation.

The research findings at different research stations are carried to farmers through Agricultural Extension Department of Sindh. The coordination between agricultural research institutes and agricultural extension is through the Sindh Coordination Committee. The committee meets every month to review their performance, and to bring new ideas and problems from the growers. Future plans and policies are made at these meetings.

(3) Sindh Seed Corporation

Sindh Seed Corporation is legally, operationally and financially an autonomous organization. The organization works as a modern seed industry in the province involving variety release, multiplication processing, certification, storage and marketing of seeds for wheat, rice, and cotton. The corporation procures good quality pre-basic seeds of wheat and cotton from the Agricultural Research Institute, Tando Jam, and of rice from the Rice Research Institute, Dokri. The seeds are also produced at different government farms. The corporation selects progressive farmers for multiplication of seeds. To maintain the quality of the seed, supervisory staff is available to supervise. The corporation distributes seed through a network of agencies in towns and rural areas and fixes the wholesale and retail prices of improved seeds. The Sindh Seed Corporation has not been involved in vegetables, fruit or fodder crops so far. Therefore the agencies of this corporation are not established in the study area.

(4) Sindh Agriculture Supplies Organization

Fertilizer marketing in the province is done by the operators of the Daharki plant, Exxon Chemical (Pakistan) Ltd., the National Fertilizer Corporation (NFC) who are supplied by all the public sector plants in the country and the Sindh Agricultural Supply Organization (SASO) which handles only imported products. SASO operates some sales parts in the more remote areas with their own staff. Karachi area has only one sub-bulk depot of SASO which is located in one of the major towns (Memon Goth) of the study area. This sales point serves to provide fertilizer in the project area.

(5) Agricultural Credit

The Agricultural Development Bank of Pakistan (ADBP) has been oprating its "Supervised Credit Programme" since 1979. This programme extends credit to borrower farmers with technical guidance from mobile credit officers of ADBP.

There is one (1) branch office of ADBP in the project area. The office started operation in 1987 and two (2) mobile credit officers cover the whole project area. As of the end of 1989, some 230 borrowers, most of whom are poultry raisers, availed themselves of the development credit up to the amount of about 106 million Rupees. Only one case of production loan for procurement of fertilizer, seeds, etc. was recorded. It seems that credit from the ADBP is not so popular with small farmers so far.

3.11 Existing Dug/Tubewells

According to the well inventory survey in 1977 by WAPDA, out of 514 wells, 406 production wells were utilized for irrigation and potable water supply, and the remaining 108 wells were abandoned. Since 1980, tubewell construction has been accelerated in and around the study area, and an additional 52 wells have been constructed during the last ten (10) years.

Since no detailed information and data were available, a well inventory survey was carried out in the study area in 1989. According to the results of the survey, there are now 516 dug and tube production wells and about 110 abandoned wells in the study area.

The aquifer in the basin to which recharge will be augmented by construction of dam(s) lies along the Malir river, and is about 30 km long, 5 km wide, and 30 m depth. Almost all of the production wells are situated along the Malir river, since the main recharge sources to the aquifer is the Malir river as seen in Fig. 6. High well distribution density is observed in the downstream area and along the river (see Fig. 8). In Konkar and Thano Union Councils located in southern (lower) part of the project area, more than 10 wells are located within one (1) km^2, and wells are interfering with each other due to overdraft of groundwater.

As shown in Fig. 9, well construction was accelerated in the 1960's and it was continued in the 1970's and 1980's. Due to excessive withdrawal of groundwater, the depth of dugwells became deeper and deeper every decade and this fact shows that the groundwater table is falling at the rate of about 5 - 7 m per decade as seen in Fig. 10. Especially in the areas of Thano and Laundhi Union Councils, the decline of the groundwater table is remarkable, and the number of abandoned wells is increasing sharply, as also shown in Fig. 10. The following table shows the average depth of wells from the ground surface in each decade:

Year	Average Depth from Ground Surface: Construction Time m	Average Depth from Ground Surface: Present (1989) m	Average Increase of Well Depth m/10 yr
1940's	8.5	36.7	6.3
1950's	13.3	33.7	5.8
1960's	15.2	30.3	6.0
1970's	19.7	29.4	6.5
1980's	20.0	24.0	8.0
Average for 12 years Drawdown of groundwater table (1977-1989)			About 7.0 m - 7.5 m

The benefited area (hereinafter referred to as the project area) is delineated based on the hydrogeological conditions and the recharge mechanism in the study area. In the project area, there are 466 production wells and its distribution is shown in the DRAWINGS. Union Council-wise and Deh-wise existing wells are summarized in Table 5, and a summary of the production wells is given below:

Dia. of Discharge P. mm (inch)	Nos. of Production Wells: Project Area	Upper R. Stretch: Darsano Chano U.C.	Middle R. Stretch: Konkar U.C.	Lower R. Stretch: Laundhi U.C.	Lower R. Stretch: Thano U.C.
50 (2.0)	92	-	76	11	5
75 (3.0)	246	44	97	89	16
100 (4.0)	121	52	28	16	25
125 (5.0 -)	7	6	-	-	1
Total	466	102	201	116	47

3.12 Irrigation

(1) Irrigation Area

In 1977, there was about 4,070 ha of irrigated area by groundwater. As clearly projected in the previous study, the groundwater table is decreasing year by year due to excessive extraction of groundwater which was accelerated by long dry spells since the early 1970's. In 1988, there was 2,600 ha of agricultural area irrigated by 466 production wells. Over the period from 1977 to 1988, the cropped area under groundwater irrigation fell by 44%, with a fall of 36% in the summer season and 59% in the winter as summarized below:

Unit: ha

Irrigation	WAPDA Study in 1978 (1)	JICA Study Project Area (2)	(2)/(1) (%)
Summer Season	4,070	2,600	64
- Fodder	530	170	
- Vegetables	1,920	1,250	
- Fruit	1,380	1,180	
Winter Season	3,760	1,540	41
- Fodder	370	50	
- Vegetables	1,510	310	
- Fruit	1,380	1,180	
Total	7,340	4,140	56

In the project area, soils are categorized as sandy loam with the high measured infiltration rate of 40 mm - 50 mm/hr . Due to limitation of supply water and high infiltration, very limited basin irrigation method (less than about 20 m x 20 m) is practiced in the basin for common crops. Water melons, gourds and onions etc., are irrigated by furrow irrigation to only root zone to save water as much as possible. All farmers are acquainted with shortage of irrigation water, and therefore, intensive irrigation water control is practical in the area.

(2) Water Withdrawal in 1987/88

In the project area, there are 2,600 ha of net irrigation area which are irrigated by 466 production wells. Based on the agricultural electric consumer's record in 1987/88 (KESC), pumped water from the production wells is estimated to be about 35.5 MCM in 1987/88 and summarized in the following table. Actual irrigation water supply in 1987/88 is limited at about 80% of necessary irrigation water requirement as calculated in ANNEX-G. This means that crops and plants in the project area regularly face shortage of irrigation water supply, due to long points of drought over the last 20 years.

Item	Unit	River Stretch			Whole Project Area	Diversion* Water Requirement
		Upper	Middle	Lower		
1. Nos. of Pumped	Nos.	102	201	163	466	-
2. Pumped Volume	MCM	11.5	15.2	8.8	35.5	44.3
3. Unit Pumping Volume	1,000 m^3	113	76	54	76	-

Remarks: Refer to ANNEX-G

The irrigation area covered by each well is inferred from the diameters of the installed discharge pipes and well yields. The following table shows the net irrigation area and well yields for each discharge pipe diameter, calculated by adopting the unit actual irrigation water requirement in 1987/88:

Discharge Pipe Dia. mm (inch)	Nos. of Well Nos.	Net Irri. Area ha	Ave. Irri. Area/Well ha/well	Estimated Average Well Yield in 1987/88 1,000 m^3/year
50 (2)	92	210	2.3	31
75 (3)	246	1,220	4.9	67
100 (4)	121	1,100	9.1	124
125 (5)	7	100	14.3	195
Total/Ave.	466	2,630 Say 2,600 ha	5.7	76

(3) Existing Flood Detention Facilities

There are three (3) flood detention weirs in the project area, and their salient features are presented in Table 6. These weirs were constructed for the purpose of increasing groundwater recharge to the aquifer by detaining flood water during the Kharif (monsoon) season. There are two such weirs on the Malir river. The lower weir is located in Thano Union Council at about 4.0 km upstream of the National Highway Bridge, and the upper weir in Konkar Union Council at about 6.4 km from the Bridge, respectively. One weir is located in Laundhi Union Council at 7.5 km upstream of the confluence of the Malir and Sukkan rivers.

4. POTENTIAL WATER RESOURCES DEVELOPMENT

4.1 Water Balance

Groundwater recharge to an aquifer system is generally estimated by using a surface runoff model, namely a tank model used in estimation of surface runoff. In a tank model, a series of tanks have outlets on their bottoms and sides. Water in a tank flows out through each outlet according to the water level above the outlet. Outflows through side outlets correspond to direct runoff or natural groundwater discharge, and outflow from the outlet of the last tank corresponds to the groundwater recharge. In this study, the same tank models which were used to estimate surface runoff and calibrated by actual discharge measurements at control points, were utilized for estimation of recharge to groundwater.

(1) Recharge under the Natural Condition

The basin may be divided into six (6) sub-basins, determined by the hydrological conditions, and control points, such as river runoff gauging stations and proposed structure sites. The natural recharge into the basin phreatic aquifers is calculated by using the above model, and is estimated at 46.5 MCM/yr from 1929 to 1988 and 38.8 MCM/yr from 1977 to 1988, respectively as summarized in the following table and schematically shown in Fig. 11. The mass-curve of natural recharge into the phreatic aquifer and annual recharge amount for last 60 years from 1929 to 1988 are presented in Fig. 14.

Stretch	Average Recharge (MCM)	
	1929-1988	1977-1988
1. Damsites - Super Highway	6.6	3.2
2. Super Highway - National Highway	39.9	35.6
3. Total recharge to phreatic aquifer	46.5	38.8

The relationship between runoff into the basin and recharge (estimated groundwater recharge/runoff) is plotted in Fig. 12. It shows clearly that recharge ratios against runoff decrease with increase of runoff. If the runoff is less than 10 MCM/month, the recharge ratio is nearly 100%, but if the runoff is 20 MCM/month, its ratio decreases to about 75%.

(2) Water Balance in the Basin Aquifer (1977-1989)

The water balance of the phreatic aquifer is estimated on the basis of the recharge and discharge of the aquifer. Main recharge components are the natural recharge by precipitation, infiltration of surface water and deep percolation of irrigation water.

The main discharge components from the aquifer are the artificial discharge like pumped groundwater and outflow of groundwater to the sea and/or another aquifer.

Groundwater table records in 1977 and 1989 are available to assess the comprehensive water balance in the basin phreatic aquifer. Groundwater potential in the basin aquifer is estimated to have been at 217MCM in 1977 and 121MCM in 1989, respectively, based on results of hydrogeological investigations and studies as described in Subsection 3.7.(3). Moreover, groundwater use in 1977 and 1989 has been calculated as described in Subsection 3.12(2), as well as the average natural recharge from 1977 to 1988 in the above Subsection.

Applying these study results, a comprehensive water balance in the basin aquifer as a whole is performed as shown in the following table. The annual net withdrawal from the aquifer from 1977 to 1988 is estimated to have been 8.2 MCM/yr, which is nearly equal to the measured net withdrawal of 8.0 MCM/yr as calculated in Subsection 3.7(3).

Unit: MCM/yr

Simulation Period : 1977-1988				
A.	Recharge			
	1.	Natural recharge	38.8	Refer to Subsection 4.1(1)
	2.	Deep percolation (irrigation)	7.3	15% of Item B.1
	3.	Deep percolation (domestic water)	0.3	15% of Item B.3
	4.	Total - A	46.4	
B.	Withdrawal			
	1.	Irrigation water	48.7	(62.0 + 35.5)/2 (Refer to ANNEX-G)
	2.	Potable water supply to Karachi	2.7	(4.7 + 0.7)/2 (Refer to ANNEX-D)
	3.	Domestic water	1.9	(1.5 + 2.3)/2 (Refer to ANNEX-D)
	4.	Groundwater discharge to sea	1.3*	
	5.	Total - B	54.6	
C.	Balance		-8.2	Item A.4 - Item B.5
D.	Measured net withdrawal from the aquifer		-8.0	Refer to Subsection 3.7(3)

Remarks : *Natural groundwater discharge from the aquifer is estimated as follows:
$Q = k \times i \times A = 6{,}200\ (m/yr) \times 0.002 \times 0.106\ (km^2)$
$= 1.3$ MCM/yr

4.2 Artificial Recharge by Dam(s)

(1) Allowable Maximum Reservoir Storage

A study on the required storage capacity of reservoirs was made by WAPDA as explained in Section 3.1. Finally, taking into account flood control by curtailing flood peaks, the live reservoir storage was fixed at 54.7 MCM (crest EL. 168.6 m) for the Khadeji dam and 50.9 MCM (crest EL. 177.1 m) for the Mol dam, which were fixed at the maximum of the topographic limits (Ref. 01).

After completion of the previous study, about one decade has passed. Several important projects have been executed during the decade, which would affect implementation of this project, especially the Khadeji dam. A part of the existing two lanes and another two lanes under construction of the Super Highway from Karachi to the north will be submerged under the Khadeji reservoir, resulting in an increase in relocation costs of the Highway. Moreover, the Khadeji dam axis touches the Precision Engineering Complex (PEC) of Pakistan International Airline (PIA) belonging to the Ministry of Defence, and clearance between the proposed surcharge water level (EL. 166.3 m) in the previous study and the lowest ground elevation (EL. 169 m) of the Complex is only 2.7 m. Therefore, in order to avoid submergence of the Super Highway, to minimize the costs, as well as to provide more clearance for the PEC, the maximum surcharge elevation would be fixed at EL. 163 m for the Khadeji dam.

The maximum allowable surcharge elevation of the Mol reservoir is about EL. 175 m which shows the allowable topographic limitation as also studied by WAPDA.

Based on these conditions and newly prepared elevation-capacity curves, the maximum gross reservoir capacities are fixed at 45.7 MCM for the Khadeji dam and 54.5 MCM for the Mol dam after subtracting flood surcharge depth. Based on analysis of suspended load measurement, the design sediment load at the both damsites is estimated at 360 $m^3/km^2/yr$ after allowing for some adjustment for factors such as river bed load, trap efficiency, etc., which shows a little higher value compared to 260 $m^3/km^2/yr$ analyzed in the previous study. The useful life of reservoir is assumed to be 50 years as recommended in the previous study. The dead storage capacities are estimated to be 10.2 MCM for the Khadeji dam and 10.7 MCM for the Mol dam. The following table shows the summary:

Item	Unit	Khadeji Dam	Mol Dam
1. Maximum Allowable Surcharge Level	EL. m	163.0	175.2
2. Surcharge Depth*	m	3.9	3.4
3. Normal Full Water Level (NFWL)	EL. m	159.1	171.8
4. Maximum Gross Storage Capacity	MCM	45.7	54.5
5. Dead Storage Capacity	MCM	10.2	10.7
6. Minimum Water Level	EL. m	149.0	156.5
7. Maximum Live Storage Capacity	MCM	35.5	43.8

Remarks: Surcharge depth is calculated through the flood routing analysis described in ANNEX-H.

(2) Alternative Cases

In order to increase the recharge amount, water exceeding the recharging capacity in the study area, which drains into the sea at present, would be trapped by dams upstream of the recharge area. Small scale existing weirs along the Malir river are also useful for retarding river runoff in order to increase the amount of infiltration.

Recharge to groundwater differs in general depending on runoff pattern, reservoir capacity, combination of dams, and operation rules. The maximum net reservoir capacities of the proposed dams are fixed at 43.8 MCM for the Mol dam and 35.5 MCM for the Khadeji dam, respectively, according to the topographic limitations of the damsite. Recharges of following seven (7) alternative cases are calculated by adopting the proposed dam operation rules described in the following Subsection.

Unit: MCM

Combination of Dam	Case-1 Khadeji + Mol	Case-2 Khadeji + Mol	Case-3 Mol Only	Case-4 Mol Only	Case-5 Mol Only	Case-6 Khadeji Only	Case-7 Khadeji Only
Live Reservoir Capacity:							
Khadeji:	35.5	35.5	-	-	-	35.5	30.0
Mol;	43.8	35.0	43.8	35.0	30.0	-	-

(3) Dam Operation

Runoff at the proposed damsite(s) and water demand in the project area are generally decisive factors in determining the reservoir capacity. However, in the project area, there are huge water demands, very limited water resources, and a huge groundwater reservoir in the basin. In general, water from a reservoir is released depending on water demand in the downstream area. However, since there is a huge groundwater reservoir with a capacity of more than 300 MCM in the phreatic aquifers, it is not necessary to discharge water from the reservoir according to the water demand.

Moreover, equal recharge to the phreatic aquifer in the upper and lower stretches should be kept as much as possible. If discharge from the dam is a low, most water will be recharged to groundwater only in the upper river stretch. On the other hand, if the discharge is more than recharge capacity, excess water will be wasted into the sea without being utilized. Therefore, the allowable discharge from the dam will be the only important factor for the dam operation.

The allowable discharge from the dam(s) is determined based on three (3) approaches, i.e. (i) hydrological approach, (ii) field infiltration rate, and (iii) lateral groundwater movement, and is estimated at 8 m^3/sec (21 MCM/month) as summarized below:

Item	Allowable Recharge Rate (m^3/sec)
1. Runoff Analysis	4 - 9
2. Field Infiltration Test	9
3. Lateral Groundwater Movement	7 - 9
Adopted	8 m^3/sec (21 MCM per month)

Allowable discharge of 8 m^3/sec from the dam is applied for the dam operation. However, since there are two existing weirs on the Malir river, located at about 4 km and 6.4 km upstream from the National Highway bridge, this allowable discharge should be calibrated after completion of dam(s) construction during the operation and maintenance period.

(4) Artificial Recharge by Dam(s)

Applying the procedure and results described in Sections 4.1, a modified simulation model with storage dam(s) is prepared for calculation of recharge to the phreatic aquifer. Dam(s) operation rule is set to release water from the dam(s), which corresponds to the balance between the allowable discharge of 8 m^3/sec as fixed in the above Subsection, and the runoff from the remaining catchment area from the proposed damsites to the National Highway bridge. If the runoff from the remaining catchment area exceeds the allowable discharge, no water is released from the dam(s). Only the balance of water is released, when runoff is less than the allowable discharge.

Artificial recharge is calculated for various alternative cases, and the results are summarized in Table 7 and illustrated in Figs. 14 and 16 (see the details in ANNEX-D). The total volume combining the natural and artificial recharge may be summarized as follows:

Unit: MCM

	JICA Study							WAPDA
Combination of Dams	Khadeji+Mol	Khadeji+Mol	Mol Only			Khadeji Only		Khadeji + Mol
	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	
Live Storage Capacity	35.5 43.8	35.5 35.0	43.8	35.0	30.0	35.5	30.0	54.6 50.9
Natural Recharge from the Remaining Basin and Dam Spillout	26.1	26.9	39.6	41.1	41.6	43.81	43.8	26.8
Recharge by Dams	44.5	42.4	25.8	23.6	22.3	19.6	18.3	46.6
Total Recharge	70.6	69.3	65.4	64.7	63.9	62.7	62.1	73.4

As seen from the above table, construction of both Mol and Khadeji dams results in substantial decrease of natural recharge by runoff from the remaining basin, compared to a single dam. The catchment area is 1,520 km^2 at the confluence of the Malir river with the Thaddo and Sukkan rivers, and 1,205 km^2 at the Super Highway bridge. If two dams are constructed, the runoff from about 80% of the river basin will be regulated, but the recharge ratio sharply will drop when the runoff exceeds more than 20 MCM/month. Therefore, natural recharge by the runoff from the remaining basin and the spillout from the dams are substantially decreased.

In the case of a single dam construction, the runoff from about 60% of the total basin and spillout from a single dam can be expected, and which results in an increase in the natural recharge to the phreatic aquifer. The river runoff patterns and mass-curves at the Mol and Khadeji damsites are also presented in Fig. 4. Figure 15 shows a mass-curve of natural recharge, and augmented recharge to the aquifer with the Mol dam with a live reservoir capacity of 35 MCM.

4.3 Groundwater Model Simulation

(1) General

There are no continuous groundwater monitoring records in the project area except for two groundwater table measurements in 1977 and 1989 as discussed in Section 3.7. In addition, there is no continuous record regarding groundwater withdrawals such as irrigated area, electric energy consumption, etc. However, the average annual natural recharge during the period from 1984 to 1988 is estimated to have been about 36.4 MCM/yr as shown in Table 7, and the annual irrigation water demand in 1987/88 about 35.5MCM/yr.

These main components of natural recharge and irrigation demand are of similar volume. Though the groundwater table has fallen sharply over the last 12 years (1977-1989), the groundwater table for last 5 years (1984-1988) is presumed to have been constant, i.e. average recharge and discharge is almost balanced. Taking these limited records into consideration, the groundwater simulation is performed to assess its movement mechanism in the basin under the steady state condition.

(2) Model Construction

Aquifer modeling is carried out by a mathematical water balance modeling method using a digital computer. In this study, a quasi-three dimensional aquifer simulation model is used for groundwater simulation. The model simulates two-dimensional horizontal groundwater flow in the phreatic and confined aquifer, considering aquifer parameters, such as transmissivity and coefficient of storage, as function of piezometric head in vertical direction, which results in an approximate simulation of three-dimensional groundwater flow. In this study, the model for only the phreatic aquifer is utilized in consideration of the hydrogeological conditions.

The model is constructed mainly considering topography, aquifer distribution, hydrogeological characteristics, and results of groundwater recharge and water extraction from the aquifer. The finite-element grid mesh of the study area, which is composed of triangular and/or quadrilateral elements, covers an area of about 390 km^2. The grid is designed to be finer where more data are available and/or where hydraulic gradients are relatively steep. The distance between adjacent nodes is basically about 1.0 to 2.0 km.

On the basis of the geological and hydrogeological data obtained during the investigations, the aquifer parameters were determined as described in Section 3.7. The aquifer is not composed of a homogeneous layer but alternations, such as a layer of sand and gravel, and a layer of silty to medium grained sand with intercalation of clay and cemented gravel layers. The zonal permeabilities of the aquifer are estimated to be of the order of between 5 x 10^{-5} cm/sec for the baserock and 5 x 10^{-3} cm/sec for the sand and gravel layer.

(3) Model Calibration

In the model formulation, the steady state is adopted in this study, by assuming the two dimensional steady state of partial equation with given boundary conditions and permeabilities.

The model calibration is aimed to demonstrate the constructed simulation model that could account for the features of groundwater flow in the aquifer. Several alternative identifications are postulated and the appropriate parameters are chosen according to the monitored data. The model calibration is made by comparing the computed piezometric heads with observed heads by using the groundwater level map of 1989, and the result is shown in Fig. 16. The model matches observed conditions relatively well.

(4) Model Prediction

Groundwater recharge to the aquifer is augmented by construction of dam(s) on the Mol and/or Khadeji rivers as discussed in Section 4.2. Among the several alternatives, only the Mol dam with a live storage capacity of 35 MCM is the most economic and feasible alternative as formulated in Section 4.5.

Applying the average annual recharge amount of 64.7 MCM/yr, and the same model with the aquifer parameters, further simulation of groundwater is performed to assess the future groundwater condition. The results of the simulation is illustrated in Fig. 17. As seen in Fig. 17, there is a general tendency for the groundwater table to rise along the river stretch in the upper project area and to lower the cone depression of groundwater table in the downstream area. Hence, it is recommended that continuous groundwater monitoring is essential to evaluate the analysis, and groundwater management will also be necessary to keep sustainable use of groundwater.

4.4 Potential Agricultural Development

Total groundwater recharge in the project area is estimated at 62.1-70.6 MCM/yr depending on reservoir live storage capacity and combination of dams, as discussed in Section 4.2. Groundwater is mainly extracted for irrigation and domestic water in the project area, and potable water supply to Karachi. Moreover, natural discharge to the sea is inevitable in the lower part of the project area.

The potential irrigation area which could be served by groundwater augmented by construction of dam(s) is estimated at 4,100 to 4,860 ha depending on the combination of dams and live storage capacity as summarized below:

Unit: MCM

Item	Case-1 Khadeji + Mol	Case-2 Khadeji + Mol	Case-3 Mol Only	Case-4 Mol Only	Case-5 Mol Only	Case-6 Khadeji Only	Case-7 Khadeji Only
Live Reservoir Capacity:							
Khadeji ;	35.5	35.5	-	-	-	35.5	30.0
Mol ;	43.8	35.0	43.8	35.0	30.0	-	-
1. Recharge from precipitation, river runoff, and dam spill-out	26.1	26.9	39.6	41.1	41.6	43.1	43.8
2. Contribution to recharge by dam(s)	44.5	42.4	25.8	23.6	22.3	19.6	18.3
3. Total recharge to phreatic aquifer	70.6	69.3	65.4	64.7	63.9	62.7	62.1
4. Water supply to Karachi	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Domestic Water Supply	2.3	2.3	2.3	2.3	2.3	2.3	2.3
5. Natural discharge to sea	1.3	1.3	1.3	1.3	1.3	1.3	1.3
6. Available groundwater for irrigation	*66.0*	*64.7*	*60.8*	*60.1*	*59.3*	*58.1*	*52.5*
7. Net irrigation withdrawal per 1,000 ha*	-------- 13.4 - 13.9 (Cropping Intensity = 1.5) ----------						
8. Possible irrigation area (ha)	4,860	4,790	4,420	4,350	4,270	4,160	4,100

Remarks: *; Net irrigation withdrawal = (Irrigation water demand) - (Deep percolation)
Refer to ANNEX-G.

4.5 Optimization of Dam Scale

Comparison of the above seven (7) alternatives is made based on the Internal Rate of Return (EIRR), Benefit Cost Ratio (B/C), and Net Present Value (B-C). The results are summarized in the following table:

Case No.	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
Combination of dams	Khadeji + Mol	Khadeji + Mol	Mol Only	Mol Only	Mol Only	Khadeji Only	Khadeji Only
Live Reservoir Capacity:							
Khadeji	35.5	35.5	-	-	-	35.5	30.0
Mol	43.8	35.0	43.8	35.0	30.0	-	-
1. Irrigation Area (ha)	4,860	4,790	4,420	4,350	4,270	4,160	4,100
2. Total Economic Project Cost (10^6 Rs.)	1,451	1,426	659	633	621	793	784
3. Net Incremental Economic Benefit (10^6 Rs.)	104.7	102.5	95.2	93.7	91.3	89.6	88.3
4. EIRR (%)	5.18	5.15	10.40	<u>10.60</u>	10.53	8.40	8.37
5. B/C *1	0.67	0.66	1.33	<u>1.36</u>	1.35	1.05	1.05
6. B-C *1	-412	-408	188	<u>196</u>	187	36	33

Remarks: *1; Discount rate of 8% is applied.

As seen in the above table, the Mol dam with a live storage capacity of 35.0 MCM (Case-4) is the most economical among the seven. Details are given in ANNEX-H. Therefore, the optimum scale of the Mol dam is determined as follows:

	Item	Unit	Mol Dam
1.	Dam Type		Rockfill (Zone Type)
2.	Crest Elevation	EL. m	175.3
3.	Maximum Water Level	EL. m	173.0
4.	Normal Full Water Level	EL. m	169.6
5.	Dead Water Level	EL. m	156.5
6.	Dam Height	m	48.8
7.	Gross Storage Capacity	MCM	45.7
8.	Dead Storage Capacity	MCM	10.7
9.	Live Storage Capacity	MCM	35.0
10.	Dam Volume	10^3m^3	1,730

5. THE PROJECT

5.1 Basic Concept for Development

Based on the results of the study on the present situation of the project area described in Chapter 3, the following major constraints have been identified:

1) Disordered development and over exploitation of groundwater resources have resulted in a fall in groundwater table, reduction of the irrigated agricultural area and salt water intrusion in southern part of the Malir basin,

2) Traditional agriculture with low inputs and low quality materials results in low output, and thereby,

3) Deterioration of socio-economic situation in the area.

The project area enjoys, in many respects, a significant comparative advantage in the production of fruit and vegetables by virtue of its location in southern Sindh very close to the city of Karachi. These advantages include proximity to the country's largest market, low transport costs, the potential to respond to market changes at relatively short notices, an extended crop season, in relation to other supplying regions because of the warmer climate, and access to actual and potential suppliers.

In order to exploit these advantages and to ensure the future of fruit and vegetable production which is the single largest source of income and employment in the project area, the basic concept for future water resources and agricultural development plan in the Malir area should be formulated as follows:

1) To increase groundwater recharge by construction of the dam(s),

2) To expand the irrigation area to the maximum extent through augmentation of artificial groundwater recharge,

3) To sustain groundwater resource through monitoring and management,

4) To supply vegetables and fruit to the great Karachi market,

5) To increase crop yields through introduction of intensive farming practices,

6) To improve socio-economic situation and to increase in employment opportunities in the area,

7) To maintain a green belt located near the greater Karachi city, and

8) To improve organization to ensure the above strategies.

5.2 Agricultural Development Plan

(1) Proposed Land Use

Out of 24,200 ha of the study area, the project area to be benefited by augmentation of groundwater recharge is delineated based on the existence of the phreatic aquifer. The phreatic aquifer in the Malir river basin extends on both sides of the river between the National Highway and the proposed Mol damsite as shown in Fig. 19. Finally based on the economic comparison of the development plans, the possible irrigation area is decided to be 4,350 ha as discussed in Section 4.5. In addition to the above, a projection of the falling groundwater table is made, as a result of which the irrigation area of a long-term average in future will be decreased to 2,400 ha (see ANNEX-G). The following table shows the present land use in the study and project areas, and the future without and with the project:

Unit: ha

Land Category	Study Area in 1989	Project Area in 1989	Project Area Without Project	Project Area With Project
Agricultural Land	3,220	2,700	2,500	4,450
- Orchard field (irrigated)	1,200	1,180	1,000	1,000
- Upland field (irrigated)	1,540	1,420	1,400	3,350
- Upland field (rain-fed)	480	100	100	100
Fallow Land	2,920	2,800	3,000	1,050
Non Agricultural Land				
- Villages, hills, rivers and others	18,090	8,400	8,400	8,400
Total	24,230	13,900	13,900	13,900

(2) Proposed Cropping Pattern

For formulation of the future cropping pattern, the following basic principles for the selection of crops and cropping pattern under the project are conceived:

1) The crops and cropping pattern create maximum benefits for the farmers as well as the nation as a whole,

2) The crops and cropping pattern make the best use of water to be supplied by the project, and

3) The crops and cropping pattern should be practical and acceptable to the farmers.

Taking into account the basic principles described above, fodder, vegetable and fruit crops are selected as the main crops in making a proposed cropping pattern.

Vegetables and fruit are the most profitable crops under present economic conditions, among those considered including fodder and cereal crops. In the project area, various kinds of crops are widely grown, the farmers have long experience in fodder, vegetable and fruit crops cultivation and are likely to master the irrigated farming practices and to realize the maximum irrigation benefits under the project. It is assumed that the present proportions of each kind of vegetables will remain broadly as now.

The climate in the project area, generally characterized by summer and winter seasons which are warm and relatively dry as well as having sufficient sunshine hours, is very favorable for cultivation of fodder, vegetables and fruit crops throughout the year. No significant variation of yields for major crops is observed in the year-round cultivation which is now being practiced by the farmers in the project area. Most of the farm operations such as land preparation and sowing/planting will be started to fit the rainfall from June to September in the summer season, and February and March in the winter season. For vegetable cultivation, crop rotation will be introduced to minimize crop damage by disease and nematodes by continuous cropping.

The proposed cropping pattern is finally determined in consideration of profitability, marketability, peak water requirement, labour requirement, etc. referring to the cropping pattern in 1977, proposal by WAPDA, and the present cropping pattern (1988/89) (see Fig. 20). The cropping patterns with-project are formulated as shown in Fig. 21. A summary is presented in the following table:

Unit: ha

Crops	WAPDA Study*		JICA Study		
	Area in 1977	Proposed Project	Present Condition	Without Project	With Project
Summer season					
Fodder	590	700	150	150	150
Vegetables	2,100	2,280	1,270	1,250	3,200
Fruit	1,380	1,380	1,180	1,000	1,000
Sub-total	4,070	4,360	2,600	2,400	4,350
Winter season					
Fodder	370	450	50	40	50
Vegetables	1,520	1,740	310	290	2,100
Sub-total	1,890	2,190	360	330	2,150
Total	5,960	6,550	2,960	2,730	6,500
(Cropping intensity)	(1.46)	(1.50)	(1.14)	(1.14)	(1.50)

Source: *Ref. 01

(3) Proposed Farming Practices

Immediately after harvesting previous crops, the land should be plowed with a turning plow. Farmyard Manure (FYM) should be spread evenly at least one month before the planting operations. Seven to ten days before planting, the field should be pre-irrigated, and 3 - 5 plowings and 2 - 3 plankings are essential for a fine seed bed which is extremely critical to successful cultivation of vegetables/fruit. For cultivation of fodder only two plowings followed by planking are sufficient. It is also recommended to provide deep plowing with chisel plow after every 2 or 3 years, to bring lower soils upward and upper soils downward and finally to prepare fine seed bed with a fertile surface.

Introduction of improved seeds is an important role in increasing crop yield. Not only variety but also quality of the seeds influence crop yields. Improved high yielding varieties are recommend as shown below:

Name of Crop	Varieties
Tomato	T-10, SR-II, Pome
Eggplant	Round Black, Black Beauty
Chilli	Cluster, Longi, Ghotki
Cauliflower	Mirpurkhas Moti, Cheen-ka-Moti
Radish	MPS Selection, Japani
Turnip	Red Purple White, Desi
Peas	Blue Bantam, Early Dwarf, Kelves
Maize	Akbar Neelam
Mango	Sindhri Langra Collector

Source : *Horticulture Research Institute, Mirpurkhas

The following fertilizer application rates for attaining the target yields for respective crops are recommended and the details are described in ANNEX-E:

Crop	Urea (kg/ha)	Diammonium Phosphate (kg/ha)	Farmyard Manure (tons/ha)
Fodder	125	None	5
Vegetables	75 - 150	125	5 - 10
Fruit crops	250	None - 150	10

Fertilizer application for root vegetables by broadcasting after plowing is recommended for farming practices. Fertilizers for fruit vegetables and leaf vegetables are applied between plant rows by mixing with compost to prevent running off (loss) of elements.

There are two seedling techniques for the proposed farming. One is to prepare seedlings in a nursery bed, and thereafter, to transplant the seedlings in the main field. This practices will be applied for cultivation of fruit and some kinds of vegetables.

The other farming technique is direct sowing in the main field. This technique will be applied to fodder crops and other kinds of vegetables.

Transplanted vegetables would be irrigated by the furrow irrigation method, while others may be irrigated by the basin irrigation method. The fruit plants are irrigated by furrow irrigation method and/or drip method in future. The first irrigation for vegetable and fruit crops should be given quickly and in small quantity till the seed is germinated and plants survive, while subsequent irrigations should be given according to their requirements.

At present, insect and disease damage of crops caused is not serious. Although plant protection is not widely practiced yet, most of farmers are using local crop varieties which have a tolerance to diseases. However, when the high yielding varieties of crops are introduced, it will be necessary properly to apply agro-chemicals.

Weed control is one of the essential practices in the proposed crop production programme. At present many herbicides have been developed for weeding purposes, and their efficiency is readily accepted particularly for saving labour. However, these agro-chemicals are harmful not only for human beings, but also to livestock production and the natural environment. The proposed practice for weeding will therefore be hand weeding performed with the traditional instruments.

(5) Anticipated Crop Yields and Crop Production

In the without project condition, the future anticipated unit yields of crops are set at the same levels as present unit yields which are estimated on the two years average of 1986/87 and 1987/88 in Karachi District. It is considered that the present constraints in shortage of water, traditional farming practices and poor agricultural supporting services remains unchanged.

The unit yields of cauliflower, coconut and papaya have already attained desirable levels, so the anticipated unit yields of these crops are set at a slightly high level under the condition of proper water management and proposed farming practices, referring to the crop guide provided for extension officers of GOS. The target yields of other crops are projected at the little higher levels as present average crop yields in Hyderabad District. The anticipated unit yields under the future without and with project conditions are estimated in Table 8, and summarized in the following table:

Unit: ton/ha

Crops	Present and Without Project	With Project	Crops	Present and Without Project	With Project
Fodder:			Vegetables:		
Lucerne	13.9	26.0	Tomato	3.3	7.0
Maize	10.6	18.0	Eggplant	4.9	9.0
Fruit:			Chilli	1.0	2.5
Mango	6.1	9.0	Sponge Gourd	3.1	11.0
Guava	3.8	7.0	Bottle Gourd	4.7	8.0
Chikoo	2.3	3.0	Cauliflower	13.3	16.0
Coconut	2.7	4.0	Spinach	2.6	6.0
Papaya	7.3	8.5	Carrot	5.4	11.0
			Radish	4.0	13.0
			Turnip	6.6	15.0
			Pea, Beans	2.6	5.0

Based on the proposed cropping pattern, the cropped area, crop yields and total crop production under both "with project" and "without project" conditions are estimated in Table 9 and summarized as follows:

Item	Without Project	With Project	Increment
1. Cultivation Area (ha)			
- Fodder crops	190	200	10
- Vegetables	1,540	5,300	3,760
- Fruit	1,000	1,000	-
Annual cropped area	2,730	6,500	3,770
2. Production (tons)			
Fodder crops	2,340	4,400	2,060
Vegetables	6,960	46,650	39,690
Fruit	4,760	7,250	2,490
Total production	14,060	58,300	44,240

The annual fodder,vegetable and fruit production at full development stage would amount to 58,300 tons. The expected annual increment of fodder, vegetable and fruit production would be about 44,200 tons.

(6) Marketing and Price Prospect

The total volume of production in the study area has been estimated for 1988 at 6,900 tons of fodder, 8,600 tons of vegetables and 6,000 tons of fruit. Virtually the whole of this production was transported to, and sold in the Karachi market. With some 82,600 tons of major vegetables and 26,000 tons of major fruit crops entering the market annually (which includes varieties produced in the study area only), production from the study area accounts for about 10% of the throughput of vegetables and around 23% of the throughput of fruit.

There is a ready market for incremental fodder, fruit and vegetable production from the project area which will result from implementation of the proposed project. On the basis of past performance, retail and farmgate prices of vegetables and fruit are likely to remain constant in real terms for the foreseeable future and this assumption has been adopted for the purpose of project preparation (see details in ANNEX-F).

(7) Irrigation Benefits

Crop budget data have been used to estimate total volume of production costs and income in the project area at the full development stage (details in ANNEX-F). The full development stage will be attained after 5 years of build-up period from the completion of construction work. The annual costs and income without project and with project at full development stage are shown in Tables 10 and 11, and summarized in the table below.

Items	Unit	Without Project	With Project	Increment
Crop Income	10^3 Rs.			
Fodder		889	1,668	779
Vegetable		19,495	139,432	119,937
Fruit		13,269	20,788	7,519
Total		33,653	161,188	128,235
Total Production Costs	10^3 Rs.			
Fodder		607	914	307
Vegetable		9,685	43,057	33,372
Fruit		4,918	5,893	975
Total		15,210	49,864	34,654
Net Crop Income	10^3 Rs.			
Fodder		282	754	472
Vegetable		9,810	96,375	86,565
Fruit		8,351	14,895	6,544
Total		18,443	112,024	93,581

Total income from crop production (in constant 1989 prices) is projected to increase from Rs. 18.4 million under without project to Rs. 112.0 million under with project at full development. Incremental annual income from crop production is projected to be Rs. 93.6 million at the full development stage.

(8) Farm Budget Analysis

As a result of the average cropped area without and with project, the average owner/owner-tenant operated farm would increase from 6.7 ha to 16.5 ha, and the average tenant operated farm from 3.4 ha to 8.3 ha. Farm cost, income and gross margin estimates are based on composite crop group estimates derived as previously described. Costs, income and gross margin for the typical owner and tenant operated farms are summarized as follows:

Items	Unit	Owner Operated Farm			Tenant Operated Farm		
		Without Project	With Project	Incre-ment	Without Project	With Project	Incre-ment
1. Average Holding Size	ha	12.1	12.1	-	6.1	6.1	-
2. Cropped Area	ha	6.7	16.5	9.8	3.4	8.3	4.9
3. Crop Production	tons	34.6	148.2	113.6	17.5	74.7	57.3
4. Gross Income	10^3 Rs.	82.9	412.1	329.2	42.0	208.0	166.0
5. Production Cost	10^3 Rs.	37.0	126.2	89.2	13.6	46.3	32.7
6. Landlord's Share	10^3 Rs.	n.a.	n.a.	n.a.	21.0	104.0	83.0
7. Gross Margin	10^3 Rs.	45.9	285.9	240.0	7.4	57.7	50.3
8. Labour Income	10^3 Rs.	n.a.	n.a.	n.a.	8.5	28.9	20.4
9. Family Income	10^3 Rs.	45.9	285.9	240.0	15.9	86.6	70.7
10. Labour Requirement	man-day	334	1,146	813	169	579	410

Remarks: n.a. means "not applicable".

The estimates indicate that the gross margin on the typical owner-operated unit after meeting all production costs (including family and hired labour) would increase from Rs. 45.9 x 10^3 without project to Rs. 286x 10^3 with project mainly as a result of the increase in cropped area and unit yield. The incremental gross margin is Rs. 240x 10^3.

In the case of the tenant farmer after meeting all production costs (including payment of family or other labour), the farm gross margins are only some Rs. 7.4 x 10^3 (without project) and Rs. 57.7 x 10^3 (with project). Annual incremental income is Rs. 50.3 x 10^3.

(9) Employment in Crop Production

Incremental farm employment that is the aggregate and incremental labour requirement in crop production is estimated on the basis of cropped area using crop budget data. The results are summarized as follows:

Crops	Without Project		With Project		Increment
	Area (ha)	Man-day (10^3)	Area (ha)	Man-day (10^3)	Man-day (10^3)
Fodder	190	4.9	200	8.6	3.7
Vegetables	1,540	93.3	5,300	395.3	302.0
Fruit	1,000	37.4	1,000	46.4	9.0
Total	2,730	135.6	6,500	450.3	314.7

On-farm employment provided in crop production would increase from some 136 x 10^3 man-days without project to some 450 x 10^3 with project at full development stage. Total annual labour income would increase from Rs. 6.8 million to Rs. 22.5 million. Incremental annual employment with project at full development would amount to some 315 x 10^3 compared to without project situation at the time and incremental annual labour income to Rs. 15.7 million.

5.3 Irrigation Water Demand

(1) Irrigation Water Demand

The irrigation water requirements are calculated for the proposed cropping pattern on a monthly basis for the 60 years from 1929 to 1988. The consumptive use of water by the crop is estimated as a product of reference crop evapotranspiration (ETo) and crop coefficient (kc) at a given stage. Effective rainfall is calculated by the standard method proposed by the US Department of Agriculture (USDA) (Ref. 06).

Reference crop evapotranspiration (ETo) is calculated by the modified Penman method and the meteorological data at Karachi airport, and is summarized below:

Unit: mm/month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
110	125	192	224	253	233	193	176	179	166	123	101	2,075

In the project area, average commanded area of each well is less than 20 ha. Therefore, only field application efficiency is considered as total irrigation efficiency in estimating the irrigation water requirements. The following table gives the recommended irrigation efficiencies for different irrigation methods as stated in FAO Paper No. 24, and adopted total irrigation efficiencies in this study are shown below:

Irrigation Method		Field Application Efficiency	Adopted Total Irrigation Efficiency
Upland	(furrow, or basin)	60 - 70%	60%
	(sprinkler)	70 - 80%	70%
	(drip)	80 - 90%	80%

Irrigation water demand in various conditions is estimated for the period from 1929 to 1989 by computer programme. The irrigation water demands for the respectives cases are shown in Table 12 and the annual irrigation demand for the proposed cropping pattern in Table 13 (see ANNEX-G). The following table gives a summary of irrigation water demands for various cases:

Cropping Pattern	Irrigation Area ha	Cropping Intensity -	Irrigation Water Demand Surface MCM	Sprinkler MCM	Drip MCM
1. Cropping Pattern in 1977*	4,070	1.46	65.3	-	-
2. Present Cropping Pattern in 1989	2,600	1.14	42.0	36.0	31.5
3. Future Cropping Pattern	4,350	1.50	70.1	60.1	52.6

Remarks: * Ref. 01

(2) Deep Percolation

Irrigation water demand includes various kinds of unavoidable irrigation, operation and percolation losses. A certain amount of the above irrigation losses is expected to recharge to groundwater as deep percolation. For the water balance study, the amount of deep percolation should be considered as a usable water source. Since there is no actual measurement, it is assumed that 15% of diversion water requirement may recharge into groundwater as adopted in WAPDA report in 1982. Deep percolation for the proposed cropping pattern is also presented in Table 13 (3/3).

5.4 Proposed Project Facilities

(1) Mol Dam and Reservoir

The proposed Mol damsite is located in a relatively wide valley about 8.3 km upstream from the confluence of the Mol and Khadeji rivers (Super Highway bridge). The river valley is about 100 m wide at the axis. The lowest elevation in the river bed is about EL. 133 m, while the highest elevation at both the abutments is about EL. 175 m.

Based on the study results for optimization of the dam scale discussed in Section 4.5, the salient features of the Mol dam and reservoir are determined and presented in Table 14.

1) Reservoir

The elevation-capacity and elevation-area curves of the reservoir have been newly developed, and the full water level is determined based the optimization study of the reservoir as discussed in Section 4.5 (details in ANNEX-H). The maximum water level is defined as the water level equivalent to the normal full water level plus a surcharge depth for the design flood discharge. The dead storage capacity is equivalent to the deposited sediment load of 50 years as adopted in the previous study.

2) Geology of Damsite

Quaternary deposits underlain by the Gaj formation are distributed in the area as shown in Fig. 22 and with details in the DRAWINGS. Quaternary deposits consist of loose to calcareously cemented debris, gravels and sand. The main rock units of Gaj formation are sandy limestone with crystalline and pelitic limestone.

The strikes and dips in the area show a series of folds, and anticlines and synclines are well defined. The dips are generally gentle. According to the previous investigations, drilling along the right abutment shows that core recovery is about 80% and water losses during the water pressure tests are negligible.

Both the abutments show nearly same elevation. The drilling core on the left abutment is similar to that on the right abutment. It is hard as well as compact and few solution cavities are observed. The core recovery is nearly 80% and water losses are negligible.

The valley section is about 100 m wide and covered with overburden of different compositions, containing loose and calcareously cemented river deposits of sand and gravel with some boulders in thickness of about 5 m. The dip of the bedrock is gentle varying from 5°-20°. The dam axis area follows the limb of a syncline. The valley section suggests a competent rock foundation with good core recovery. A geological profile of the dam axis is shown in Fig. 23.

As far as surface investigation is concerned, the solution cavities are very few and can only be seen on the right abutment. No major open joints, tension cracks and bigger cavities are observed. It is generally considered that there are no large and continuous solution cavities in the damsite and reservoir area, judging from (1) geological-age of the Gaj formation (Neogene-Miocane being younger age than Mesozoic - Jurassic), (2) less rainfall area, (3) no observation of Karst topography such as Doline and Lapies, (4) less existence of fissure, crack, fault and fold axis in the Gaj formation, and (5) no observation of old solution cavities along these fissure, crack and old axis.

A few samples were taken from the recovered core and were tested by WAPDA for determination of the unconfined compressive strength. The results of the laboratory test show that the limestone rock appears to be quite compact and sound enough to sustain the load of proposed structures.

3) Type of Dam

The proposed Mol damsite is topographically more suitable for a fill dam in the relatively wide valley, moreover a suitable spillway site is available on the left bank as shown in Fig. 24. In the WAPDA report, a homogeneous type filldam was proposed and designed, taking into account availability of filling materials and ease of construction.

However, judging from the results of laboratory tests carried out by WAPDA and additional laboratory tests in the present study, the grain size passing 74μ sieve is about 20-50% at the proposed borrow area as analyzed in ANNEX–C, and impermeability of the core materials should be maintainable under proper moisture control during construction. Accordingly, a zone type rock-fill dam is proposed for the Mol damsite in consideration of availability of core materials and excavation materials at the spillway, stability of dam body, as well as economic advantage as described in detail in ANNEX-H.

4) Typical Section of Dam

The Mol dam is designed as a rockfill dam with an impervious center core. General map, geological section, and standard cross section are shown in Figs. 22 to 25.

The maximum height of dam is 48.8 m above the foundation, the crest elevation is designed at EL. 175.3 m with a freeboard of 2.3 m including crest road pavement of 0.5 m thick, and the dam has 10 m top width. The length of the dam crest is 2,347 m being 848 m of main dam and 1,499 m of saddle dam. The slopes of the dam faces are designed at 1:2.5 for the upstream and 1:2.0 for the downstream. The total embankment volume of the dam will be about 1,730 x 10^3 m^3 and is divided into five (5) zones to permit optimum use of materials excavated from the spillway and available in the vicinity of damsite.

The impervious core zone will have a maximum thickness of 24 m and a volume of about 324 x 10^3 m^3. The materials to be used for the core embankment will be taken from a borrow area located at about 2.5 km downstream on the right bank (details in ANNEXEs-C and H). Stockpilling of core material will be required to control moisture content and to obtain uniform quality.

Reservoir seepage through the embankment and foundation will be controlled by the filler zone provided along the downstream face of the impervious zone and under the transition zone. The upstream filter zone is also designed to reduce internal hydrostatic pressure and improved stability during rapid fluctuations in reservoir water level. Filter materials will be borrowed from the upstream and downstream river beds.

The outer zones of the upstream and downstream filter zones are designed to be transition zones. Materials for the transition zones will be excavated at the dam spillway, and upstream of the spillway. The total volume of the transition zones is estimated to be 566 x 10^3 m^3.

Rock zones are provided on the outer sides of the transition zones. Rocks will be excavated rocks materials from the spillway and the quarry site located upstream of the spillway. Stability of the dam against sliding is analyzed by slip circle, sliding and surface plate sliding methods for the cases summarized below (details in ANNEX-H):

Method	Case	Water Level of Reservoir	Portion	Earthquake Coefficient	Safety Factor
Slip Circle Sliding	1	M.W.L 173.0	Upstream	0.00	2.08
			Downstream	0.00	1.67
	2	N.F.W.L 169.6	Upstream	0.10	1.25
			Downstream	0.10	1.32
	3	D.W.L 156.5	Upstream	0.10	1.24
	4	N.F.W.L 169.6 D.W.L 156.5 (Rapid Drawdown)	Upstream	0.05	1.21
Surface Plate Sliding			Upstream	0.10	1.26
			Downstream	0.10	1.33

5) Foundation Treatment

The dam foundation and abutment will be treated by curtain grouting to seal all fractures, shears, joints and all cracks made after excavation of the dam axis, mainly for the purpose of prevention of piping action. The maximum depth of curtain grouts is designed at 15 m under the core trench in the main dambody and 10 m at the abutments. In addition to curtain grouting, consolidation grouting will be arranged in four (4) rows in the main dambody.

6) Spillway

An overflow type ungated spillway is designed on the left bank which has a natural saddle and possible channel showing a quite suitable site for a spillway. The crest elevation is fixed at EL. 169.6 m and its length is 320 m. Design flood is 4,100 m^3/sec and a surcharge depth of 3.6 m.

7) Intake and Outlet Structure

The design discharge of the intake structure is fixed at 40.5 m^3/sec at the mean water level, taking into account the emergency release. The intake structure is designed at the left abutment as a drop-inlet type. The outlet conduit diameter is designed to be 2.4 m, and the water flow will be controlled by a high pressure gate 2.1 m in diameter installed near the outlet structure.

8) Diversion Works

The 20-year flood discharge is estimated at 1,090 m^3/sec. Considering the topography of the damsite, the only feasible solution is to contain the river flow in the main channel while the works progress. The width of the main channel will be about 30 m during the embankment, and about 8 m high protection of the embankment will be provided for the flood (details in ANNEX-H).

(2) Causeway

At present, there are no crossing structure other than the two (2) bridges at the Super Highway and the National Highway. After completion of the project, the dam will be operated to release the allowable discharge of 8 m^3/sec at the Mol dam downstream for two (2) to three (3) months. Therefore in the project, four (4) causeways on the Malir river will be provided to keep the existing trafficability in the project area.

Location and dimensions of causeways are presented in DRAWINGS.

(3) Pilot Demonstration Farm

A pilot demonstration farm will play an important role in the project to achieve the project target by demonstrating advanced irrigation and farming techniques. The principal objectives of the pilot demonstration farm will be (1) to demonstrate advanced irrigation techniques (especially sprinkler and drip irrigation methods) in order to save irrigation water and to allow increase in irrigation area, and (2) to demonstrate an advanced farming techniques.

It is proposed to construct the pilot demonstration farm within the Plant Introduction Center at Saleh Mohammed Goth, Laundhi Union Council, which is situated in the southern part of the project area. This center is operated by the Federal Government of Pakistan, though it was initially established by the Sindh Government as a research center for horticulture until this function was transferred to another research center in the Indus river basin.

Out of 10 ha (25 acres), only 2.4 ha (6 acres) are used as orchard research fields and the remaining 7.6 ha (19 acres) are fallow due to the limited irrigation water supply. Moreover, there is a section of extension services which belongs to the Agriculture, Livestock and Fisheries Department of GOS. Therefore, the most favorable circumstances are available at the center to establish a pilot demonstration farm.

The basic alignment of existing experimental plots would basically be utilized. Three (3) irrigation methods, i.e. basin (prevailing irrigation method in the project area), sprinkler and drip irrigation methods will be introduced into the demonstration farm for demonstration purposes. Drip irrigation will be applied mainly for the existing orchard field and four plots of other crops, and basin and sprinkler for other crops. A preliminary plan of field layout is presented in Fig. 26.

The existing dugwell and a new tubewell to be constructed will be connected to a storage tank of about 400 m^3 (2 x 20 x 10 m). A booster pump station will be constructed beside the storage tank and a steel pressure tank will be provided to the booster station in order to avoid water hammer and to provide for automatic operation.

Two main lines for high and low pressure will be aligned along the existing roads in the center.

5.5 Implementation Schedule

(1) Construction of Mol Dam

The main project works are to construct the Mol dam, which will involve a large amount of earth moving. The earth moving works have to be executed by heavy duty construction equipment. Earth works are mostly affected by rainfall but the monthly workable days are estimated at 25 days even in the monsoon season. Due to the dry conditions throughout the year, the moisture contents of impervious materials would be checked throughout the construction period and whenever necessary water would be added to the materials at the borrow area and/or filling places.

From the results of the soils and geological investigations, the dam embankment materials would be obtained from the following places:

Item	Work Q'ty 1,000 m^3	Place
Zone 1 (Core)	324	Borrow Area (about 2.5 km downstream)
Zone 2 (Random)	566	Quarry-1, Spillway, Dam Excavation
Zone 3 (Rock)	571	Quarry-1, Spillway, Dam Excavation
Rock Facing	87	Quarry-1
Filter	181	River Deposit (up- and down-stream)

Excavation of dam foundation would be started from the left abutment, because concrete works for intake structure and conduit should be completed prior to the start of filling works. Excavation of the spillway would be performed in parallel with the dam embankment, because the excavated materials could be hauled directly to the dam.

A crushing plant for concrete aggregates and batching plant would be located near the spillway. The details of the construction plan are described in ANNEX-I.

(2) Construction Plan

The quantities of major works are summarized in the following table, and the major construction equipment is estimated based on the work quantities, construction time schedule, construction method and site specific conditions. Heavy duty earth moving equipment will be deployed for the construction (see details in ANNEX-I).

Unit: 10^3 m^3

Major Item	Description	Work Q'ty
Excavation	Common	233
	Weathered Rock	405
	Rock	325
Filling	Zone-1 (Core)	324
	Zone-2 (Random fill)	566
	Zone-3 (Rock fill)	571
	Rock facing	87
	Filter	181
Concrete		31.3

(3) Implementation Schedule

The implementation period of the project is assumed to be four (4) years from 1991 to 1995 as shown in Fig. 27. The whole of 1991 would be required for detailed design and mobilization. Actual construction works would be commenced in 1992. Dam construction including excavation, foundation treatment, embankment, appurtenant structures, etc. will need three (3) years in all. The dam embankment would be commenced in 1993 and be completed in March 1995.

Construction of the pilot demonstration farm will be commenced in late 1992 and be completed before the monsoon in 1993. Demonstration and field research will be commenced from the monsoon season in 1993.

5.6 Cost Estimate

(1) Basic Conditions of Cost Estimate

The costs for implementation of the project consist of direct construction costs, compensation cost for ground facilities including the relocation costs for facilities and land compensation cost, administration cost, engineering service cost, and contingencies. The costs are estimated on the basis of preliminary design of the project facilities, and on the following basis:

1) All the costs are estimated at February 1990 price levels. The following exchange rates are applied:

   US$1.0 = Rs. 21.5 = J.Yen 150.0

2) The construction works will be carried out by contractor(s) selected through international competitive bidding.

3) Unit prices of the works are composed of labour cost, material cost, depreciation and operation cost of construction plants and machinery, and contractor's overhead.

4) Taxes on the construction materials, machinery and plants to be imported from abroad shall be exempted from estimation in the construction costs.

5) The compensation cost are estimated on the basis of prevailing government expropriation compensation assessment for land, building and other private properties.

6) Construction costs are divided into foreign and local currency portions. Local currency portion is estimated based on the current prices of materials in Karachi in February 1990, and foreign currency portion is also based on the CIF prices at Karachi in the beginning of 1990.

7) Physical contingencies related to the construction quantities are assumed as 15% of the total estimated direct costs.

8) Price contingencies are estimated at 7% per annum only for the local currency portion.

(2) Project Cost

The project cost comprises the direct construction cost, procurement of O&M equipment, administration and engineering costs, physical and price escalation contingencies. The project cost is estimated based on the detail unit cost analysis and quantity calculations of the preliminary design shown in DRAWINGS. Total project cost is estimated to be Rs. 685.6 million (US$31.9 million equivalent) consisting of Rs. 530.9 million (US$24.7 million equivalent) for foreign currency portion and Rs. 154.7 million for local currency portion, as presented in Table 15 and summarized below:

Unit: Rs. 10^6

	Major Item	Foreign Currency	Local Currency	Total
1.	Preparatory works	27.0	5.9	32.9
2.	Mol dam	362.6	76.8	439.4
3.	Causeway	2.4	3.8	6.2
4.	Pilot demonstration farm	10.4	2.9	13.3
5.	Project office	0.4	0.8	1.2
6.	O&M equipment	10.3	0.0	10.3
7.	Physical contingency	58.2	12.8	71.0
8.	Administration cost	0.0	6.7	6.7
9.	Engineering services	59.6	16.4	76.0
10.	Price contingency	0.0	28.6	28.6
	Grand Total	530.9	154.7	685.6

(3) Annual Disbursement Schedule

The annual disbursement schedule is prepared based on the construction time schedule as discussed in Section 5.5, and is presented in Table 16. summary is as follows:

Unit: Rs. 10^6

Year	Total	Foreign Currency	Local Currency
1991	15.1	10.6	4.5
1992	171.1	130.4	40.7
1993	269.2	210.2	59.0
1994	192.2	149.2	43.0
1995	38.0	30.5	7.5
Total	685.6	530.9	154.7

(4) Operation and Maintenance Cost

Annual operation and maintenance cost covers the salaries of administrative staff, the material and labour costs for repair and maintenance of project facilities, the cost for operation, repair and maintenance of O&M equipment. The annual operation and maintenance cost is estimated at Rs. 5.1 million.

(5) Replacement Cost

Some of the facilities installed or constructed in the project will have a shorter useful life than the project life, and will require replacement within the project useful life. The replacement costs and useful lives of gates and O&M equipment are assumed to be as follows:

Item	Useful Life (Year)	Replacement Cost (Rs. 10^3)
Gate	25	10,300
O&M Equipment	10	25,500

6. PROJECT ORGANIZATION AND MANAGEMENT

6.1 Organization for Project Implementation

The Irrigation and Power Department (IPD) of GDS will be the executing agency for implementation of the project. IPD will appoint a project manager for the Malir Project Office to coordinate the execution of the project, which will be established near the Mol dam. The function of the office will involve approval of construction methods and schedules, preparation of design revision, construction progress, coordination of contracted works, monitoring of construction progress, work quantities and quality control, approval of payment, etc. as well as groundwater monitoring and establishment of the Groundwater Users Association by beneficiary farmers.

The Consultants will be employed by IPD to assist the activities of the project manager of the Malir project office, and will act as the Engineer for the construction works. However, establishment of the groundwater monitoring system will be the total responsibility of IPD with the assistance of the Consultants. The groundwater monitoring system and the Groundwater Users Association should be established prior to completion of the construction work as shown in Fig. 27.

The organization during the construction stage is presented in Fig. 28.

6.2 Organization for Operation and Maintenance of the Project

After completion of construction, the Malir project office will be re-organized into the Project O&M Office under IPD for operation and maintenance of the dam and groundwater monitoring in cooperation with the Groundwater Users Association as shown in Fig. 29.

The dam O&M section will be responsible for operation of the dam to maximize recharge to the groundwater in the basin aquifers, and maintenance of the dam and the river course. Another groundwater management section will be totally responsible for management of groundwater to maintain a proper groundwater level and to ensure the sustainable development and utilization of the groundwater. Since farmers in general are innocent to groundwater management, technical guidance through the monitoring in collaboration with the Groundwater Users Association will be made by the engineers of the Malir Project Office.

However, the functions of the groundwater management section in the Malir Project Office should gradually be transferred to the Association, so that ultimately the Association will be responsible for all groundwater management and monitoring.

6.3 Groundwater Users Association

In order to maintain proper groundwater levels, pumping of groundwater must be controlled and regulated. For this, it is recommended that a water extraction management system be established as discussed in the preceding section. Although water extraction management should ultimately be made by beneficiary farmers themselves, they will not be capable of doing such self-management at present. The farmers should first be trained to be aware of the groundwater volume to be extracted. This training should be made by an engineer in IPD, through some influential people like chairmen of Union Councils and/or chiefs of Dehs.

As described in the Section 6.1, a water management section in the Malir Project Office will be established for the project under IPD at the beginning of the construction period. This section will be responsible for groundwater extraction management, so as to ensure the sustainable development and proper utilization of groundwater. The functions of the water management section are to monitor the groundwater table and pumping record in the project area periodically and to establish a guideline on the water extraction volume in each well.

This section will be established prior to completion of dam construction as shown in Fig. 28. The series of monitoring works should be done with beneficiary farmers through the supervision of Chairmen and/or Chiefs of Union Councils and/or Dehs under the strong initiative by IPD, so that the farmers can understand the importance of monitoring works. In this period, the following should be done by the groundwater management section in the Malir Project Office:

1) Establishment of Groundwater Users Association by beneficiary farmers,
2) Determination of the groundwater volume which can be extracted, and
3) Determination of the groundwater extraction plan.

The farmers should be organized by Deh or Union Council under the supervision of IPD to undertake the monitoring works and to maintain the groundwater at a proper level. The Groundwater Users Association will prepare the articles under the guidance of IPD. The articles will include the following:

1) Name, address and purpose of the association
2) Membership
3) Rights and duties of members
4) Termination and suspension of membership
5) Membership fees and dues
6) Membership meeting
7) Board of directors and committee
8) Officers of the association
9) Education and training committee
10) Finance and development committee
11) Monitoring committee
12) Dissolution and liquidation
13) Other rules and regulations
14) Amendments and miscellaneous provisions

After the completion of the dam, the groundwater extraction plan will be revised to allow for the increase in groundwater recharge under the guidance of the groundwater management section in the Malir Project Office. The monitoring works should gradually be transferred from the Malir Project Office under IPD to the Association, and the Association will ultimately be responsible for all groundwater management works.

6.4 Future Improvement of Agricultural Support Services

At present, agricultural support services such as the supply of qualified seed, fertilizer and agro-chemicals, agricultural credit, etc. are not operating well. There is only one (1) dealer in fertilizers and agro-chemicals in the project area. The loan extended by the Agricultural Development Bank of Pakistan (ADBP) has not been popular among the small farmers so far.

Considering the expected increase in fertilizer and agro-chemicals consumption, farm input supply services will be encouraged. Agricultural credit will be increased through the introduction of a supervised credit system by ADBP, so as to help small farmers to avail themselves of farm inputs.

6.5 Pilot Demonstration Farm

In order to demonstrate the proposed improved farming practice with high inputs and to introduce new irrigation technology, a demonstration farm is proposed. Demonstration of high yields of crops with improved farming practice will give farmers the incentive to adopt the new technology. Further expansion of the cultivated area will be expected through the introduction of water-saving irrigation technology such as sprinkler and drip irrigation methods.

The proposed farm will be located at Laundhi, sharing the area with the existing Plant Introduction Center, and be composed of two divisions: (1) production division and (2) irrigation division.

In the production division, new farming technology will basically be introduced from the Horticulture Research Institute located in Mirpurkas. The new technology will be demonstrated to visitors by researchers employed by the Director General of Agricultural Research, and a farming manual will be prepared. The division should have close relations with extension workers.

In the irrigation division, sprinkler and drip irrigation methods will be introduced and be tested. This division will be operated by irrigation engineers belonging to the Malir Project Office under IPD.

7. PROJECT EVALUATION

7.1 General

A preliminary economic evaluation was performed for seven (7) alternative water resources development options as a part of the optimization process of the dam scale discussed in Chapter 4. After examining the economic efficiency, possible irrigation area, socio-economic effect, etc., the Mol dam with a height of 48.8 m, and a live storage capacity of 35 MCM was selected as a best alternative, and irrigation area was fixed at 4,350 ha.

In this Chapter, the project evaluation is made through assessment of the project feasibility in view of economic, financial and socio-economic aspects. The economic feasibility is assessed by relevance to the economic internal rate of return (EIRR), benefit-cost ratio (B/C) and the net present value (NPV).

Financial evaluation is carried out by analyzing the effect of the project on a typical farm budget. The indirect benefits and socio-economic impacts from the implementation of the project are also briefly studied.

7.2 Economic Evaluation

(1) Basic Assumptions

The economic evaluation is based on the following assumptions:

1) The project implementation period will be four (4) years including one (1) year for detailed design and preparatory works.

2) The economic useful life of the project will be 50 years.

3) All prices are expressed at constant 1990 prices.

4) The exchange rate of US$1.00 = Rs. 21.5 = ¥150.0 as of 1990 would be used throughout.

(2) Evaluation of Economic Factors

For evaluation of economic prices and costs, the following criteria are utilized:

1) The standard conversion factor (SCF) is fixed at 0.85.

2) Transfer payments are excluded from the financial project cost.

3) Economic prices for agricultural outputs and inputs are determined considering the international price, SCF, etc.

4) Economic opportunity cost of farm labour and unskilled construction labour is priced at Rs.35/man-day.

5) Economic cost of electricity for pumping water is priced at Rs. 0.14/m^3.

(3) Economic Benefits

The irrigation benefits are primarily derived from the increased crop production attributable to a stable irrigation water supply. These benefits are estimated as the difference of the annual net crop production values under future with and without project conditions.

The net production value is defined as the difference between the gross production value and the crop production cost. The net production values under future with and without project conditions are summarized as follows:

Items	Unit	Without Project	With Project	Increment
Crop Income	10^3 Rs.			
Fodder		889	1,668	779
Vegetable		19,495	139,432	119,937
Fruit		13,269	20,788	7,519
Total		33,653	161,888	128,235
Total Production Costs	10^3 Rs.			
Fodder		711	983	272
Vegetable		9,557	42,850	33,293
Fruit		6,460	7,417	957
Total		16,728	51,250	34,522
Net Crop Income	10^3 Rs.			
Fodder		178	685	507
Vegetable		9,938	96,583	86,644
Fruit		6,809	13,370	6,562
Total		16,925	110,638	93,713

It is assumed that after completion of dam construction, the irrigation benefits will gradually increase during the built-up period of five (5) years from 50% of full incremental benefits in 1st year to 100% in 5th year. The expected incremental benefit at full development stage is Rs. 93.7x10^6.

Further well deepening will be necessary to keep the pumping volume of groundwater constant in the future in the without-project condition. With the increase of well depth, electricity for pumping will also be increased. Such costs will be saved with the implementation of the project and are considered as benefits in with-project condition. The expected benefits will amount to Rs. 2.5x10^6 for the period of the years from 1996 to 2000, Rs. 4.5x10^6 for the period from 2001 to 2005 and Rs. 1.2x10^6 for the rest of the years.

(4) Economic Costs

1) Economic Construction Cost

The project cost broadly comprises (1) cost for preparatory works, (2) construction cost for project facilities including contractor's overhead and profits, (3) cost for land acquisition, (4) cost for compensation and resettlement, (5) administration expenses, (6) procurement cost of O/M equipment, (7) expenses for engineering services, (8) physical contingencies and (9) price contingencies.

The financial costs are converted into the economic costs by applying the construction conversion factors for each of major components as described in Subsection 7.2(2) (see Table 17). Economic cost of the project including pilot demonstration farm is calculated at Rs. 632.8×10^6, and this amount will be disbursed in five (5) years according to the implementation schedule.

2) Annual Operation and Maintenance (O&M) Cost

Annual operation and maintenance costs will consists of administration cost, operation cost of O&M equipment and office operation cost. Total economic annual O&M cost will amount to Rs. 4.3×10^6.

3) Replacement Costs

O&M equipment and gates will be replaced every 10 years for O&M equipment and every 25 years for gates respectively. Economic replacement cost is estimated at Rs. 10.3×10^6 for O&M equipment and at Rs. 25.5×10^6 for gates.

(5) Economic Internal Rate of Return (EIRR), Benefit-Cost Ratio (B/C) and Net Present Value (NPV)

The Economic Internal Rate of Return (EIRR), Benefit-cost Ratio (B/C) and Net Present Value (NPV) are calculated on the basis of the flows of economic benefits and costs mentioned above (see Table 18), as shown below:

IRR	=	10.6%	
B/C	=	1.36	(at a discount rate of 8%)
NPV	=	Rs. 196.4×10^6	(at a discount rate of 8%)

7.3 Financial Evaluation

Financial evaluation of the project is made by analysis of the typical farm budgets to assess whether the project will have sufficient incentive to the farmers in the project area and will bring enough income increase in the farmer's economy.

Owner operator farmers and tenant farmers were selected as typical farmers for analysis. Their farm budgets on different farm sizes are analyzed as shown in Table 19. Owner operators will earn about Rs. 20,000 when cultivate one (1) hectare in with-project condition, being exceeding five times of income in without-project condition. Tenant farmers will also get about Rs. 5,000/ha, being more than five times their income in without-project condition. Farmers economy will certainly improve in the with-project condition as compared with the without-project condition.

It is assumed that the average per capita annual expenditure of Rs. 5,300 is the same as the average per capita annual income in Pakistan, and this amount is a target income of the beneficiary. The amount of income to be reached per one family will be about Rs. 30,000, since the average family size in and around of the project area is 5.6 persons/household. In the with project condition, the number of families expected to reach the target income will be about 420, comparing with about 165 in the without project condition as seen in the following table. Judging from the following analysis, the project can be justified financially from the beneficiaries' viewpoint..

Expected Income of over Rs. 30,000/year

	Owner	Owner/Tenant	Tenant
Land holding size (ha)			
Without project condition:	6	11	30
With project condition:	2	3	6
Number of Family			
Without project condition:	about 100	about 60	about 5
With project condition	about 150	about 120	about 150

7.4 Indirect Benefits and Socio-Economic Impacts

(1) Stable Supply of Water

The dam construction will ensure the reliable water supply by augmenting the groundwater recharge volume. Irrigation water will be supplied steadily and it will make it possible to cultivate crops two times a year as well as fruit trees. Drinking water will also be supplied more than at present.

(2) Increase of Employment Opportunities

Construction of the Mol dam will produce about 270 x 10^3 man-days of employment opportunity for unskilled labour, which is equivalent to Rs. 24.3 x 10^6. Those workers will be employed near the construction site, maybe from the project area, and this will contribute to improve economic situation in the area. In addition the project will creates a demand for farm labour requirement accrued from increased farming activities due to increasing irrigation area as well as intensive use of the land. The incremental farm requirement is estimated at 315 x 10^3 man-days annually .

(3) Increase of Crop Production and Stable Supply of the Products to the Karachi City

The project will increase agricultural production of vegetables (46,650 tons), fruits (7,250 tons) and fodder crops (4,400 tons), which will bring about considerable profit to the beneficiaries in the project area. These products except fodder crops for domestic will be marketed in the Karachi city. People in the Karachi city will enjoy those fresh and stable supply of the products from the project area due to the locational advantage.

(4) Increase of Farmers' Income

The farmers' income will be expected to improve considerably due to the increase of crop production, as described in the previous chapter. The income will become about 3 to 4 times of that at present, which will provide farmers with motivation of improving living standard.

(5) Improvement of Water Quality

The quality of groundwater is getting worse in the downstream of the project area, and this suggests sea water intrusion resulted from overdrafting of groundwater from below the sea level. In some place in the project area, electric conductivity of groundwater is reported at as high as 3,000 uS/cm. This deterioration of groundwater quality will make it impossible for people to utilize this water as drinking purpose. With the implementation of the project, increased groundwater recharge will be expected to improve the water quality in such an area in long term by pushing sea water back.

(6) Flood Mitigation Effects

The dam will decrease peak flood occasionally occurred in Kharif season, due to its storage effect of the reservoir. Peak-cut effects by construction of the Mol dam would be estimated at 3 to 6 per cent depending on the initial water level of the reservoir. Though the flood protection dike in the downstream of the project area has been constructed to protect the urban and industrial complex areas, peak-cut by the Mol dam would be a favorable effect for flood protection in the project area and the downstream area.

(7) The Use of Fertilizer and Agro-chemicals

The project will increase crop production with the introduction of somewhat intensive farming technology. The dosage of fertilizer and agro-chemicals will considerably increased. The trade of fertilizer and agro-chemicals will be stimulated in this regards.

Since the use of fertilizer and agro-chemicals is not common practice in the area, this practice will be extended through the guidance of extension worker. As for the use of agro-chemicals, such toxic commodities as Methyl Parathion, Benzene Hexa Chloride (BHC), DDT, Dieldrin, etc. are still in commonly use in Pakistan. Such chemicals should be replaced with low toxic ones, especially in the project area, and the frequency of the use of fertilizer should be kept minimum, since people depend their drinking water on groundwater which tends to be easily contaminated with those chemicals.

(8) Demonstration Effect of Pilot Farm

A pilot demonstration farm proposed as a part of the project will play an important role on extension of modern or intensive farming technology to the farmers. The farmers will be encouraged to follow a new technology when they prove to see crop production increase with the use of such technology. New species or cultivar may also be introduced to the project area.

7.5 Environmental Aspects

Usually dam projects are large social investment. The main component of this project is also dam construction, which has been planned for augmenting irrigation water supply and domestic water supply to the Karachi city through recharge to aquifers as well as for flood control in its downstream areas. By these nature, the Mol dam and its associated reservoir would create changes in the pre-existing environment. Water is impounded and upstream areas are inundated. There are also downstream effects that result from changes in the quantity, quality, timing, and use of water flows. Some of these impacts are positive, and others are negative. This section describes overviews on the range of environmental effects associated with this storage dam project.

As mentioned before, the gross storage capacity of the Mol reservoir would be 45.7 MCM, and the area to be inundated is estimated at about 550 ha. Most of the reservoir area is bare land covered with very limited and scattered bushes. Since there exist no populations within the area, the resettlement of people will not be required in connection with the dam construction. In addition, any parmanent infrastructures do not exist in the area. It can be said, therefore, that there will be no negative environmental effects in terms of both the physical and social aspects.

As already discussed, on the contrary, some positive impacts will be anticipated: they are increase in irrigation and domestic water supplies, change in quality of groundwater and flood control effects. The irrigated land in the project area decreases since last decade or more mainly due to overdraft of groundwater from the potential aquifers. In fact, some areas especially in the downstream parts of the area have been devastated because of insufficient irrigation water supply. Such areas devastated at present will become again productive land by augmenting recharge to the aquifers through water release from the Mol reservoir.

The increase in recharge to the aquifers will also improve the present dry-land situation in the vicinity of Karachi city, expanding further green belt zone where fresh vegetables and fruit are being produced for supply to the Karachi market. In addition, it is anticipated some effects to improve the groundwater quality in the downstream area where sea water intrusion may occur unless further fresh groundwater supply is provided for potential shallow aquifers in the area. The flood control effect will also be expected by the Mol dam construction for mitigation of flood damages to the industrial areas located in the estuary of the Malir river.