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Table 6.3.3.3-3 Hardware and Software for Data Transmission from Local Stations

	Content
Hardware	
1	Router (to Leased Line)
2	Remote terminal unit (RTU)
3	PI/O station
4	PI/O modules (DI)
5	PI/O modules (AI)
6	Station box
Software	
1	System software (to PI/O)
2	System software (to SCADA)

Notes :
1. Local station means pump station, water reservoir, etc.
2. PI/O : Process Input/Output
3. DI : Digital Input
4. AI : Analog Input
5. SCADA : Supervisory Control and Data Acquisition System

6.3.4 Proposed Implementation Schedule

The proposed implementation schedule for the National Water Supply Control System is shown in Fig. 6.3.4-1.

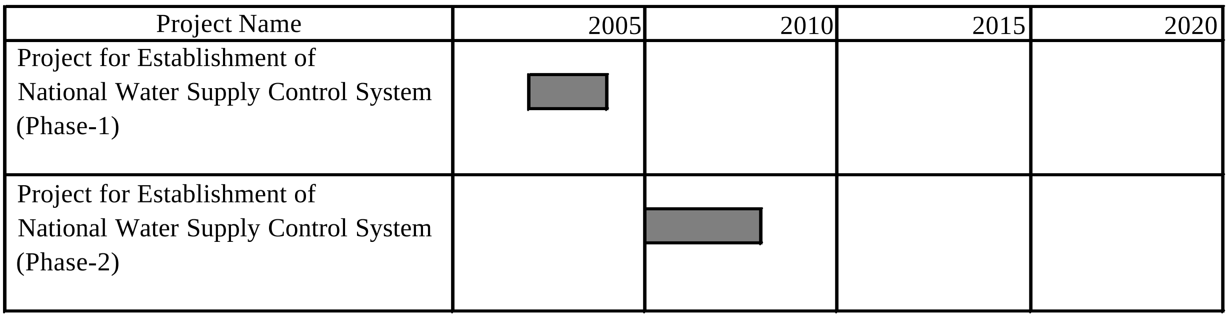

Fig. 6.3.4-1 Proposed Implementation Schedule for NWSCS

6.4 Proposed Desalination Facilities

Since the scarcity of water resources is chronic in the country, brackish groundwater resources, whose sustainable potential has been assessed at approximately 250 MCM/year in the former study, is a precious resource for future development. On the other hand, desalination technology in the field of desalination of brackish water and seawater have progressed drastically in these decades and the unit treatment cost in both investment and O & M has decreased accordingly.

Cost reduction in RO desalination is especially significant. Furthermore, since brackish groundwater desalination of 30 MCM/year at Hisban/Kafrain in Balqa, seawater desalination of 5 MCM/year in Aqaba and brackish groundwater spring development of 30 MCM/year in Zarqa Main are listed in the Investment Plan of Ministry, the application of RO desalination and/or a combination of RO and spring groundwater development to municipal water shall be worth examining.

6.4.1 Quality of Brackish Water and Seawater

The following Table 6.4.1-1 and Table 6.4.1-2 show the water quality analysis records of the anticipated sites for the brackish groundwater and seawater.

It has been confirmed in the previous study that the TDS values of brackish groundwater from the Hisban /Kafrain area, located in the Southern Jordan Valley, are small compared to those from the Northern Jordan Valley, and that the TDS of the groundwater which springs up in the Zarqa Main area is fairly small as shown in Table 6.4.1-2.

Table 6.4.1-1 Water Quality of Brackish Groundwater Wells

	EC	PH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
	mS/m	Mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Kafrain*1	7748	6.77	52.69	4.65	21.67	12.6	55.78	14.07	18.96	1.5	-	-
Zarqa Main	3240	8.37	404.8	62.95	180.36	68.07	755.09	304.54	207.4	4.43	0.68	8.49

*1: No.6 well of JICA study.

Table 6.4.1-2 TDS of Brackish Groundwater & Seawater

	TDS (mg/L)
Hisaban/Kafrain (brackish groundwater)	5,000
Zarqa Main (brackish spring groundwater)	1,000-1,500
Aqaba (seawater)	42,000

6.4.2 Quality of the Treated Water

The objective quality of the treated water after desalination should be decided taking into consideration the following: (i) Jordanian drinking water quality standards and internationally and commonly acceptable TDS value, (ii) attainable water quality by RO treatment and (iii) the possibility of blending the desalinated water with the water supplied from other water sources to produce a large quantity of drinking water.

In the Jordanian Drinking Water Quality Standards, the TDS is set at two levels, -- the permissible value of 500 mg/L and the maximum allowable value of 1500 mg/L. The WHO guideline for TDS is 1000 mg/L.

RO is a process that can produce very high quality water, with up to a TDS of less than 10 mg/L. The treated water from most of the RO plants in the world has a TDS of 200-300 mg/L. Since the TDS of raw brackish groundwater in Hisban is rather small (5,000 mg/L), a TDS of 150-200 mg/L of the treated water from RO can be expected.

On the other hand, the brackish spring groundwater in Zarqa Main has a TDS of 1,000-1,500 mg/L. Therefore, there is a possibility that the desalinated water of Hisban could be blended with the raw brackish spring groundwater from the Zarqa Main areas to produce a large quantity of drinking water at a low cost. This blended water can produce a TDS of 500mg/L or less than 1,000 mg/L which meets the WHO guideline and the permissible value of the Jordanian Standard.

However, in many countries as well as in Japan, 500 mg/L is set as the maximum allowable TDS value. Hence the blending ratio of the desalinated water and raw brackish groundwater shall be considered to produce a value closer to TDS 500 mg/L, which is within the range of 500 -1,000 mg/L.

6.4.3 Applicable Treatment Process

The RO (reverse osmosis) process is considered most suitable for the desalination system as discussed in the previous JICA Desalination Study.

RO is becoming a major technology for seawater and brackish water desalination, using natural osmosis phenomena. The proposed desalination plants are to be designed to utilize this technology together with the state-of-the-art application technology, which has been developed and tested at large seawater and brackish water desalination plants.

RO is a technology which utilize a man-made, semi permeable membrane, which allows water to pass through but which rejects solutions such as salt, bacteria and organic matters. Thus the permeate from reverse osmosis is the most suitable permeate for drinking water application.

This method has numerous benefits. It saves energy, it has reasonable construction cost, it saves space, and it is easy to operate. It also minimizes total water production cost. The technology used for Reverse Osmosis is made so that it enables the operator and/or technician to obtain the required know-how within a short time. Another benefit is flexibility in increasing the capacity of the system by adding some modularized units.

6.4.4 Development Plans

For the desalination development plan of Seawater and Brackish groundwater, the following plans are considered:

1) Seawater desalination development: Aqaba seawater desalination development plan

2) Brackish groundwater development:

The following two alternative plans are being examined in the brackish groundwater development.

a) Hisban–Zarqa Main desalination and spring water combined development plan

b) Hisban desalination development plan

6.4.4.1 Aqaba seawater desalination development plan

(1) Summary of Aqaba seawater desalination development plan

- 5 MCM/year production from seawater expecting to start operation in 2005
- 15 MCM/year production(additional 10 MCM/year) from seawater expected to start operation in 2015
- Municipal and Industrial use in Aqaba
- Brine discharge is expected into Aqaba bay

(2) Construction cost

The construction cost of the Aqaba desalination plant is shown in Table 6.4.4.1-1.

Table 6.4.4.1-1 Construction cost of Aqaba desalination plant

(1,000JD)

	Aqaba	
	2005-2014(5MCM/Y)	2015～(15MCM/Y)
Ⅰ.Production Wells	-	-
Ⅱ.RO Desalination Plant	27,363	54,720
Ⅲ.Brine Discharge Line Construction	Included in RO desalination plant	Included in RO desalination plant
Ⅳ.Electric Power Supply	Included in RO desalination plant	Included in RO desalination plant
Ⅴ.Water Supply System	-	-
a. water transfer pipe line	-	-
b. water transfer pump facilities	-	-
Total	27,363	54,720

The principles of cost estimation are as follows:

1) RO desalination plant

- The calculation results by IDA (International Desalination Association) Seawater

Desalting Costs is referred(Refer to Table 6.4.7-1).

- The mean unit cost of the RO desalination plant is shown in Table 6.4.4.2-3.

(3) Operation and Maintenance Cost

The Operation and Maintenance Costs are shown in Table 6.4.4.2-4

(4) Water Production Cost

The water production cost of the Aqaba desalination plant is as follows:

- Aqaba desalination plant: 976 fils/m3(1.39 US$/m3)

6.4.4.2 Alternative Plan of brackish groundwater development plan

(1) Summary of brackish groundwater development plan

The summery of the brackish groundwater development plan is shown on Table 6.4.4.2-1.

1) **Plan-A**: Hisban–Zarqa/Main desalination and spring water combined development plan

- 30 MCM/year production from brackish groundwater by mixing 20 MCM/year desalinated water of Hisban with 10MCM/year raw brackish spring groundwater of Zarqa Main
- expectede to start operation in 2005
- Municipal use in Amman
- Water transfer pipeline of 600mm diameter to convey raw brackish spring groundwater from Zarqa Main to Hisban
- Brine discharge from Hisban desalination plant is expected to flow into the Dead Sea through Wadi Ijarfa

2) **Plan-B**: Hisban desalination development plan

- 30 MCM/year desalination production from brackish groundwater
- expected to start operation in 2005
- Municipal use in Amman
- Brine discharge from Hisban desalination plant is expected to flow into the Dead Sea through Wadi Ijarfa

Table 6.4.4.2-1 Summary of Hisban and Zarqa Main Brackish Groundwater Development Project

	PLAN A		PLAN B	
	Hisban	Zarqa Main	Hisban	Zarqa Main
Summary of Project	To obtain 30MCM/Y drinking water of TDS 500-1,000mg/l by mixing 20MCM/Y (TDS150-200mg/l) of treated water from Hisban desalination with 10MCM/Y (TDS 1,000-1,500mg/l) from Zarqa Main raw brackish spring water		To obtain 30MCM/Y drinking water of TDS 500mg/l from Hisban desalination	
Ⅰ.Production Wells	24MCM/Y of brackish groundwater by wells(TDS:5,000mg/l)	10MCM/Y of brackish spring groundwater(TDS:1,000-1,500mg/l)	36MCM/Y（brackish groundwater,TDS:5,000mg/l)	-
Ⅱ.RO Desalination Plant	20MCM/Y of produced water(TDS:150mg/l-200mg/l)	-	30MCM/Y（produced water,TDS:500mg/l)	-
Ⅲ.Brine Discharge Line Construction	by a 8 km pipeline from the RO plant to downstream of Wadi Ijafra and then to the Dead Sea through the wadi course.	-	by a 8 km pipeline from the RO plant to the downstream of Wadi Ijafra and then to the Dead Sea through the wadi course.	-
	500mm diameter reinforced concrete pipe, L= 8 km	-	600mm diameter reinforced concrete pipe, L= 8 km	-
Ⅳ.Electric Power Supply	Electric facilities included in RO desalination	-	Electric facilities included in RO desalination	-
Ⅴ.Water Supply System	Raw brackish spring water(10MCM/Y) of Zarqa Main will be transferred to the Hisban plant site.			
a. water transfer pipe line			-	-
	600mm diameter ductile pipe, L= 30 km		-	-
b. water transfer pump facilities	Water pumps of 400mm diameter :3 regular + 1 standby		-	-

(2) Construction Cost

The construction cost of 2 alternative plans is shown in Table 6.4.4.2-2.

Table 6.4.4.2-2 Construction cost of Alternative Plan for Hisban and Zarqa Main

(1,000JD)

	PLAN A		PLAN B	
	Hisban(RO:20 MCM/Y)	**Zarqa Main(Raw water10MCM/Y)**	Hisban(RO:30MCM/Y)	Zarqa Main
Ⅰ.Production Wells	**6,975**	**2,904**	10,465	-
Ⅱ.RO Desalination Plant	**42,599**	-	63,898	-
Ⅲ.Brine Discharge Line Construction	**975**	-	822	-
Ⅳ.Electric Power Supply	-	-	-	-
Ⅴ.Water Supply System	**10,554**		-	-
a. water transfer pipe line	**8,280**		-	
b. water transfer pump facilities	**2,274**		-	
Total	**64,006**		75,185	
Judgment	○PLAN A can save a cost than PLAN B		×	

The principles of cost estimation are as follows:

1) Production wells

- The construction cost for production wells in JICA Study in 1995 is referred to.

2) RO desalination plant

- The calculation results by IDA (International Desalination Association) Brackish Water Desalting Costs Program is referred to(Refer to Table 6.4-A1, A2 & A3 attached at the end of Chapter 6.4).
- The mean unit cost each raw water quality of the RO desalination plant is shown in Table 6.4.4.2-3.
  a) A mean unit cost of 7.81 $/m3 is applied for the Aqaba seawater desalination plant
  b) A mean unit cost of 2.48 $/m3 is applied for the Hisban brackish groundwater desalination plant, having a value closer to the DS of river water

Table 6.4.4.2-3 Mean Unit Cost of the RO desalination plant

NO.	Raw Water Quality	Range of TDS	Mean Unit Cost in $/m3
1	BRINE WATER	Over 50,000mg/l	9.82
2	SEA WATER	from 20,000 to 50,000mg/l	7.81
3	WASTE WATER		4.33
4	BRACKISH WATER	from 3,000 to 20,000mg/l	3.04
5	RIVER WATER	from 500 to 3,000mg/l	2.48
6	PURE WATER		2.17

Notes:

1. The mean unit cost is calculated based on the result of 2,000 IDA Worldwide Desalting Plants, Inventory Report No.16 issued on December 31,1999.
2. The unit cost is calculated by total cost divided by yearly product volume for the RO system.
3. TDS: total dissolved solids content.

3) Brine discharge pipeline
   - The price of materials and the construction cost are based on the local level.

4) Raw brackish spring groundwater transfer facilities
   - The price of materials and the construction cost of the pipeline is based on the local level
   - The construction cost of the pumping facilities is estimated according to the consultant's experiences

(3) Operation and Maintenance Costs

Operation and Maintenance Costs are shown in Table 6.4.4.2-4.

Table 6.4.4.2-4 O & M cost for the Aqaba and Hisban desalination plant

NO.	Item		Aqaba		Hisban	
			(seawater)		(brackish water)	
			5MCM/Y（２００５−２０１４）	１５MCM/Y（２０１５～）	20MCM／Y（２００５～）	30MCM／Y（２００５～）
1	O&M cost of RO Desalination Facilities			O&M cost for １５MCM／Y		
		Electricity	690.5	2071.5	1066.3	1599.5
		RO membrane	310.1	930.3	720.1	1080.1
		Chemicals	303.2	909.6	2646	3969
		Safety filter	66.5	199.5	124.1	186.2
		Labor	76	228	50.7	76
		Maintenance	100	300	300	450
	Total O&M cost of RO(1,000JD/Y)		1,546	4638.9	4907.2	7361
2	O&M cost of Water Transfer Facilities					
		Electricity			109	
		Labor			0	
		Maintenance			17.6	
	Total O&M cost of water transfer facilities（1,000JD/Y)		0	0	126.6	0

(4) Water Production Cost

The water production cost of Plan A & Plan B for the Hisban and Zarqa Main development plant is as follows:

1) Plan A of Hisban and Zarqa Main combination plant: 349 fils/m3(0.50US$/m3)
2) Plan B of Hisban desalination plant: 450 fils/m3(0.64US$/m3)

6.4.4.3 Selection of the brackish water development plan

Since Plan A has the smallest water production cost, Plan A is selected as the brackish groundwater development plan.

6.4.5 Preliminary Design of Aqaba seawater desalination project

The proposed plants are designed for the application of the Reverse Osmosis Modules, which is designed to contain a large membrane area within a small volume. A high pressure saline water will be fed continuously by a pump and the membrane separates the saline water into desalinated water and concentrated brine.

The plants consist of four major sections, --Pretreatment, Reverse Osmosis, Post treatment and Discharge treatment.

The purpose of the Pretreatment is to remove suspended solids and moderate the condition in order to achieve stable operation, longer membrane life and economical operation by avoiding scale formation at the concentrated brine.

Reverse Osmosis is used to separate the above pre-treated water into permeates of the Reverse Osmosis membrane and its concentrated brine.

Post treatment is used to adjust the characteristic of the permeate, such as chlorination and pH adjustment.

Waste treatment is used to remove the high concentration of suspended solids discharged from Pretreatment in order to prevent environmental pollution.

The Basic Flow, Tentative flow diagram and Tentative Plant Layout of the Desalination Plant are shown on Fig. 6.4.5-1, Fig. 6.4.5-2 and Fig. 6.4.5-3.

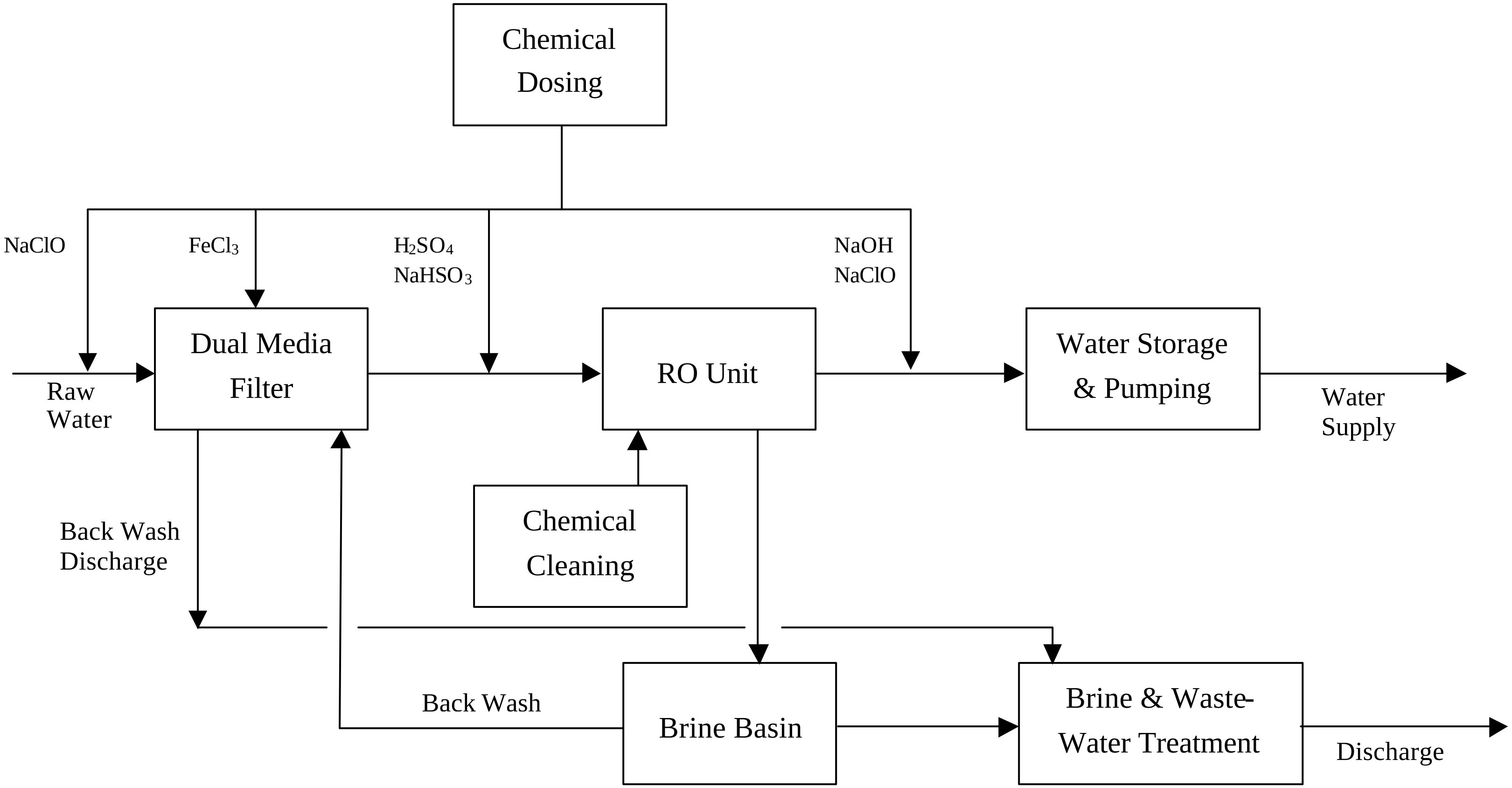

Fig. 6.4.5-1 Aqaba/Basic Flow of the Proposed Desalination Plan

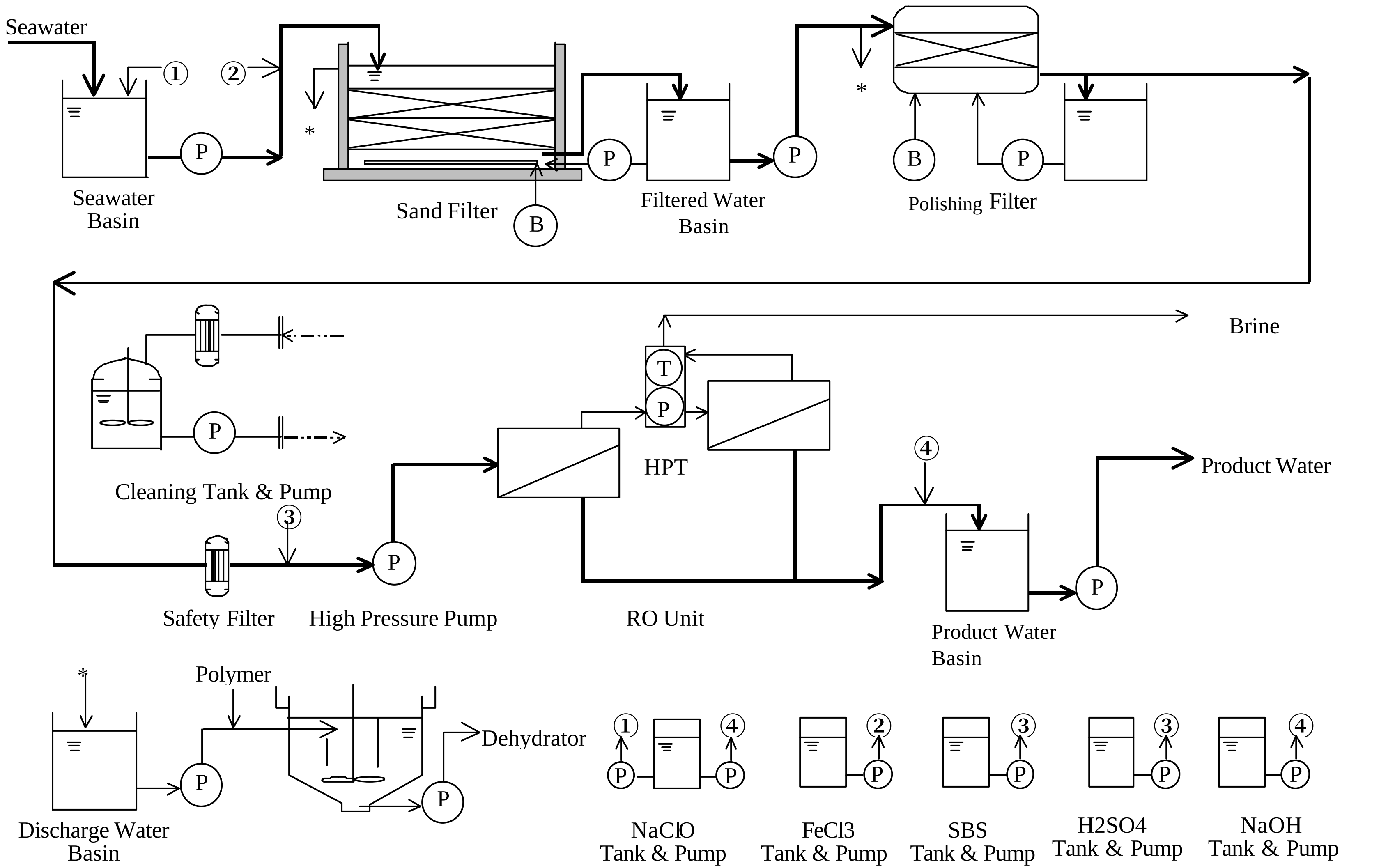

Fig. 6.4.5-2 Tentative Flow Diagram of the Seawater Desalination Plant of Aqaba (5MCM/Y)

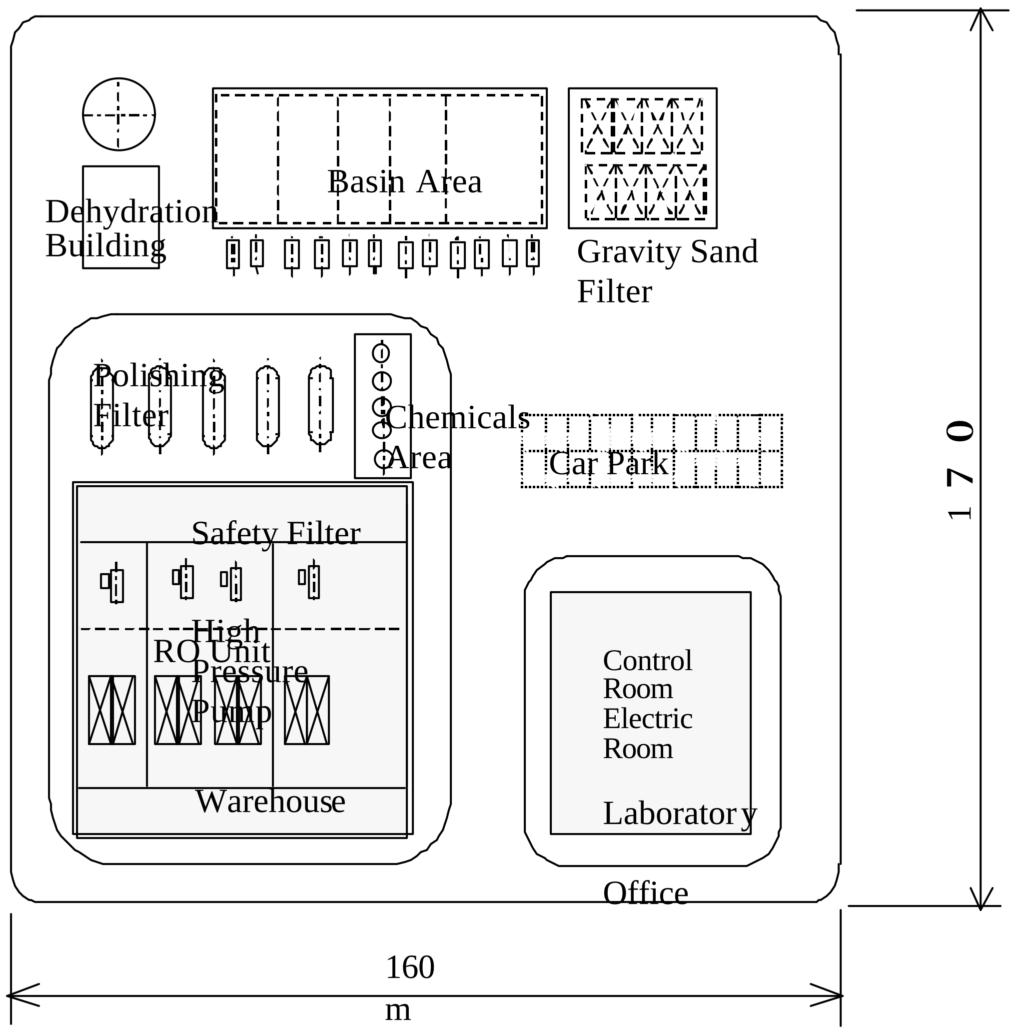

Fig. 6.4.5-3 Tentative Layout for the Seawater Desalination Plant of Aqaba (5MCM/Y)

6.4.6 Preliminary Design of the brackish groundwater development project

The brackish groundwater development project involves the production of drinking water of 30 MCM/year by mixing the desalinated product water of 20 MCM/year from Hisban with raw brackish spring water of 10 MCM/year from Zarqa Main.

The quality of raw water brackish spring water of Zarqa Main shall be examined furthermore in the future and if there are organic matters found, small-scale filtering facilities shall be considered.

The location of the proposed brackish water desalination and spring groundwater development site is shown in Fig. 6.4.6-1.

The project basically consists of :

a. Hisban: two parts - raw water system (production wells and water collection pipes) and desalination system(RO process)
b. Zarqa Main: two parts - raw water system (production wells and water collection pipes) and raw brackish spring water transfer pipe line from Zarqa Main to Hisban

A. Hisban Desalination Project

(1) Production wells and water collection pipes

1) Production wells

The specifications of the wells are as follows:

- Well depth : 350 m
- Production Capacity : 125 m^3/hour/well(1 MCM/year/well)
- Numbers of wells : 24

2) Raw water collection pipes

(2) RO desalination system

The Basic Flow and Plant Layout of the proposed Desalination Plant are shown in Fig. 6.4.6-2 and Fig. 6.4.6-3.

(3) Brine discharge

It is reported that the brine can be discharged into the Dead Sea without causing environmental problems according to the JICA study in 1995.

1) Brine disposal

- Brine disposal site : the Dead Sea
- Brine discharge line : by a 8km pipeline from the plant to downstream Wadi Ijarfa

and then to the Dead Sea through the wadi course (refer to Fig. 6.4.6-1)

2) Brine discharge equipment

- Brine basin : to receive the brine from the RO unit
- Discharge basin : to receive the overflow from the brine basin and the filter washing waste and the treated chemical cleaning waste from the waste water basin.
- Discharge Pump : to discharge the brine through Wadi Ijarfa into the Dead Sea.

B. Zarqa Main Brackish Spring Water Development Project

(1) Intake facilities of brackish spring water

(2) Raw brackish spring water transfer pipeline

The raw brackish spring water is transferred from Zarqa Main to Hisban by a 30km water transfer pipeline (refer to Fig. 6.4.6-1).

1) Water transfer pipe
- 600mm diameter ductile cast iron pipe

2) Water pump
- 400mm pumps : 3 regular + 1 standby

Fig. 6.4.6-1 Location of Proposed Brackish Water Desalination and Spring Groundwater Development Site

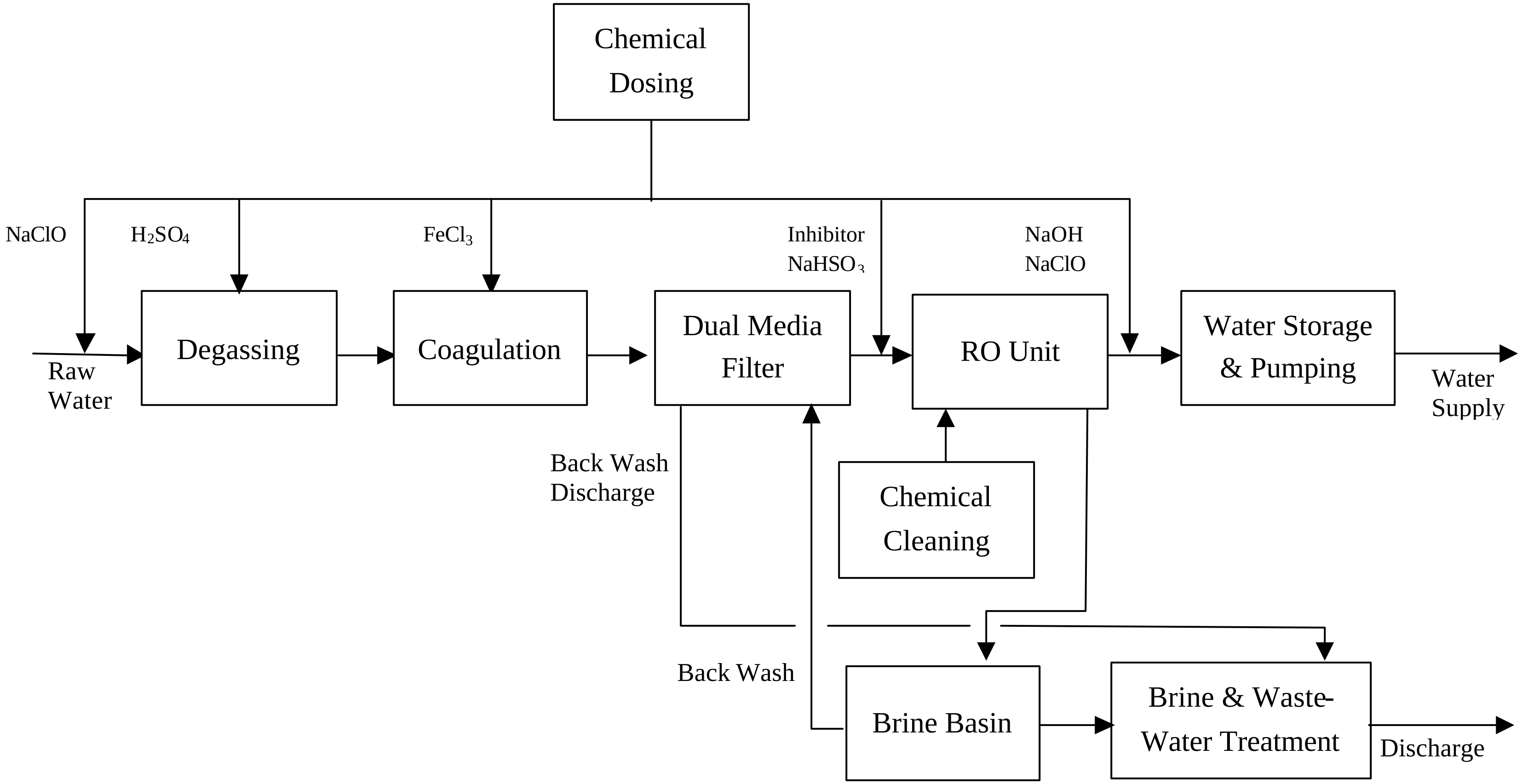

Fig. 6.4.6-2 Hisban/Basic Flow of Proposed Desalination Plant

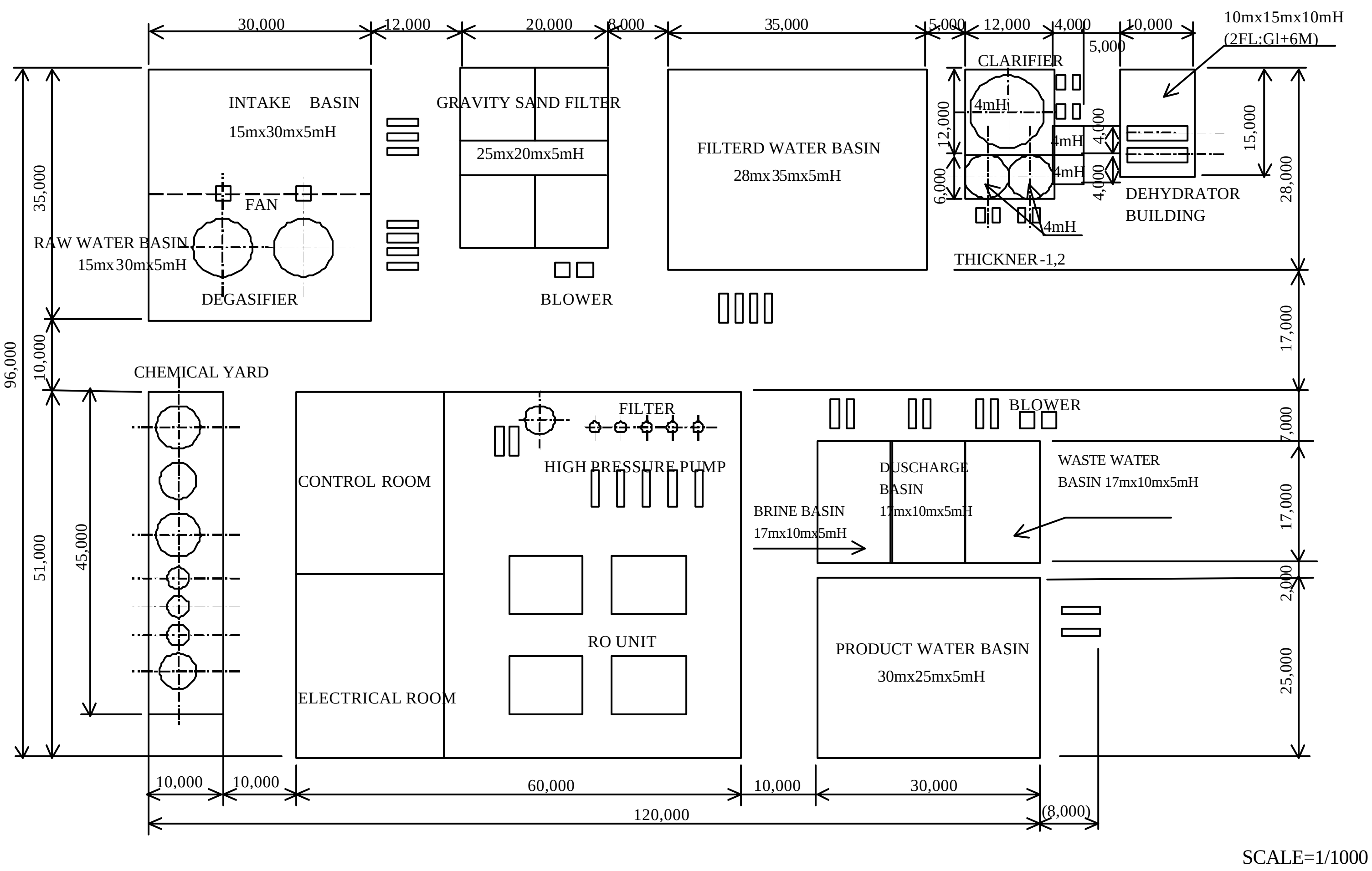

Fig. 6.4.6-3 Tentative layout for brackish water desalination plant of Hisban(20 MCM/Y)

6.4.7 Proposed Implementation Schedule

The proposed implementation schedule for desalination facilities is shown in Fig. 6.4.7-1.

Proposed Implementation Schedule

Project Name	Plant Name	2005	2010	2015	2020
Project for Establishment of Aqaba Seawater Desalination	5 MCM/year RO Desalination				
	Additional 10 MCM/year RO Desalination			(total 15 MCM/Y)	
Project for Establishment of Hisban -Zarqa Main groundwater development	20 MCM/year RO Desalination Plant				
	10 MCM/year Spring water development Plant				

Fig. 6.4.7-1 Proposed Implementation Schedule for Desalination Facilities

The outline of the existing desalination plants of RO system in Middle East and North Africa is listed in Table 6.4.7-1.

Table 6.4.7-1 Desalting plants rated at 500(m3/d) or more by Process (Reverse Osmosis) :Middle East & North Africa -1/3

country	location	total capacity (m3/d)	total capacity (m3/y)	units	Equipm.	Customer	Raw Water Quality	user	Con.Year	Op.Year	Cost in Mil.$	Unit Cost in $/m3	Plant Supplier	Consultant	Membrane Supplier
	Hurghada	500	165000	1	SWM		BRINE	TOUR	1995	1995	1.62	9.82	UAT USA		DOW FILMTEC USA
	Sharm El Sheikh	500	165000	1	SWM		BRINE	TOUR	1997	1997	1.62	9.82	UAT USA		DOW FILMTEC USA
	Sharm El Sheikh	500	165000	1	SWM		BRINE	TOUR	1996	1996	1.62	9.82	UAT USA		DOW FILMTEC USA
	Ras Abu Jarjur	11640	3841200	8	MTU	MEW	SEA	MUNI	1998	1998	29.85	7.77	SASAKURA J	SWECO	
Egypt		500	165000	1	MTU	SWISS RIVIERA H	SEA	TOUR	1999	1999	1.33	8.06	CULLIGAN I		
		1500	495000	1	HFM		SEA	MUNI	1997	1997	3.84	7.76	REDCON		DUPONT USA
		2000	660000	2	MTU	EL SOKHNA	SEA	INDU	1998	1998	5.21	7.89	CULLIGAN I		
		3000	990000	1	SWM		SEA	MUNI	1996	1996	7.3	7.37	UNIHA A		
		3000	990000	1	SWM	PVC	SEA	INDU	1999	2000	7.3	7.37	UNIHA A		
	Abu Ramad	500	165000	1	MTU	MODEV	SEA	MUNI	1996	1996	1.33	8.06	CULLIGAN I		
	Alexandria	600	198000	1	MTU	MOD	SEA	MIL	1995	1995	1.59	8.03	CULLIGAN I		
	Cairo	960	316800	1	MTU	Arab Hospital	SEA	MUNI	1996	1996	2.5	7.89	CULLIGAN I		
	Dahab	3600	1188000	3	HFM	DAHAB CO.	SEA	TOUR	1997	1998	9.31	7.84	METITO GROUP UA	ALI EL SAIE ET	DUPONT USA
	Halayeb	500	165000	1	MTU	MODEV	SEA	MUNI	1995	1995	1.33	8.06	CULLIGAN I		
	Hurghada	500	165000	1	MTU	MODEV	SEA	MUNI	1995	1995	1.33	8.06	CULLIGAN I		
	Marsa Alam	500	165000	1	MTU	MODEV	SEA	MUNI	1995	1995	1.33	8.06	CULLIGAN I		
	Shalatin	500	165000	1	MTU	MODEV	SEA	MUNI	1995	1995	1.33	8.06	CULLIGAN I		
	Sharm El Sheikh	500	165000	1	SWM	CHARMING CHARM	SEA	TOUR	1997	1998	1.33	8.06	METITO GROUP UA		TORAY J
	Sharm El Sheikh	500	165000	1	HFM	Hospital	SEA	MUNI	1997	1998	1.33	8.06	METITO GROUP UA		DUPONT USA
	Sharm El Sheikh	1000	330000	2	SWM	SHERATON HOTEL	SEA	TOUR	1997	1998	2.65	8.03	METITO GROUP UA		DOW FILMTEC USA
	Sharm El Sheikh	2000	660000	4	SWM	Private	SEA	TOUR	1996	1997	5.3	8.03	HYDROPRO USA		KOCH FLUID SYST
	Sharm El Sheikh	3000	990000	3	SWM	Private	SEA	MUNI	1996	1997	7.82	7.9	PREUSSAG D		HYDRANAUTICS USA
	Sharm El Sheikh	4000	1320000	1	SWM	Government	SEA	MUNI	1996	1997	9.42	7.14	ZENON CDN		
	Sharm El Sheikh	4000	1320000	1	SWM	SSWC	SEA	MUNI	1994	1998	9.42	7.14	GAWA D		TORAY J
	Sharm El Sheikh	7000	2310000	2	SWM	SINAI WATER CO	SEA	MUNI	1995	1997	16.75	7.25	GAWA D		DOW FILMTEC USA
	Taba	2400	792000	4	SWM	TABA GOLDEN COA	SEA	TOUR	1999	2000	6.34	8.01	METTO GROUP UA		
	Kish Island	3000	990000	1	SWM	Government	SEA	MUNI	1997	1998	7.3	7.37	WEIRWESTGARTHU K		
	Kish Island	3000	990000	1	SWM	Government	SEA	MUNI	1997	1998	7.3	7.37	ZENON CDN		
	Kish Island	5000	1650000	5	SWM	Municipality	SEA	MUNI	1999	2001	13.03	7.9	WTD I		

Notes:
1) Brine:TDS over 50,000 mg/l
2) Sea Water:TDS from 20,000 to 50,000 mg/l
3) BrakishWater:TDS from 3,000 to 20,000 mg/l
4) River Water:TDS from 500 to 3,000 mg/l

Table 6.4.7-1(2) Desalting plants rated at 500(m3/d) or more by Process (Reverse Osmosis) :Middle East & North Africa -2/3

country	location	total capacity (m3/d)	total capacity (m3/y)	units	Equipm	Customer	Raw Water Quality	user	Con.Year	Op.Year	Cost in Mil.$	Unit Cost in $/m3	Plant Supplier	Consultant	Membrane Supplier
Israel	Tripoli	650	214500	1	SWM		SEA	MUNI	1995	1996	1.71	7.97	IONICS USA		
	Tripoli	1000	330000	1	SWM		SEA	MUNI	1995	1996	2.61	7.91	IONICS USA		
	Tripoli	2500	825000	1	SWM		SEA	MUNI	1995	1996	6.19	7.5	IONICS USA		
Oman	Wudham	2400	792000	2	SWM	MOD	SEA	MIL	1995	1996	6.21	7.84	VATECH WABAG A	MOTT MACDONALD	
Qatar	Doha	1000	330000	2	HFM		SEA	INDU	1995	1996	2.65	8.03	USF ARABIA KS		DUPONT USA
	Ras Laffan	1000	330000	2	SWM		SEA	MUNI	1996	1996	2.65	8.03	ACE WATER J		ACE WATER J
	Ras Laffan	2000	660000	2	SWM		SEA	INDU	1996	1996	5.21	7.89	ACE WATER J		ACE WATER J
kuwait	El Obour	2500	825000	1	SWM	Government	WASTE	MUNI	1997	1998	3.44	4.17	ZENON CDN		
	Hurghada	1000	330000	1	SWM	Private	WASTE	TOUR	1996	1997	1.45	4.39	ZENON CDN		
	Mubarek City	4000	1320000	1	SWM	Government	WASTE	MUNI	1997	1998	5.23	3.96	ZENON CDN		
	Sabiya	5400	1782000	2	SWM	MEW	WASTE	POWER	1997	2000	7.37	4.14	MITSUBISHI J		NITTO J
Bahrain		1,980	653400	2	SWM	Golf Course	BRACK	IRR	1998	1998	1.92	2.94	SEATEC USA		DOW FILMTEC USA
	Bourq el Arab	4000	1320000	2	SWM	Government	BRACK	TOUR	1995	1995	3.92	2.97	ZENON CDN		HYDRANAUTICS USA
	El Alamain	2000	660000	1	SWM	GOUT	BRACK	TOUR	1995	1996	1.96	2.97	ZENON CDN		HYDRANAUTICS USA
	SINAI	4000	1320000	1	SWM	Government	BRACK	MUNI	1996	1997	3.66	2.77	ZENON CDN		
Iran		2800	924000	3	MTU	DANIELI	BRACK	INDU	1996	1996	2.84	3.07	CULLIGAN I		
	Sdom	1920	633600	1	SWM	DEAD SEA BROM	BRACK	INDU	1995	1996	1.88	2.97	IDE IL		HYDRANAUTICS USA
Lebanon	Beirut	1893	624690	2	MTU	COCA COLA	BRACK	INDU	1995	1996	1.92	3.07	ENVPRODUCTS		
Libya	Benghazi	500	165000	1	MTU	CIMI MONTUBI	BRACK	INDU	1996	1996	0.52	3.15	CULLIGAN I		
	Ras Laffan	1130	372900	1	SWM		PURE	INDU	1996	1996	0.81	2.17	ACE WATER J		ACE WATER J
Saudi Arabia		2500	825000	5	SWM	Royal Family	SEA	MUNI	1998	1999	6.63	8.04	UAT USA		DOW FILMTEC USA
		3000	990000	1	HFM		SEA	MUNI	1997	1997	7.3	7.37	SAUDI TRAD KS		DUPONT USA
	Jeddah	1000	330000	1	HFM		SEA	MUNI	1995	1996	2.61	7.91	AQUAMATCH USA		DUPONT USA
	Jeddah	1135	374550	1	HFM	ADC	SEA	MIL	1995	1996	2.94	7.85	AL KAWTHER KS		DUPONT USA
	Jeddah	1135	374550	1	HFM	MODA	SEA	MIL	1995	1995	2.94	7.85	AL KAWTHER KS		DUPONT USA
	Jeddah	1150	379500	2	HFM	PRINCE NAIF	SEA	TOUR	1997	1998	3.04	8.01	AQUAMATCH USA		DUPONT USA
	Jeddah	3000	990000	2	SWM	Hotel	SEA	TOUR	1999	2000	7.68	7.76	USF ARABIA KS		
	Jeddah	3000	990000	1	SWM	Private	SEA	MUNI	1997	1998	7.3	7.37	ZENON CDN		
	Jeddah	15234	5027220	7	SWM	SISCO	SEA	INDU	1999	2000	38.11	7.58	IONICS USA	BECHTEL USA	DOW FILMTEC USA
	Obhur	500	165000	1	SWM	Private	SEA	MUNI	1998	2000	1.33	8.06	USF ARABIA KS		DUPONT USA
	Obhur	1500	495000	2	HFM	Resort	SEA	TOUR	1997	1998	3.94	7.96	USF ARABIA KS		DUPONT USA
	Jeddah	500	165000	1	SWM	Private	WASTE	MUNI	1996	1997	0.74	4.48	ZENON CDN		

Notes:
1) Brine:TDS over 50,000 mg/l
2) Sea Water:TDS from 20,000 to 50,000 mg/l
3) BrakishWater:TDS from 3,000 to 20,000 mg/l
4) River Water:TDS from 500 to 3,000 mg/l

Table 6.4.7-1(3) Desalting plants rated at 500(m3/d) or more by Process (Reverse Osmosis) :Middle East & North Africa -3/3

country	location	total capacity (m3/d)	total capacity (m3/y)	units	Equipm.	Customer	Raw Water Quality	user	Con.Year	Op.Year	Cost in Mil.$	Unit Cost in $/m3	Plant Supplier	Consultant	Membrane Supplier
Saudi Arabia	Abquaiq	2182	720060	4	HFM	ARAMCO	BRACK	MUNI	1996	1998	2.21	3.07	USF ARABIA KS		DUPONT USA
	Al Jobail	2160	712800	3	SWM	Glass Factry	BRACK	INDU	1995	1996	2.25	3.16	USF ARABIA KS		DOW FILMTEC USA
	Al Kharj	900	297000	1	HFM		BRACK	MIL	1995	1996	0.92	3.1	USF ARABIA KS		DUPONT USA
	Al Kharj	2608	860640	2	SWM	Dairy	BRACK	MUNI	1996	1998	2.61	3.03	USF ARABIA KS		DOW FILMTEC USA
	Al Kharj	3130	1032900	1	SWM		BRACK	INDU	1998	1998	2.95	2.86	GETCO KS		DOW FILMTEC USA
	Al Kharj	5700	1881000	6	SWM	MODA	BRACK	MIL	1999	2000	5.79	3.08	USF ARABIA KS		DOW FILMTEC USA
	Al Khobar	570	188100	1	SWM	Residence	BRACK	MUNI	1997	1998	0.59	3.14	USF ARABIA KS		USF ARABIA KS
	Al Khobar	750	247500	1	SWM	PEPSI COLA	BRACK	MUNI	1999	2000	0.77	3.11	USF ARABIA KS		DOW FILMTEC USA
	Damman	600	198000	1	SWM	ALUPCO	BRACK	MUNI	1999	2000	0.62	3.13	USF ARABIA KS		TRISEP USA
	Damman	600	198000	1	SWM	Gas Company	BRACK	MUNI	1999	2000	0.62	3.13	USF ARABIA KS		TRISEP USA
	Damman	720	237600	1	SWM	SADAFCO	BRACK	INDU	1998	1999	0.74	3.11	USF ARABIA KS		TRISEP USA
	Damman	1000	330000	1	SWM		BRACK	MUNI	1996	1997	1.01	3.06	GETCO KS		KOCH FLUID SYST
	Damman	7000	2310000	4	SWM		BRACK	INDU	1997	1998	6.91	2.99	GETCO KS		DOW FILMTEC USA
	Dhahran	600	198000	1	SWM	Air Base	BRACK	MIL	1997	1998	0.62	3.13	USF ARABIA KS		USF ARABIA KS
	Hafr Al Batin	2000	660000	1	SWM	KKMC	BRACK	MUNI	1998	2000	1.96	2.97	USF ARABIA KS		TRISEP USA
	Hawiyah	1800	594000	2	MTU	ARAMCO	BRACK	INDU	1999	1999	1.83	3.08	ACE WATER J		ACE WATER J
	Hawiyah	1800	594000	1	SWM	ARAMCO	BRACK	INDU	1999	2000	1.77	2.98	ACE WATER J		ACE WATER J
	Jeddah	700	231000	1	SWM		BRACK	INDU	1999	1999	0.72	3.12	GETCO KS		DOW FILMTEC USA
	Jeddah	1300	429000	1	HFM	EGCS	BRACK	INDU	1995	1995	1.3	3.03	AL KAWTHER KS		DUPONT USA
	Jeddah	4000	1320000	1	SWM	Private	BRACK	MUNI	1997	1998	3.66	2.77	ZENON CDN		
	Kyriat Mushayd	900	297000	1	SWM	Compound	BRACK	MUNI	1996	1997	0.92	3.1	USF ARABIA KS		USF ARABIA KS
	Riyadh	500	165000	1	SWM		BRACK	MUNI	1997	1997	0.52	3.15	GETCO KS		DUPONT USA
	Riyadh	500	165000	1	HFM	AL JOMAIH	BRACK	INDU	1995	1995	0.52	3.15	AL KAWTHER KS		TRISEP USA
	Riyadh	500	165000	1	SWM	Farm	BRACK	IRR	1998	1999	0.52	3.15	USF ARABIA KS		DUPONT USA
	Riyadh	750	247500	1	SWM		BRACK	MUNI	1997	2000	0.77	3.11	GETCO KS		USF ARABIA KS
	Riyadh	800	264000	1	SWM	factory	BRACK	MUNI	1996	1997	0.82	3.11	USF ARABIA KS		TRISEP USA
	Riyadh	1500	495000	1	SWM		BRACK	MUNI	1997	2000	1.49	3.01	GETCO KS		DOW FILMTEC USA
	Riyadh	1500	495000	1	SWM	SAUJI CARPET	BRACK	MUNI	1998	2000	1.49	3.01	USA ARABIA KS		
	Riyadh	14000	4620000	2	MTU	Airport	BRACK	INDU	1997	1997	11.68	2.53	AES USA		DUPONT USA
	Shaybah	2600	858000	4	SWM	CCL	BRACK	INDU	1996	1997	3.75	4.37	ACWA UK		KOCH FLUID SYST
	Tabuk	1500	495000	1	HFM	FIAFI TRADING	BRACK	MIL	1995	1995	1.49	3.01	AL KAWTHER KS	MACDONALD	DUPONT USA
	Bisha	677	223410	1	SWM		River	INDU	1995	1996	0.56	2.51	USF ARABIA KS		USF ARABIA KS
	Damman	1440	475200	2	SWM	Can Factory	River	INDU	1995	1995	1.18	2.48	USF ARABIA KS		DOW FILMTEC USA
	Jeddah	908	299640	1	SWM	Water Factory	River	MUNI	1995	1996	0.74	2.47	USF ARABIA KS		DOW FILMTEC USA
	Riyadh	1200	396000	1	SWM	Residence	River	MUNI	1995	1996	0.97	2.45	USF ARABIA KS		DESALINATION USA

Notes:
1) Brine:TDS over 50,000 mg/l
2) Sea Water:TDS from 20,000 to 50,000 mg/l
3) BrakishWater:TDS from 3,000 to 20,000 mg/l
4) River Water:TDS from 500 to 3,000 mg/l

6.5 UFW Improvement Measures

6.5.1 Definition of UFW

Unaccounted-for water (UFW) is defined as follows.

UFW = Water distribution (or production) volume – Water sales

UFW is categorized into physical loss and administration loss.
In Jordan, the physical loss and the administration loss will consist of the following.

Physical Loss

- Leakage from primary, secondary and tertiary mains
- Leakage from service pipes upstream to water meters
- Overflows or leakage at reservoirs

Administration Loss

- Inaccuracy of water meters at distribution pump stations and reservoirs
- Defects of production water meters
- Inaccuracy of customers water meters
- Under registration of customers meters
- Water used for pipe cleaning, maintenance and operation work at water supply facilities (water treatment plant, pump station, etc.)
- Illegal connections
- Water theft from hydrants or stand pipes

6.5.2 Current Situation of UFW

6.5.2.1 Current Situation

The UFW volume and ratio for all the Governorates in 1998 are shown in Table 6.5.2.1-1.

Table 6.5.2.1-1 Current Situation of UFW in Jordan (1998)

No.	ID	Governorate	Production (m^3) ①	Water Billed (m^3) ②	UFW (m^3) ①−②	UFW (%) [(①−②)/①]x100
1	AM	Amman	85,213,886	41,378,189	43,835,697	51.4
2	ZA	Zarqa	32,372,409	13,442,435	18,929,974	58.5
3	MF	Mafraq	19,208,168	3,748,794	15,459,374	80.5
4	IR	Irbid	30,531,567	14,470,051	16,061,516	52.6
5	AJ	Ajloun	3,946,446	1,654,285	2,292,161	58.1
6	JA	Jerash	4,545,319	2,037,345	2,507,974	55.2
7	BA	Balqa	19,148,504	7,442,511	11,705,993	61.1
8	MA	Madaba	11,737,138	1,625,492	10,111,646	86.2
9	KA	Karak	9,328,577	3,741,898	5,586,679	59.9
10	MN	Ma'an	6,845,830	2,191,668	4,654,162	68.0
11	TA	Tafilah	2,354,915	1,303,282	1,051,633	44.7
12	AQ	Aqaba	16,333,461	5,019,993	11,313,468	69.3
Total			241,566,220	98,055,943	143,510,277	59.4

(Data source : MWI)

As shown in Table 6.5.2.1-1, the UFW ratio of the whole of Jordan is about 60%. The ratio of Mafraq and Madaba is extremely high and goes over 80%.

It is widely recognized that such a high UFW ratio as 60% includes a physical loss of 25 to 30% and the rest is an administration loss.

6.5.2.2 Problems to be Solved

The reasons for the high UFW ratio are listed as follows.

<u>For physical loss</u>

(1) Defects on water supply system
- The distribution network is not divided into distribution blocks. Water is distributed directly from pump stations to the distribution areas so that the water pressure in the areas is not constant.
- Since water is distributed by pressure mains to the end of the distribution network, the water pressure of the pump is very high. This leads to high water leakage due to high pressure in the areas around the pump station.
- Intermittent water supplies, where applicable, badly affect the satisfactory functioning of water meters.

(2) Defects on water supply facilities
- Water supply pipes have been used longer than their service life.
- Water supply pipes have been damaged due to poor quality of piping materials and poor workmanship in the construction.

<u>For administration loss</u>

(1) Accurate measurement and reporting have not been done.
- Measurement of water production volume in wells and springs has not been done accurately and regularly.
- Most of the water meters installed at the water sources are mechanical types. These are subject to measurement errors and many meters are being damaged.
- Maintenance of water meters has not been done regularly.
- Measurement of water meters for consumers has not been done or reported accurately.
- Water meters are not installed in all the water supply facilities so that most of the reported figures of water production and distribution are merely estimated ones.

(2) Staff members engaged in the UFW management are not enough.
(3) There are many illegal house connections.

6.5.3 Improvement Measures for UFW

6.5.3.1 Considerations for UFW Improvement Plan

(1) Considerations for the formulation of the UFW improvement plan

For the formulation of the UFW improvement plan, the following points shall be taken into account:
- In general, more than 90% of water leakage happens in service pipes.

- Many visible leaks will appear in the area around the water treatment plant and the pump station due to relatively high water pressure.
- For invisible leakage, a leakage sound detection method will be much more effective in the area around the water treatment plant and pump station because the leakage sound is big enough and the leakage, if any, will be easily detected.
- It will be more effective if the leakage detection survey starts from the pumping facilities, such as water treatment plant, and extends to the distant distribution areas.

(2) Check points for the formulation of the UFW improvement plan
The items shown in Table 6.5.3.1-1 shall be checked or confirmed for the formulation of the UFW improvement plan.

Table 6.5.3.1-1 Check Points for Formulation of UFW Improvement Plan

<table>
<tr><th>Check Point</th><th colspan="2">Description</th></tr>
<tr><td>Field Survey</td><td colspan="2">• Location of distribution and service pipe
• Diameters and material of distribution and service pipe
• Installation conditions of valves (whether they are in good condition or not)
• Survey of the road conditions and adjacent facilities</td></tr>
<tr><td>Preparation of Drawings</td><td>• Distribution network drawings
• Detailed drawings
• Off-set drawings of stop valves</td><td>Diameters, materials and locations of pipes and valves shall be indicated in the drawings.
Diameters, lengths, materials of service pipes, relation with distribution pipes and water meters for house connections shall be shown in the drawings.</td></tr>
<tr><td>Survey of Water Leakage and Repair</td><td colspan="2">• Leakage survey for exposed pipes (area around meters on house connections, aqueducts, etc.) and their repairs
• Survey on visible leakage on the ground (on the road, in the garden of each house, inside the valve chamber, etc.) and repairs
• Survey on invisible leakage under the ground
□ Check on each household's meter
□ Detection by leak sound detection bar : leak sound from exposed pipes, meters, valves and hydrants will be detected.
□ Detection by leak detection equipment</td></tr>
<tr><td>Pressure Survey</td><td colspan="2">Current water pressure and the pressure after the leakage repair shall be checked.</td></tr>
<tr><td>Sorting-out of Data</td><td colspan="2">• Water pressure of each distribution pipeline
• Location of detected leaks and records of their repairs
• Reasons for leaks
• Estimated leakage volume by eyes</td></tr>
</table>

6.5.3.2 UFW Improvement Plan

(1) Physical Loss

The measures for improving the physical loss of the UFW are described as follows. These measures are being adopted in the on-going project in Amman called "the Project for Restructuring & Rehabilitation of Greater Amman Water Network".

<u>Improvement Measures for Physical Loss</u>

- To establish a National Water Supply Control System that will enable the accurate measurement of water supply and pressure, efficient water supply, effective operation and maintenance, etc.
- To separate the main supply pipelines from sub-distribution networks.
- To reduce the operational pressure in the network down to a maximum of 5 bar.
- To divide the water networks of the capital into distribution areas separated from each other and supplied by natural gravity.
- To replace galvanized steel pipes of small diameters with polyethylene pipes
- To lay down a strategy to execute what has been mentioned above into two stages of network restructuring and network rehabilitation.
- To conduct leak detection campaigns and measurement of leakage percentage after each stage mentioned above.

(2) Administration loss

It is expected that the administration loss will be improved surely and steadily through the measures mentioned below.

1) Training and/or securing of a competent staff and strengthening of organization for UFW.
A sufficient number of competent personnel with high aspirations shall be trained and/or secured. These personnel shall be positioned in the department related to UFW in WAJ.

2) Introduction and establishment of up-to-date management theory
UFW improvement can be realized not only through technical measures, but also through staff education and management organization reform. Such target will be realized using the up-to-date management theory.

(a) Target management and personnel evaluation on results bases
Each employee is required to make efforts to achieve the quantitative target within the designated period. For this purpose, it is required to enhance the ability and morale of the staff through education and training by the organization. Remuneration has to be paid according to the achievement degree of the target and not according to the employee's career and/or qualification.

(b) Activation of organization and creation of willingness in the members of the staff
A work environment shall be so created that all those comprising the staff can execute their duties as best they can, fully respecting and trusting each other.

(c) Development of a philosophy considering customers as top priority
When customers raise complaints to the related department of WAJ about all sorts of

inconveniences and troubles regarding water supply services, the staff personnel must respond to their complaints earnestly and solve them as promptly as possible. This attitude is indispensable to the prosperity of the business.

(d) Establishment of strategic management basis
First, a long term business strategy shall be formulated. Then, a business policy and scheme will be reached. Projects will be implemented based upon the business scheme. The evaluation of results from the implementation will be reflected in the future business strategy.

(e) Management in which profit is regarded as top priority
Business targets to be achieved in the year, such as profit ratio of total liabilities and net worth, profit ratio of sales, turnover of total capital, labor productivity, cash flow indices, etc., shall be set up. Business activities shall be done positively to reach the targets.

(f) Introduction of information technology (IT)
Information technology shall be permeated as early as possible in every field of the different business activities.

(g) Privatization and division of water supply and sewerage enterprise
At present, the water supply and sewerage enterprises in Jordan are being operated as a state-owned, monopolized undertaking, which is the main cause behind the high UFW ratio. In Japan, the state-owned, state-run Japan National Railway (JNR) was disintegrated around a decade ago into several private enterprises operating over their respective allocated areas in Japan. JNR had been suffering from perennial deficits. But after the private railways were started, their management improved rapidly and remarkably, and they now enjoy financial success. The same thing can happen by dividing the water supply and sewerage services of Jordan into several private entities so that they may compete with each other. As a result, it will lead to a considerable reduction of the UFW.

(h) Strict enforcement of laws and regulations
Strict enforcement of laws and regulations shall be executed against water theft from illegal connection of service pipes and nonpayment of water and wastewater charges.

6.5.3.3 Expected UFW Ratio

The UFW in other countries, for example in Japan, has been reduced as shown in Table 6.5.3.3-1.

Table 6.5.3.3-1 Experience of UFW Reduction in Other Country (Japan)

(Unit : %)

Parameter \ Year	1965	1970	1975	1985	1998
Water Sales to Water Production	69.2	74.0	77.4	82.8	88.1
UFW	30.8	26.0	22.6	17.2	11.9
Physical Loss (leakage ratio)	26.8	22.4	18.9	13.6	8.7
Administration Loss	4.0	3.6	3.7	3.6	3.2

As shown in the above table, UFW ratio or physical loss for the most part has improved by about 18% (1.0 to 0.5% per year) during the last 33 years in Japan.

The reduction of physical loss in Japan has been achieved through continuous efforts such as replacement of old pipes with good quality ones, frequent leakage detection, etc.

Therefore, when similar efforts being adopted in the Project for Restructuring and Rehabilitation of Greater Amman Water Network are applied to other Governorates, it will be possible that the current physical ratio of about 25 to 30% is reduced to 15%, which is the target physical ratio in 2020 set by World Bank.

6.6 Cost Estimation for the Plans

6.6.1 Water Transfer/Supply Facilities

6.6.1.1 Unit Costs

The adopted unit construction costs are established based on the following information and documents:

- Several previous Study Reports of MOWI
- Latest price list of the Ministry of Public Works and Housing, version 1999 (The Government Tenders Directorate Annual Report)
- Quotation and consultation with local contractors and manufacturers
- Experience of the Consultant

Unit prices include all the costs for construction works including belongings and all indirect prices except owner's engineering cost and contingencies. The prices given in the previous study reports of MOWI mentioned above are converted to year 2000 prices considering the annual escalation ratio of 3 % per annum.

Table 6.6.1.1-1 shows the basic construction cost for civil works taken into account for unit price estimation. Table 6.6.1.1-2 summarizes unit prices for the estimates of investment cost for water transfer facilities. Both tables are based on prices of the year 2000.

Table 6.6.1.1-1 Basic Construction Cost for Civil Works

		Unit	Unit price (JD/unit)
Land acquisition			
North Jordan Valley		ha	16,000
Middle and South Jordan Valley		ha	12,000
Others		ha	8,000
Earth work			
Site leveling		m^2	2.0
Excavation	Common	m^3	3.5
	Rock	m^3	8.5
Backfill		m^3	2.5
Concrete			
Lean concrete		m^3	45
Mass concrete		m^3	70
Reinforced concrete		m^3	140
Anchor block		m^3	115
Steel			
Steel bar		t	520
Structural steel		t	1,570
Building			
High quality		m^2	350
Middle quality		m^2	200
Low quality		m^2	160
Road construction		m^2	9.5
Fence and gate		m	25

Table 6.6.1.1-2 Unit Prices for Water Transfer Facilities (1/2)

Component	Unit	Unit cost (JD/unit)
Pump Station		
Capacity 100 m^3/h, H= 30m	JD/(m^3/h)	850
Capacity 780 m^3/h, H= 50m	JD/(m^3/h)	600
Capacity 1120 m^3/h, H=200m	JD/(m^3/h)	960
Capacity 1450 m^3/h, H= 50m	JD/(m^3/h)	480
Capacity 2120 m^3/h, H=100m	JD/(m^3/h)	600
Capacity 3425 m^3/h, H= 70m	JD/(m^3/h)	480
Transmission Main-Ductile Iron (DI) pipe		
DN 100	m	48
DN 150	m	61
DN 200	m	75
DN 250	m	88
DN 300	m	102
DN 350	m	123
DN 400	m	151
DN 500	m	199
DN 600	m	276
DN 700	m	330
DN 800	m	397
DN 900	m	474
DN 1000	m	577
DN 1100	m	665
DN 1200	m	775
DN 1350	m	936
DN 1500	m	1,128
Water Reservoir		
50 m^3	m^3	350
100 m^3	m^3	350
200 m^3	m^3	295
300 m^3	m^3	260
400 m^3	m^3	240
500 m^3	m^3	225
600 m^3	m^3	210
700 m^3	m^3	195
800 m^3	m^3	185
900 m^3	m^3	180
1,000 m^3	m^3	175

6.6.1.2 Estimation of Investment Cost

For the estimation of investment costs one must distinguish between base construction cost, engineering cost and contingencies as described in the following.

(1) Basic design assumptions for base construction cost estimation

Costs shall be estimated for all the facilities of the Inter-Governorate water transfer lines.

Investment cost estimate considers all the required facilities between the water receiving point and distribution point. This means that they will be comprised of a water transmission pump station with balancing/regulation reservoir(s), water transmission pipeline facilities, a water distribution reservoir and a water distribution pump station.

The unit construction cost for pump stations is given in JD per m³/h of installed capacity (see Table 6.6.1.1-2). Unit prices decrease with the increasing total capacity of the pumping station. Investment cost for pumping facilities will be calculated accordingly, whereby the portion of cost for each (electromechanical equipment and civil works) is estimated to be 50 % of the total price.

For transmission pipes, ductile iron pipes shall be adopted.

(2) Costs for engineering and contingencies

Engineering costs include the cost for engineering services such as surveys, planning, designs, site supervision, etc. The amount of these services is estimated as 15 % of the base construction cost according to the experience of the consultant. Allowance is taken into account for unpredictable variation in construction conditions and other unforeseen difficulties that may increase the final construction cost. The amount of these contingencies is estimated to be 15 % of the base cost.

6.6.1.3 Estimation of Operation Cost

Two types of operation and maintenance costs have to be distinguished, i.e. fixed and variable costs. The fixed costs do not depend on the quantity of water volume to be transmitted (e.g. staff and maintenance cost). The variable costs are directly related to the water volume to be transmitted and refer to such items as electrical power consumed for pumping.

(1) Staff cost

The following criteria are applied to estimate required staff for operation and maintenance of water transfer facilities.

Criteria	Required staff
Transmission volume of pump station < 1,000 m³/hr	1
Transmission volume of pump station 1,000 to 3,000 m³/hr	2
Transmission volume of pump station 3,000 m³/hr or more	3

The estimates of personnel costs are based on current salaries paid including all overhead costs (e.g. allowances, pension fund etc.). Total annual costs for one staff member are estimated to be 3,500 JD/a (basic salary) plus 5,300 JD/a (overhead cost), which results in a total of 8,800 JD/a.

(2) Maintenance cost

Operation and maintenance requirements are calculated as a percentage of the investment costs. This item includes the equipment (including all materials and small tools) required but does not include personnel cost, which is considered separately. The following percentages of the capital cost are to be considered for the annual maintenance cost:

0.5 % p.a. for civil works

2.0 % p.a. for mechanical and electrical equipment
0.5 % p.a. for transmission mains

These percentages are based on experience and are widely accepted as representative of typical conditions.

(3) Power Cost

Electrical energy is consumed by transmitting water by pump(s) to water reservoir(s) or a booster pump station. Power consumption is calculated according to the transmitting volume of water. The present average compound rate per kWh for water supply sector is 0.034 JD.

6.6.1.4 Result of Cost Estimation

Table 6.6.1.4-1 summarizes the results of preliminary estimates for capital, operation and maintenance costs, as far as the Inter-Governorate water transfer facilities is concerned.

Table 6.6.1.4-1 Summary of Preliminary Estimates for Capital and Operation Costs

No.	Inter-Governorate Water Transfer Facility	Total Investment Cost (JD)	Annual (2020) Operation Cost (JD/a)	Specific (2020) Operation Cost (JD/m^3)	Remarks
①	Abu Alanda-Khaw	11,915,800	22,915	0	Gravity flow system
②	Zatary-Khaw	27,568,060	132,844	0.044	Pumped system
③	KM124-Zatary (1/4)	1,260,350	24,252	0.028	Pumped system
	KM124-Zatary (2/4)	3,783,000	74,640	0.011	Pumped system
	KM124-Zatary (3/4)	4,132,050	125,209	0.010	Pumped system
	KM124-Zatary (4/4)	5,527,600	297,568	0.016	Pumped system
④	Houfa-Zatary	29,621,150	38,211	0	Gravity flow system
⑤	Houfa-Ajloun/Jerash (1/2)	3,467,360	151,496	0.038	Pumped system
	Houfa-Ajloun/Jerash (2/2)	5,394,740	166,791	0.042	Pumped system
⑥	Disi-Madaba Branch	3,434,600	228,613	0.016	Pumped system
⑦	Disi-Ma'an Branch	5,394,740	166,791	0.042	Pumped system
	Total	101,499,450	1,429,330		

6.6.2 Desalination Plant

6.6.2.1 Unit Costs

The adopted unit construction costs are established based on the following information and documents:

- Several previous Study Reports of MOWI
- Latest price list of the Ministry of Public Works and Housing, version 1999 (The Government Tenders Directorate Annual Report)
- Quotation and consultation with local contractors and manufacturers
- Experience of the Consultant

Unit prices include all the costs for construction works including belongings and all indirect prices except owner's engineering cost and contingencies. The prices given in the previous study reports of MOWI mentioned above are converted to year 2000 prices considering the annual escalation ratio of 3 % per annum.

Table 6.6.2-1 summarizes unit prices for the estimates of investment cost for water transfer pipes. This table is based on prices of the year 2000.

Table 6.6.2-1 Unit Prices for Water Transfer Pipes

Component	Unit	Unit cost (JD/unit)
Brackish water transfer pipes-Ductile Iron (DI) pipe		
DN 200	m	75
DN 250	m	88
DN 300	m	102
DN 350	m	123
DN 400	m	151
DN 500	m	199
DN 600	m	276
DN 700	m	330
DN 800	m	397
DN 900	m	474
DN 1000	m	577
DN 1100	m	665
Brine water discharge pipes-RC pipe		
RC 200	m	55
RC 300	m	74
RC 400	m	97
RC 500	m	122
RC 600	m	164

6.6.2.2 Estimation of Investment Cost

Costs shall be estimated for all the facilities of the Aqaba desalination plant and the Hisban & Zarqa Main brackish water development plant.

1) Production Well
The cost was estimated based on the result of the JICA Study in 1995.

2) RO desalination plant

- The calculation results by the IDA (International Desalination Association) Brackish Water Desalting Costs Program is referred to (refer to Table 6.4-A1, A2 & A3 attached at the end of Chapter 6.4).
- The mean unit cost of the RO desalination plant is shown on Table 6.6.2.2-1.
  a) The mean unit cost of 7.81 $/m3 is applied for the Aqaba seawater desalination plant
  b) The mean unit cost of 2.48 $/m3 is applied for the Hisban brackish groundwater desalination plant, having a value closer to the TDS of river water

Table 6.6.2.2-1 Mean Unit Cost of RO desalination plant

NO.	Raw Water Quality	Range of TDS	Mean Unit Cost in $/m3
1	BRINE WATER	Over 50,000mg/l	9.82
2	SEA WATER	From 20,000 to 50,000mg/l	7.81
3	WASTE WATER		4.33
4	BRACKISH WATER	From 3,000 to 20,000mg/l	3.04
5	RIVER WATER	From 500 to 3,000mg/l	2.48
6	PURE WATER		2.17

Notes:
1. The mean unit cost is calculated based on the result of 2,000 IDA Worldwide Desalting Plants Inventory Report No.16 issued on December 31,1999.
2. The unit cost is calculated by total cost divided by yearly product volume for RO system.
3. TDS: total dissolved solids content.

3) Brine discharge pipeline
- The price of materials and construction cost is based on the local level.

4) Raw brackish spring groundwater transfer facilities
- The price of materials and construction cost of pipeline is based on the local level
- The construction cost of the pumping facilities is estimated according to the consultant's experiences

6.6.2.3 Estimation of Operation Cost

The calculation of Operation and Maintenance Costs is based on the following principles.

(1) Electricity
- The current electricity price of 0.03 JD/Kwh for WAJ's water supply was used.

(2) RO membrane replacement
- The price of RO membrane modules was set on the international base.

- An annual replacement of 20% membrane modules was considered.

(3) Chemicals
- Consumption of chemicals was estimated according to the consultant's experience and the raw water quality.
- Both local purchasing and international standard prices were referred to in setting the unit prices of chemicals.

(4) Labor
- The present salary of laborers in Jordan was considered.

(5) Maintenance
- Annual maintenance cost was estimated according to the equipment level and the consultant's experience.

6.6.2.4 Result of Cost Estimation

Table 6.6.2.4-1 summarizes the results of preliminary estimates for capital, operation and maintenance costs for the RO desalination plant.

Table 6.6.2.4-1 Summary of Preliminary Estimates for Capital, Operation and Maintenance Costs

No.	RO Desalination Plant	Total Investment Cost (2005) (1,000JD)	Total Investment Cost (2015) (1,000JD)	Annual (2005) O & M Cost (1,000JD/a)	Annual (2015) O & M Cost (1,000JD/a)
①	Aqaba desalination plant	27,363	54,720	1,546	4,639
②	Hisban-Zarqa Main brackish water development plant	64,006	0	5,034	5,034
	Total	91,369	54,720	6,580	9,673

6.6.3 National Water Supply Control System

6.6.3.1 Estimation of Investment Cost

For the estimation of investment costs, one must distinguish between facility cost, engineering cost and contingencies as described in the following.

(1) Basic design assumptions for facility cost estimation

Costs shall be estimated for all the facilities of the National Water Supply Control System (NWSCS).

The investment cost estimate considers all the required facilities and equipment for the computerized supervisory and control system for NWSCS. However, the electrical supply work for the facilities and equipment is not included in the estimation on the condition that electrical supply shall be secured from the existing system.

(2) Costs for engineering and contingencies

Engineering costs include the cost for the engineering services such as planning, designs, system coordination, etc. The amount of these services is estimated as 10 % of the base facility cost according to the experience of the consultant. Allowance is taken into account for unpredictable variation in the implementation conditions and other unforeseen difficulties that may increase the final cost. The amount of these contingencies is estimated to be 10 % of the base cost.

6.6.3.2 Estimation of Operation Cost

Two types of operation and maintenance costs have to be distinguished, i.e. fixed and variable costs. The fixed costs do not depend on the quantity of water volume to be transmitted (e.g. staff and maintenance cost). The variable costs are directly related to the water volume to be transmitted and refer to such items as electrical power consumed for pumping.

(1) Staff cost

The following criteria are applied to estimate the required staff for the operation and maintenance of the Main Control Center, the Sub-Centers and the local stations.

Criteria	Required staff	Remarks
Main Control Center	5	2 shifts
Sub-Center	5	2 shifts
Local Station	3 (for one Sub-Center)	

Estimates of personnel costs are based on current salaries paid, including all overhead costs (e.g. allowances, pension fund etc.). Total annual costs for one staff member are estimated to be 3,500 JD/a (basic salary) plus 5,300 JD/a (overhead cost), which results in a total of 8,800 JD/a.

(2) Maintenance cost

Operation and maintenance requirements are calculated as a percentage of the investment costs. This item includes the equipment (including all materials and small tools) required but does not include personnel cost, which is considered separately. The following percentages of the capital cost are to be considered for the annual maintenance cost:

3.0 % p.a. for hardware and software

This percentage is based on experience and widely accepted as representative of typical conditions.

(3) Communication Cost

The communication cost shall be estimated, taking into account the usage of leased telephone line, cellular phone and Internet. However, at the moment, the conditions for the availability of communication measures are not clear. Therefore, the communication cost will be estimated in the next stage (or pre-feasibility stage) of this study.

6.6.3.3 Result of Cost Estimation

Table 6.6.3.3-1 summarizes the results of preliminary estimates for capital, operation and maintenance costs as far as the facilities and equipment for NWSCS is concerned.

Table 6.6.3.3-1 Summary of Preliminary Estimates for Capital and Operation Costs

	Facilities for National Water Supply Control System	Total Investiment Cost (JD/a)	Annual (2005) Operation Cost (JD/a)	Annual (2010) Operation Cost (JD/a)	Remarks
Phase-1	Main Control Center	1,245,000	125,000		
	Sub-Center (3 nos.)	3,092,000	355,000		
	Local stations (RTU, flow meters, etc.)	2,824,000	111,000		
	Engineering & Contingency	1,400,000			
	Phase-1 Total	8,396,000	589,000		
Phase-2	Main Control Center	132,000		128,000	addition of software only
	Sub-Center (8 nos.)	3,721,000		1,167,000	
	Local stations (RTU, flow meters, etc.)	4,486,000		454,000	
	Engineering & Contingency	1,629,000			
	Phase-2 Total	9,769,000		1,748,000	
Grand Total		18,165,000	589,000	1,748,000	

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