CHAPTER 10 CONCEPTUAL DESIGN FOR WATER TRANSMISSION

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10.1 Design Criteria

In view of the existing facilities and in consideration of Master Plan, the design concept for the facilities to be constructed within the Barka Plant site for the water reservoir, pump station and the main water transmission line from Barka will be given in the following:

The basis of design will be as follows:

(1) The entire design will be in harmony with the existing facilities.

(2) The facilities will be structurally safe, conform with hydrological conditions and will have the required capacities.

(3) The facilities shall meet the water quality requirements.

(4) The facilities shall comply with the legal requirements and standards.

(5) Consideration shall be given to cost effectiveness, and for sound construction and efficient operation and maintenance.

(6) The transmission pipeline should be constructed at one time, as the staged construction of pipeline is not suitable due to cost and environmental impact.

10.2 Water Transmission Plan

10.2.1 Scope

The conceptual design for the facilities (water reservoir and pump station) within the Barka Plant site and the main water transmission pipeline is included.

Water transmission to South Batinah is mentioned in 10.4.

10.2.2 Proposed Water Service Areas

Figure 10.2.1 indicates the development schematic chart for the entire water transmission system for Muscat. Table 10.2.1 lists existing and proposed service reservoirs scheduled for construction under the development project.

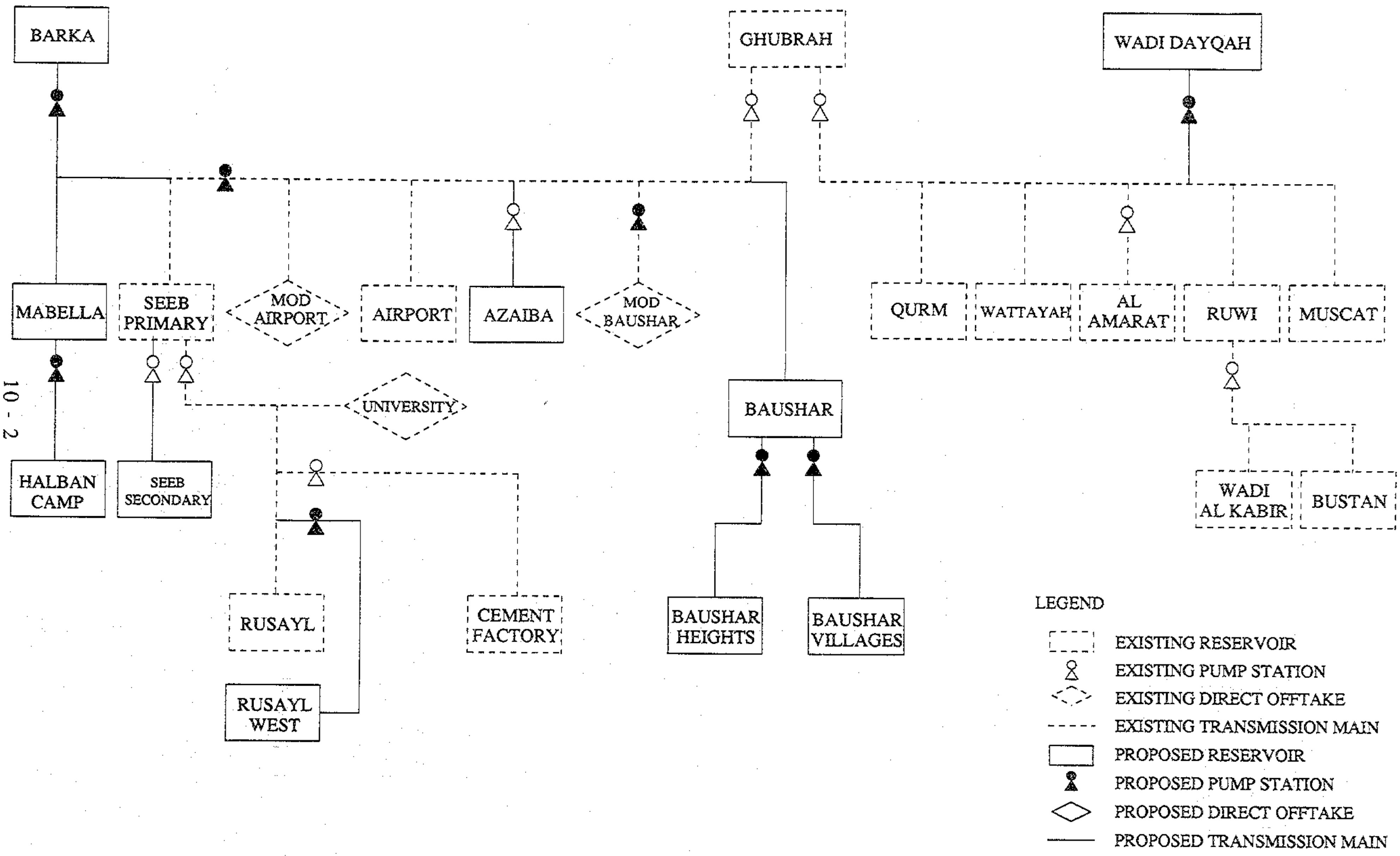


Figure 10.2.1 General System Development Schematic
(Source: Water Supply Master Plan For Muscat)

TABLE 10.2.1 EXISTING AND PROPOSED SERVICE RESERVOIR SUMMARY (SOURCE: WATER SUPPLY MASTER PLAN FOR MUSCAT)

RESERVOIR	STATUS	EXISTING CAPACITY (m3)	T.W.L (m)	B.W.L (m)	2010 DESIGN DEMAND (m3/d)	ADDITIONAL CAPACITY REQUIRED (m3)
EASTERN SYSTEM :						
Qurm	Existing	18,000	32.0	77.0	32,958	14,958
Qurm II	Existing	5,000	97.0	92.0	5,000	
Wattayah	Existing	9,000	75.0	70.0	13,313	4,313
Ruwi (G.Muttrah)	Existing	18,000	70.0	65.0	32,106	14,106
Muscat	Existing	18,000	70.5	65.5	20,130	2,130
Al Kabir	Existing	3,000	117.0	112.0	9,835	6,835
Bustan	Existing	3,000	55.0	51.0	3,066	66
Al Amarat	Under Const.	5,000	213.0	208.0	22,488	17,488
SUBTOTAL EAST		79,000			138,896	59,896
CENTRAL SYSTEM						
Baushar	Proposed	0	47.5	42.5	49,808	49,808
Baushar His	Proposed	0	85.0	80.0	3,602	3,602
Baushar Villages	Proposed	0	125.0	120.0	3,602	3,602
SUBTOTAL CENTRAL		0			57,012	57,012
WESTERN SYSTEM :						
Airport	Existing	10,000	52.0	47.0	9,936	(64)
Azaiba	Proposed	0	85.0	80.0	5,016	5,016
Seeb	Existing	18,000	39.5	34.5	36,264	18,284
Mabella	Proposed	0	39.5	34.5	38,130	38,130
Seeb Secondary	Proposed	0	65.0	60.0	26,620	26,620
Rusayl	Existing	5,000	135.0	130.0	11,844	6,844
Rusayl West	Proposed	0	170.0	165.0	5,544	5,544
C. Factory	Existing	5,000	203.0	198.0	1,464	(3,536)
Halban	Proposed	0	90.0	85.0	4,005	4,005
MOD Airport	N/A	—	—	—	9,972	9,972
SQ University	N/A	—	—	—	4,240	4,240
MOD Baushar	N/A	—	—	—	2,628	2,628
SUBTOTAL WEST		38,000			155,683	117,683
TOTAL		117,000			351,591	234,591

NOTE : ( ) INDICATES SURPLUS
NA INDICATES THESE SYSTEMS ARE SUPPLIED BY A DIRECT CONNECTION TO MEW SUPPLIES, MEW IS NOT RESPONSIBLE FOR FUTURE EXPANSION OF THESE SYSTEMS.

Master Plan forecasts significant water demand increase in the Western District of Ghubrah as a result of the area's anticipated rapid development. Master Plan also projects smaller increase of water demand in the Eastern District of Ghubrah.

Water produced at Ghubrah and Barka Desalination plants, two major water sources for the future, is classified by the Master Plan according to where it will be delivered. Water produced at Ghubrah Plant will be supplied to the Eastern and Central Districts, while the Barka Plant's water will serve the Western District.

The water supply structure (supply areas) of these plants is expected to change, depending on the desalination capacity at each plant, particularly the gradual increase in the Barka Plant's capacity. Based on a 63,600 m^3/d unit capacity at the Barka Plant during a stage when only one or two units are in operation, part of the Western District will need to be supplied with water from the Ghubrah Plant. The Barka Plant will be able to supply not only to the Western District but also to the Central District at the final stage of the Project.

10.2.3 Planning of Transmission Pipeline

The water quantities delivered through pipeline depend on the following factors:

- Head (or pressure) available at the source, i.e. pump or reservoir.
- Difference in elevation between source and discharge point.
- Diameter of pipeline.
- Friction loss (head loss) caused by pipes, fittings and valves.

In determining the pipeline diameter, calculation of head loss is necessary as a first step.

(1) Calculation of Head Loss

There are numerous formulas for the calculation. In water pipeline, however, Hazen-Williams Formula is principally used.

$$hf = \frac{6.78\ L}{D^{1.165}} \left(\frac{V}{C} \right)^{1.85}$$

where

hf: head loss (m)
C: Coefficient related to the pipe condition
D: Diameter of pipe (m)

V: Mean velocity of flow (m/s)

L: Length of pipeline (m)

(2) Selection of Pipeline Diameter

Pipeline diameter is selected in considering the head loss, difference in elevation between pump and the target point, etc.

Table 10.2.2 shows the proposed pipe diameter and cost calculation of respective section of the pipeline.

10.2.4 Water Transmission Pipe Route

(1) Selection of Route

The main water transmission pipes will follow a route along the main road (National Highway Route 1) between Muscat and Sohar, leading from the Barka Site to Mowallah, and to Ghubrah Reservoir (through existing pipeline). For a stretch of about four kilometers between the Barka Site and the main roads, the main pipe will be buried along the existing road and along the plant access road.

There is sufficient vacant areas to bury the pipes along the main roads, which account for over 90 % of the route. Maintenance of the buried water pipes can be done more effectively if they are buried along the road.

(2) Terrain and Soil Conditions of the Pipe Route

The route is virtually flat along its entire length. The following points need to be considered in planning the route.

a. Elevation

The elevation of the transmission line route is directly connected on the supply pressure, and so it is necessary to have sufficient knowledge of the elevation.

The high elevation of the Barka - Mowallah - Ghubrah route is 15 m above the sea level, and the elevation of Barka is the same as that for Ghubrah. There are high points up to 50 m above the sea level at several points at the Seeb Airport and Bausher.

Table 10.2.2 Pipeline Design Parameters

Depreciation Rate 0.02
Power Cost Rate 0.014 R.O./KWh

Total

		Barka	Mabella	Seeb Res.	Mowallah
		Mabella	Seeb Res.	Mowallah	Ghubrah
Pipe Length	km	17	13	13	22
Height from Sea Water Level	m	39.5	39.5	65	65
Flow rate	m^3/d	200,000	160,000	70,000	70,000
Velocity	m/sec	1.50	1.20	1.03	1.03
Pipe Dia.	m	1.40	1.40	1.00	1.00
Pipe Installation Cost	R.O./m	570	570	0	0
Press. Loss	m/km	1.64	1.08	1.21	1.21
Total Press. Loss	m	27.83	14.04	15.75	-
Calculated Pump Head	m	67.33	0	30.08	-48.59
Designed Pump Head	m	100.00	0.00	100.00	-
Pump eff.		0.75	0	0.75	-
Pump Power	kW	3,027	0	1,060	0
Energy Consumption	kWh/t	0.363	0.000	0.363	0
Investment Cost	M.R.O.	9.69	7.41	0.00	0.00
Investment Cost	$Baiza/m^3$	2.95	2.17	0.00	0.00
Energy Cost	$Baiza/m^3$	5.09	0.00	5.09	0
Total Cost	$Baiza/m^3$	8.04	2.17	5.09	0

b. Road and Wadi Crossings

There are several paved roads for the pipeline to cross, and it will be necessary to provide adequate countermeasure during the construction of the pipeline.

c. Soil Conditions

The soils along the entire route of the pipeline are generally sand or earth, and there are no big obstacles expected. However, it is recommended to take borings along the entire route, and take samples of the soils and to check for buried underground obstacles.

10.3 Water Transmission Facilities

10.3.1 Water Reservoir

(1) Capacity of Water Reservoir

The capacity of the water reservoir facilities at the Barka Site will be equal to the daily production of the desalination plant of 254,000 m^3 in accordance with the Guidelines of MEW.

The reservoir should be constructed with 2 compartments each of 4 stages to meet the production capacity and for ease of maintenance and operation.

(2) Structure

For ease of operation and maintenance and for not being affected by the ambient temperature, the reservoir will be semi-underground structure constructed of concrete.

The reservoir is furnished with ventilation and drainage facilities and the bottom will be sloped for drainage.

(3) Reservoir Specification

Reservoir capacity:	31,800 m^3 x 2 compartments x 4 sets ≑ 254,000 m^3
Dimensions:	100 m wide x 107 m long (each 2 compartments)
Average depth:	6 m

10.3.2 Blending Facility

Desalination plants require blending of the product water as a post treatment process. This post treatment of the desalinated water prevents the corrosion of the water supply facilities and makes the water more palatable as drinking water.

Use of well water for blending at the Barka Site will not be certain for the following reasons:

- It is not known whether well water can be obtained at the Barka site.

- There are restrictions on the use of well water in order to maintain the quality of water.

Although blending at the source is preferable, if it is not possible, it may be performed locally or at the main transmission pipeline.

10.3.3 Quality of Supply Water

The quality of the distributed water will conform with the "Omanian Standard No. 8 Drinking Water".

10.3.4 Water Pump Station

(1) Pump Station

The underground pump station which contains 10 identical units of single stage centrifugal pump is arranged adjacent to the water reservoir. The pump station includes an operation room, electrical room and office. An overhead crane is to be installed in the pump station for maintenance.

(2) Water Pump

In order to cope with the variations in the supply demand and the maintenance and operation of the pumps, a total of 10 centrifugal pumps (8 for normal use and 2 for standby) will be provided. The pumps are operated by automatic control.

Specification of water pump (per one unit)

Type	:	Single stage centrifugal pump
Capacity	:	1,460 m^3/h

Head	:	100 m	
Revolution	:	980 rpm	
Drive	:	Electric motor 640 kw	
Materials	:	Casing	Cast iron
		Impeller	Stainless steel
		Shaft	Stainless steel

10.3.5 Transmission Pipe

(1) Pipeline Route

Transmission pipeline route is shown in Figure 10.3.1.

(2) Selection of Pipe Material

The material of the pipe will be selected to meet the requirements of the long distance transmission pipe. As this pipe is important, reliability, durability and maintainability are to be taking into account.

Although the cement lined ductile cast iron pipe, lined steel pipe, mortar pipe, plastic pipe, etc. are considered for transmission pipe, the cement lined ductile cast iron pipe is applied, considering many references and reliability.

(3) Pipe Specification

Type of Pipe	:	Cement lined ductile cast iron pipe (ISO 2531 K-9 T-type or JIS G-5526 T-type Class - 3 or equivalent)
External surface	:	Zinc spray 30 μm + tar epoxy 250 μm + polyethylene sleeve
Internal surface	:	Cement mortar lining

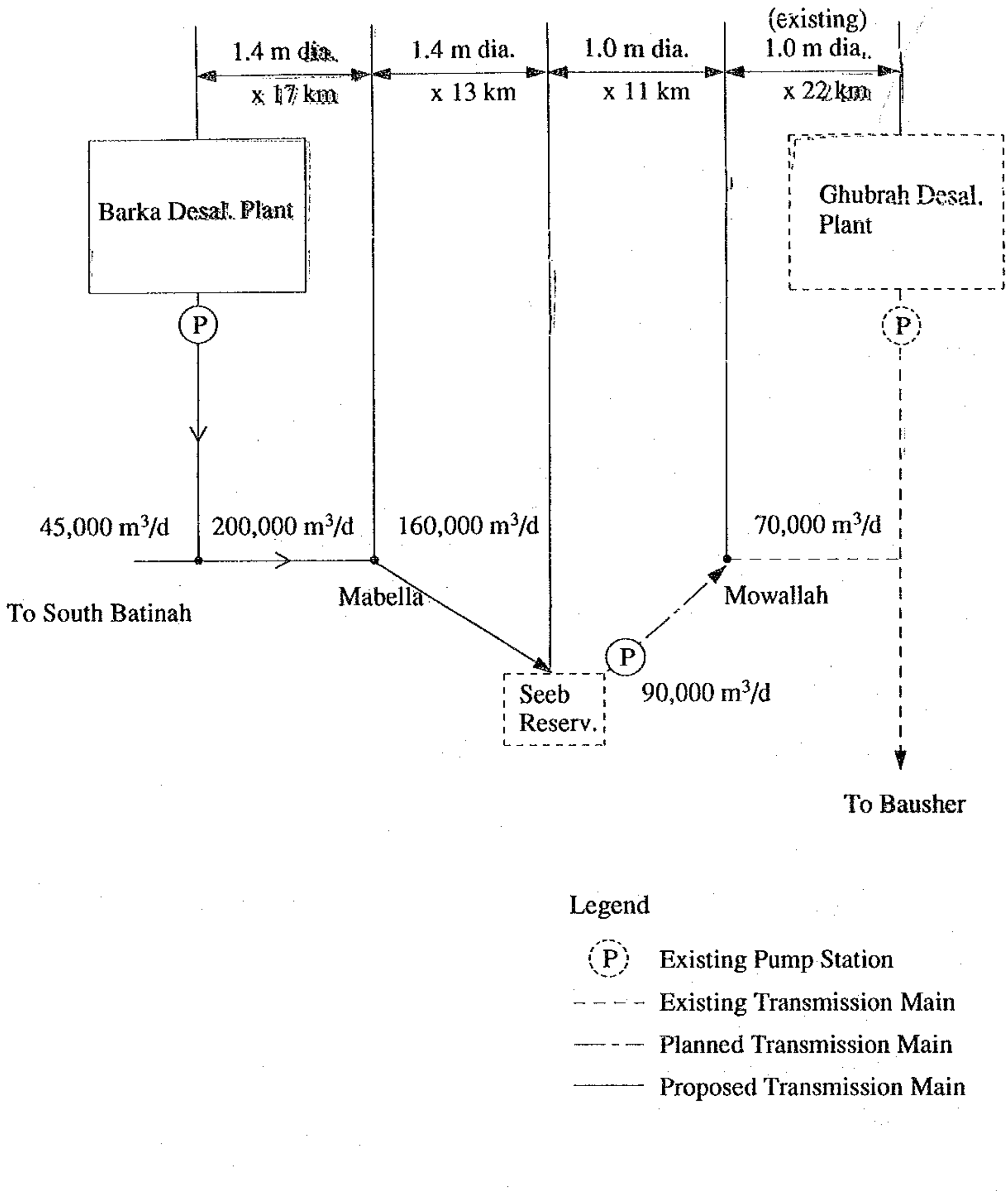


Figure 10.3.1 Transmission Pipeline Route

10.4 Water Transmission to South Batinah

South Batinah district is far from the source of water supply, and there are inevitable differences in elevation on its routing. The conceptual design of the water transmission to South Batinah is considering such condition, as follows:

10.4.1 Water Transmission Plan

(1) Proposed Service Areas

Water produced at the Barka Desalination Plant will be partly delivered to South Batinah (Barka, Nakhl, Al Musannah, A'Rustaq, Al Awabi). Table 10.4.1 indicates the population, forecasted water demand in 2010, distance and height.

(2) Pipeline Route

Figure 10.4.1 indicates the proposed pipeline route. The proposed pipeline route consists of two separate lines:

Route A: Barka plant → Barka → Point "A" → Nakhl
Route B: Point "A" → Point "B" → A'Rustaq → Al Awabi
→ Al Musannah

Table 10.4.1 South batinah Walayat

Walayat		Barka	Nakhl	Al Musannah	A'Rustaq	Al Awabi	Total
Population in Dec. 1993		61,164	12,570	45,414	59,379	8,488	187,015
Aproximate Design Demand at 2010	m³/d	15,000	3,000	11,000	14,000	2,000	45,000
Distance from Barka Plant	km	7	42	43	94	100	
Heights from See Water level	m	10	200	10	400	500	
Estimated Construction Cost	Million R.O.	0.42	3.41	2.69	7.41	2.36	16.30
Transmission Cost Depreciation	Baiza/m³	1.7	69.3	14.9	32.2	71.9	
Transmission Cost Power	Baiza/m³	5.1	30.6	10.7	52.0	60.0	
Transmission Cost Total	Baiza/m³	6.8	99.9	25.6	84.2	131.9	

10.4.2 Water Transmission Facilities

(1) Pump Station

In South Batinah, as the pipeline runs in a long distance and districts to be served are located at a high elevation from the sea level, a pump station with a small buffer reservoir should be installed at the level of approximately 100 m above each other.

(2) Pipe Specification

Pipe specification shall be the same as in the Clause 10.3.5.

10.4.3 Economical Evaluation

Water transmission cost calculation is made on the basis of the following assumptions:

(1) Unit investment cost including all transmission facilities is estimated as follows:

Pipe diameter (mm)	Unit cost (RO/m)
600	180
400	132
300	108
200	84

(2) Investment cost and energy cost for pump operation are calculated on each line, as shown in Table 10.4.2

(3) Those figures are summed up as a total. The transmission cost of each district is considered to share the total cost of each line in proportion to the water consumption, and results are shown in Table 10.4.1.

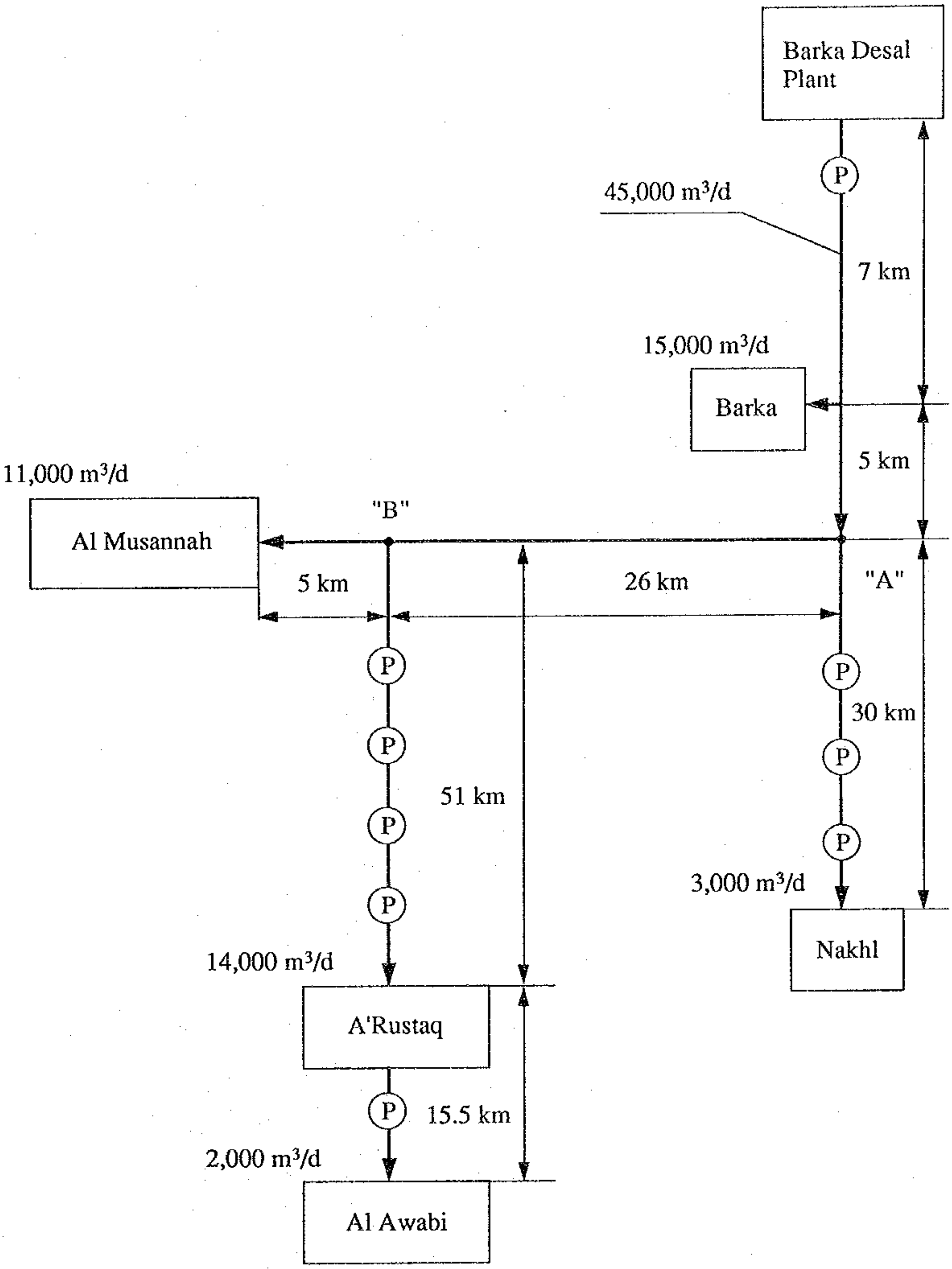


Figure 10.4.1 Transmission Pipeline Route to South Batinah

Table 10.4.2 Water Transmission Plan to South Batinah

Route		A				B			
Pipeline From	Unit	Barka Plant	Barka	A	A	B	B	Rustaq	Total
To		Barka	A	Nakhl	B	Musannah	Rustaq	Al Awabi	
Pipe Length	km	7	5	30	26	5	51	15.5	139.5
Flow rate	m^3/d	45,000	30,000	3,000	27,000	11,000	16,000	2,000	45,000
Velocity	m/sec	1.84	1.23	0.49	1.11	1.01	1.47	0.74	
Pipe Dia.	m	0.6	0.6	0.3	0.6	0.4	0.4	0.2	
Designed Pump Head	m	100.00	0.00	400	110	0.00	650.00	120.00	
Energy Consumption	kWh/t	0.364	0.000	1.824	0.4	0.000	2.952	0.552	2.699
Investment Cost	M.R.O.	1.26	0.90	3.24	3.43	0.66	5.51	1.30	16.30
Transmission Cost Depreciation	$Baiza/m^3$	1.70	1.83	65.75	7.74	3.65	20.96	39.63	-
Transmission Cost Power	$Baiza/m^3$	5.09	0.00	25.54	5.60	0.00	41.33	7.73	-
Transmission Cost Total	$Baiza/m^3$	6.80	1.83	91.29	13.34	3.65	62.29	47.36	-

CHAPTER 11 CONCEPTUAL DESIGN FOR CIVIL AND ARCHITECTURAL FACILITIES

CHAPTER 11 CONCEPTUAL DESIGN FOR CIVIL AND ARCHITECTURAL FACILITIES

11.1 Design Conditions

11.1.1 Standards and Criteria

1) British Standards (BS)
2) General Specifications for Buildings in Oman
3) Building Research Establishment Digest (BRE)
4) The CIRIA Guide to Concrete Construction in the Gulf Region

11.1.2 Design Conditions

1)	Concrete	:	Ordinary Portland Cement Concrete
2)	Significant Wave Height	:	$H_{1/3}$ = 3.7 m
3)	Design Wind Speed	:	V = 80 knots (approx. 40 m/s)
4)	Horizontal Seismic Coefficient	:	Kh = 0.02
5)	Pile (Driven Cast-in-situ Concrete Pile)		
	① Diameter	:	Ø = 500 mm
	② Allowable Axial Bearing Capacity	:	qa = 90 t

(1) Concrete

It is well known that, in the Gulf Region both sulphates and chlorides exist in the soil and groundwater. Due consideration for chemical attack on concrete is required in the selection of materials and fixing design parameters.

The primary cause of deterioration of reinforced concrete is corrosion of the reinforcement resulting in extensive cracking and spalling of the concrete cover. Corrosion results from attack by chlorides present either within concrete aggregates or in the environment and can only occur in the presence of both oxygen and water. Thus this risk of corrosion can be reduced by assuring that the amounts of chloride in concreting materials are kept to a minimum and by ensuring both the adequacy and integrity of the concrete cover.

Sulphate may also be present in concreting materials and in the environment to which concrete is exposed, often in combination with chlorides. Their main effect is on the concrete itself where the attack leads to internal expansion and disintegration. Their effect can be reduced by the use of certain selected cements or in extreme conditions by protecting the concrete by tanking.

Sulphate-resisting Portland cement (SRC) is recommended in the presence of sulphates, while it is not advisable where the risk of chlorides exists. The CIRIA Guide also states that the use of SRC may be inadvisable where sulphates and chlorides exist together.

In this F/S, we assume that ordinary Portland cement is used for concrete since both sulphates and chlorides exist in the proposed site. However, it is required, as a matter of course, to re-examine chemical attack on concrete based on results of detailed investigation to be conducted in the detailed design stage, and then to select a suitable type of cement, concrete mixes and design parameters in accordance with the CIRIA Guide and BRE.

(2) Wave

According to the data recorded in 1991 and in the period from March, 1983 to April, 1984 by MCI at Mina Qaboos, the maximum wave height (H_{max}) is 8.0 m. This is considered to be the maximum value among a numerous number of waves observed in the said period. It is generally known, from the statistical analysis, that the significant wave height ($H_{1/3}$) can be obtained by the following equation;

$$H_{1/3} = \frac{H_{max}}{1.07\sqrt{\log N}}$$

N: number of waves observed.

Assuming N = 10,000, $H_{1/3}$ is obtained as 3.7 m.

(3) Wind

Table 11.1.1 is the records of maximum gust observed at Seeb from 1977 to 1991. By analyzing this data statistically, the relation between a return period and a corresponding gust speed is obtained as shown in Table 11.1.2.

Table 11.1.1 Max. Gust at Seeb

Sultanate of Oman
Ministry of Communications
Directorate General of Civil Aviation & Meteorology
Department of Meteorology

Station : Seeb
Parameter : Surface wind data [speed in knots] 'Maximum gust with direction

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	040	260	240	330	120	090	210	200	070	060	330	340	200
	30	25	20	26	30	40	20	50	30	18	20	18	50
1978	340	360	270	270	300	060	230	240	050	210	200	060	270
	16	22	29	32	26	30	26	25	22	22	25	23	32
1979	210	230	210	180	210	030	050	060	050	050	040	200	200
	28	30	33	42	30	30	25	25	23	28	24	48	48
1980	330	200	320	220	200	200	210	050	020	170	030	060	320
	25	39	53	44	37	29	36	28	27	27	25	28	53
1981	250	320	190	180	280	210	190	050	050	200	040	050	280
	34	40	31	55	66	40	26	36	25	25	22	25	66
1982	200	230	200	050	210	200	050	040	200	060	060	060	200
	35	36	43	32	30	34	27	28	28	25	27	22	43
1983	280	220	310	270	200	040	090	060	040	040	050	340	060
	35	30	34	37	35	30	27	38	20	18	19	20	38
1984	210	060	200	210	210	290	070	060	170	060	060	060	200
	22	22	30	30	27	22	29	16	25	17	20	19	30
1985	070	340	210	310	210	210	210	050	340	340	050	320	310
	19	19	30	31	20	20	21	18	14	17	16	19	31
1986	060	210	200	260	210	060	210	070	210	060	340	060	210
	20	26	29	25	30	27	25	28	24	19	16	21	30
1987	340	010	200	300	060	210	210	050	020	200	040	040	200
	18	30	46	34	32	36	29	21	24	29	19	21	46
1988	270	320	210	220	330	280	210	060	060	190	060	250	220
	25	27	35	37	27	27	29	21	23	20	19	25	37
1989	310	320	200	330	070	010	230	040	230	350	090	360	330
	26	24	29	38	31	23	30	22	24	23	26	31	38
1990	300	290	010	360	330	220	270	090	100	100	090	070	270
	24	35	23	29	29	29	40	25	20	26	20	26	40
1991	220	250	250	240	210	210	210	070	280	060	070	310	220
	43	31	31	33	28	27	30	29	24	25	19	23	43

Table 11.1.2 Gust Speed by Return Period

Return Period T (year)	Gust Speed (knots)
200	73.2
100	69.2
50	65.0
30	61.8
10	54.5

On the other hand, there are records of cyclones affecting the coast of Oman. The report says that the cyclone in 1977 is probably the worst one within the past 100 years.

Table 11.1.3 Gusts by Cyclones

Year	Recording Place	Gust (knots)
1963	Salalah	80
1977	Masirah	95+
1983	Masirah	47
1992	Umm Zamaim	49

The courses of cyclones are generally distributed in the southeast coast of Oman and it seems rare to experience cyclones around the project site.

From the above studies, it is considered reasonable to assume the design wind speed of 80 knots (≒ 40 m/s) in this F/S.

(4) Earthquake

Figure 11.1.1, which is reported in "Seismic Risk Maps for High Seismic Regions in The World" published by the Building Research Institute, Ministry of Construction, Japan, shows the maximum acceleration on the ground (A_{max}) for a return period of 200 years. From this figure, A_{max} in the area around the proposed site is read as 20 gal (= 20 cm/sec^2). The horizontal seismic coefficient is obtained dividing it by the acceleration of gravity.

$$Kh = \frac{20}{980} \fallingdotseq 0.02$$

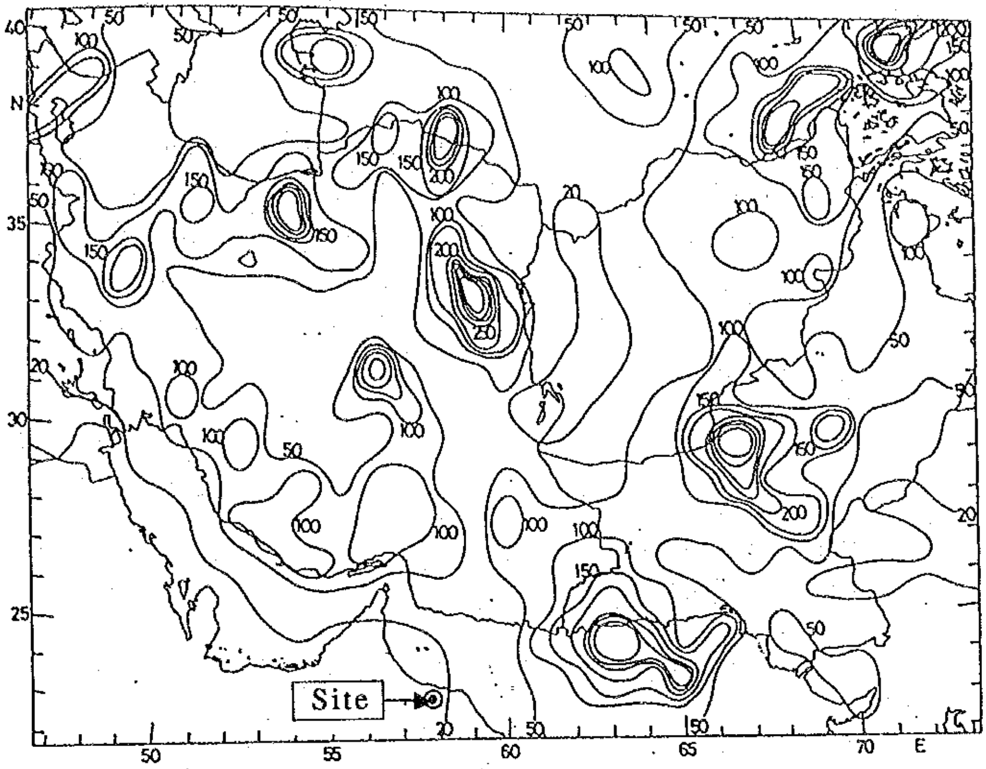


Figure 11.1.1 Amax for return period Tr = 200 Years

(5) Foundations

The soil investigation was conducted in this F/S, and consisted of boring at 6 locations and laboratory tests for soil and water samples. According to the results of the investigation, the geological features are summarized as follows;

1) Firm strata with SPT-value ≥50 (rock, gravel, sand) are distributed at 5.0 ~ 11.0 m below the ground surface. The depth to these strata tend to be deeper toward the sea (north) and the west.

2) Sand strata, in general, exist above the firm strata while spots of gravel or silty soil also occasionally exist. The top 1.0 ~ 2.0 m is a loose sandy layer and, below this, medium to dense sand is distributed.

3) Each type of stratum is distributed irregularly and discontinuously.

Direct foundations or pile foundations are to be considered as a foundation system for the plant facilities. In case of direct foundations, soil strata with SPT-value ≥20 are generally required to support main facilities in the plant. It is indicated, in the results of the soil investigation, that soil strata with SPT-value ≥20 exist at a depth of more than 3.0 ~ 8.0 m from the ground surface. Considering that the site is to be raised about 2.2 ~ 4.0 m as mentioned in

Section 11.2 hereinafter, a huge amount of excavation (5.0 ~ 12.0 m) is required for construction of foundations. This is not feasible in economic and technical terms, such as costs, construction period, space and so forth. Furthermore, there is a possibility of differential settlement because of irregularity of soil strata. We, therefore, adopt pile foundations for the main plant facilities (medium to heavy loaded structures), which reach the firm strata with SPT-value ≥50.

There is a choice of piles, namely, steel pipe piles, PC piles or driven cast-in-situ piles. In our study, an allowable axial bearing capacity is estimated, by using the modified Meyerhof's formula, for a driven cast-in-situ pile which is often adopted in Oman.

The results of the calculation are shown in Table 11.1.4.

<u>Assumptions</u>

Soil conditions	:	See Figure 11.1.2
Pile diameter	:	d = 500 mm
Safety factor	:	F = 3.5

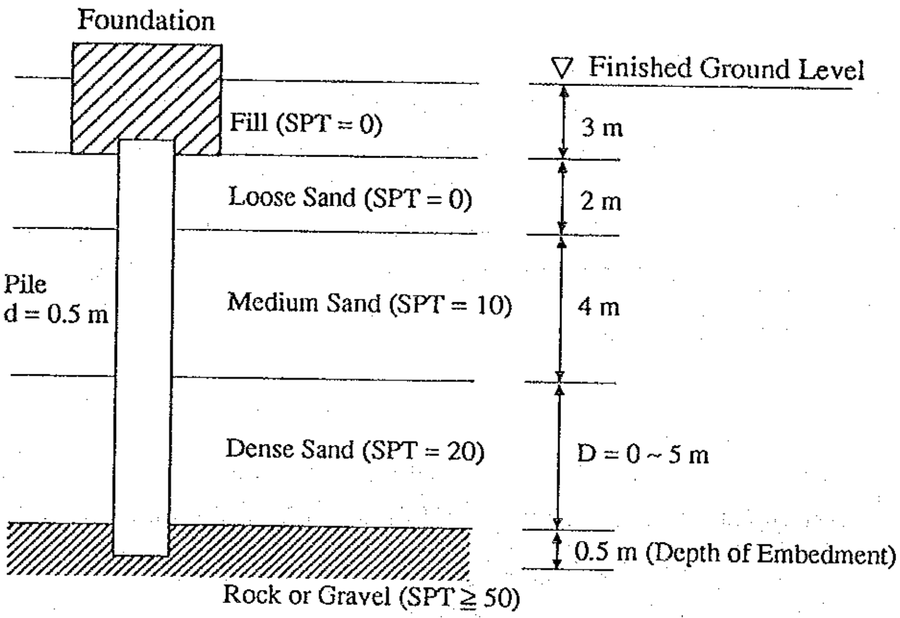


Figure 11.1.2 Soil Conditions

Table 11.1.4 Allowable Axial Bearing Capacity of Pile

D (m)	Qp (t)	Qf (t)	qa (t)
0	294	13	87.7
5.0	294	44	96.6

D : thickness of dense sand layer with SPT-value of more than 20

q_a : allowable axial bearing capacity of pile (t)

Qp : ultimate point bearing capacity at the tip of pile (t)

Qf : ultimate skin friction of pile (t)

For lightly loaded structures or deep structures such as the water intake pit and underground water reservoir, it is considered that the direct foundation system can be adopted, provided that compaction of founding soil is duly carried out or improvement of soil is locally undertaken in order to obtain a safe bearing capacity.

Since our soil investigation was carried out to get the outline of subsoil conditions for the conceptual design, it is necessary to conduct a detailed soil investigation in the detailed design stage.

11.2 Finished Ground Level of Site

The typical profile of the site is as shown in Figure 6.2.1. It is necessary to raise the ground level of the site to secure the safe operation of proposed plant.

The finished ground level of the site is to be determined, considering the high water level, wave height and drainage system of the plant, by the following concepts;

1) to limit the volume of wave overtopping below an allowable value.
2) to determine the finished level above the run-up height of wave.

(1) Wave Overtopping

From Section 11.1.2, $H_{1/3}$ = 3.7 m which corresponds to the design wave height Ho'.

Design wave height	: Ho' = 3.7 m
Period of wave	: T = 10 sec.
Slope of seabed	: Assuming as S = 1/30 (safe side)
Wave length	: Lo = 1.56 T^2 = 156 m
	∴ Ho'/Lo = 0.024

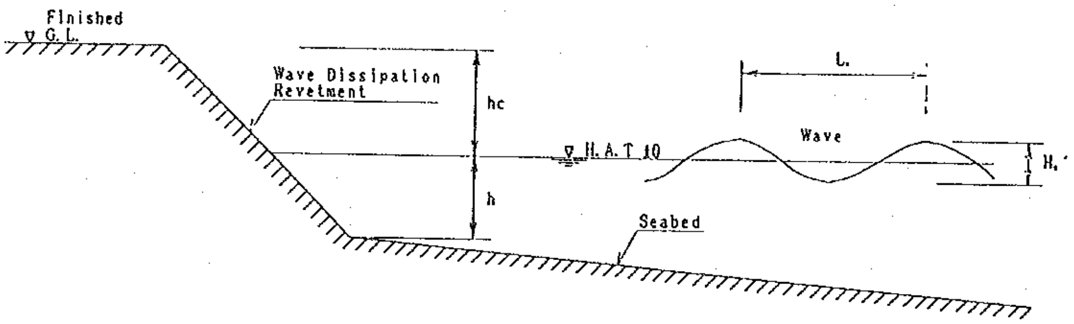


Figure 11.2.1 Design Parameters

Assuming

h = 2.1 m → h/Ho' = 0.57

hc = 3.5 m → hc/Ho' = 0.95

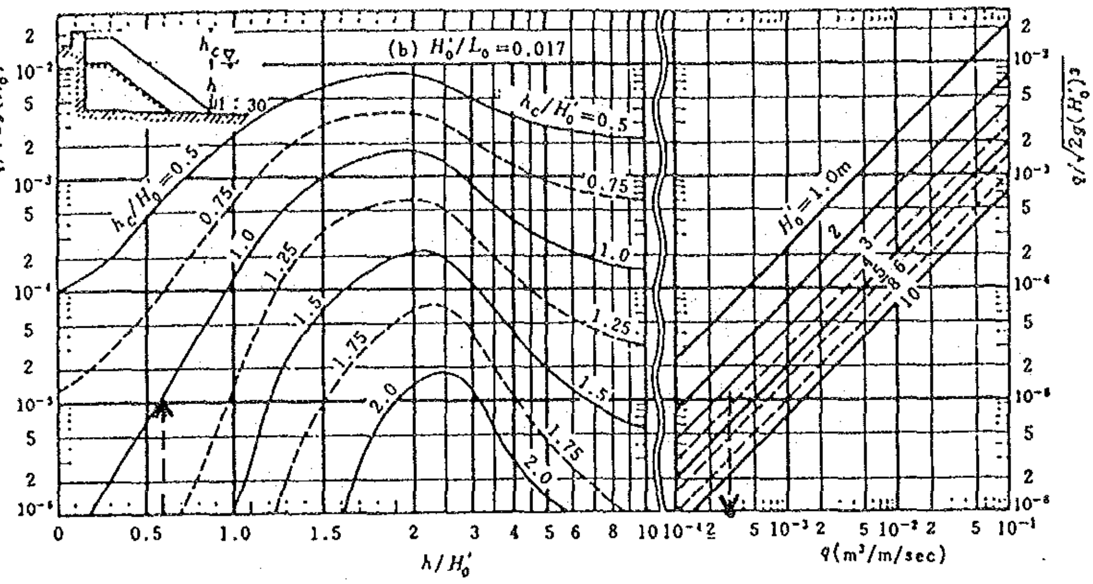
The volume of wave overtopping (q) is obtained from Figure 11.2.2.

q = 3 x 10^{-3} m^3/m/sec

This is considered to be below an allowable limit comparing with the guidance in Japan.

The actual slope of the seabed is 1/100 ~ 1/200, and the corresponding volume of wave overtopping, q_1 is much smaller. It is, however, recommended to raise a further 0.5 m as a freeboard considering the vital importance of the plant.

Finished Ground Level = HAT + 3.5 m + 0.5 m = HAT + 4.0 m



(source: Design Criteria for Coast Protection Works)

Figure 11.2.2 Estimation Chart for the Volume of Wave Overtopping at Wave Dissipation Revetment (S = 1/30)

(2) Run-up Height of Wave (refer to Figure 11.2.3)

The run-up height of wave (R) is estimated by using the following equation.

$$R/Ho' \fallingdotseq (52 \frac{Ho'}{Lo})^{-2.7}$$

(source: Manual for Planning and Design of Beach, Ministry of Communication, Japan)

Ho' = 3.7 m

Lo = 156 m

$$\therefore R \fallingdotseq (52 \frac{3.7}{156})^{-2.7} \times 3.7 = 2.1 \text{ m} < 4.0 \text{ m}$$

In case that wave dissipation revetment exists, the above R can be reduced to 70 ~ 80 %.

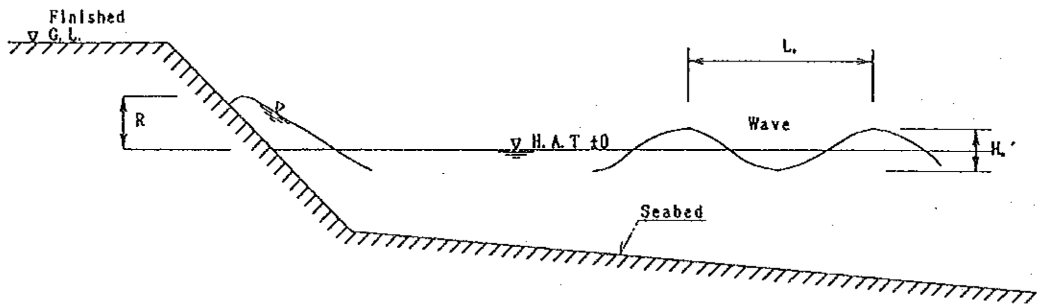


Figure 11.2.3 Run-up of Wave

From the above studies, the finished ground level of the site is determined as HAT + 4.0 m so that the plant can be operated safely and continuously. As a result, the present ground level will be raised about 2.2 ~ 4.0 m.

11.3 Layout of Plant Facilities and Housing Area

The layout of the plant facilities and housing area is shown in Figure 11.3.1.

The land area selected for the project is approximately 610,000 m^2 (610 x 1,000 m). However, the effective land area for the plant facilities is approximately 580,000 m^2 since the ground level is to be raised about 2.2 ~ 4.0 m as mentioned in Section 11.2. In addition, the following points were considered to make the layout plan.

(1) Principal Elements

Layout should consider ease of operations and maintenance, optimal economic routes for pipes and cables, restrictions imposed by the desalination plants, and operational and maintenance staff safety issues such as clearance from equipment. The main control room will be located in the center of the plant to facilitate centralized control. Equipment which requires protection from severe climatic conditions, such as substation equipment, shall be located away from the shore and enclose to minimize salt contamination.

(2) Fuel Stock Yard

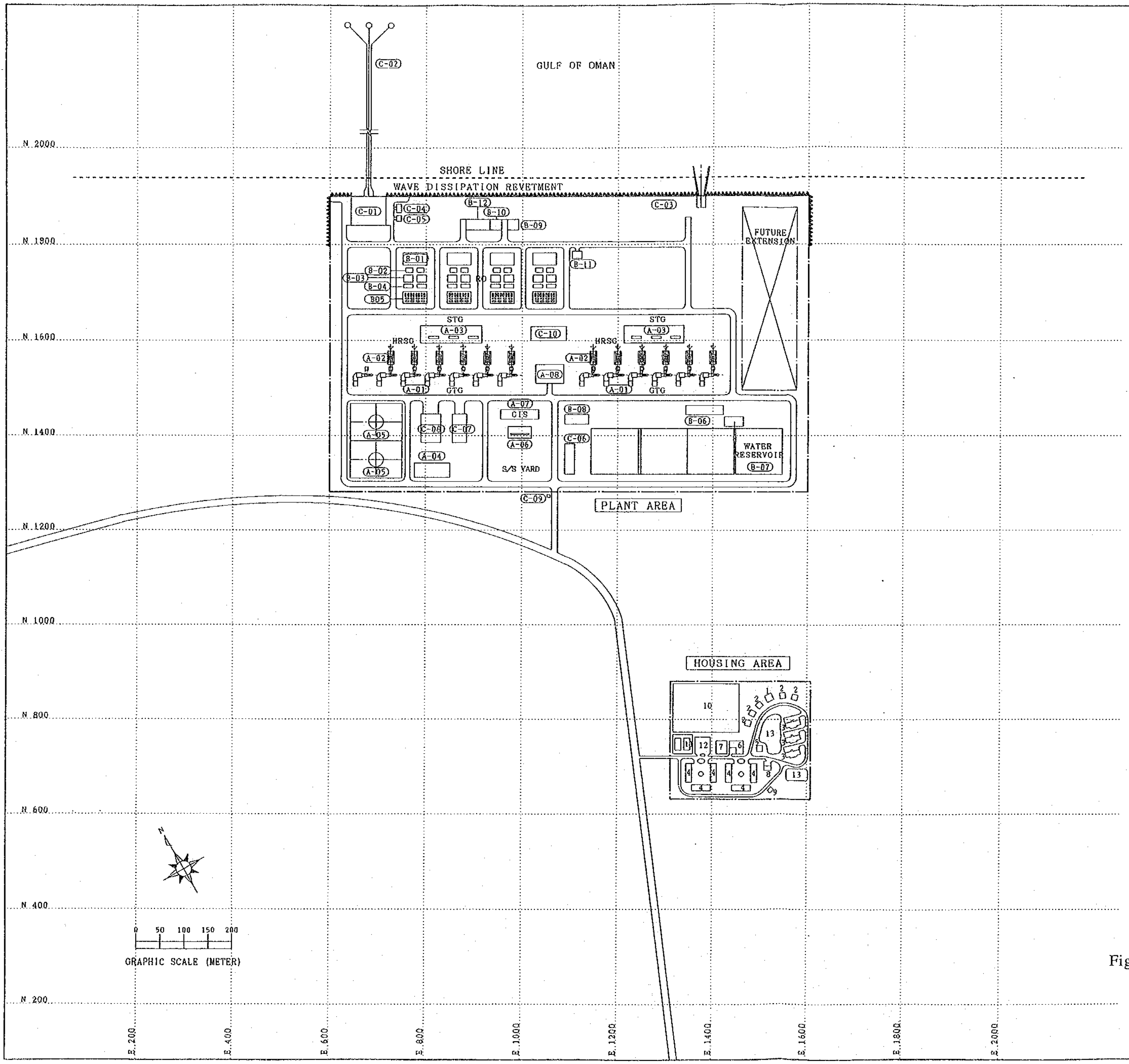
Natural gas is transferred via a pipeline. In designing the stock yard, it is therefore necessary to give consideration to the tank for the distillate oil used as emergency fuel. The tank should be located in a convenient position to accept distillate oil from the refinery and transfer it to the gas turbine.

(3) Water Intake and Outfall

Since the deep-water intake and the buoyant surface discharge are to be adopted as described in Section 11.5, it is considered that hot water re-circulation does not occur. It is, however, preferable to keep a sufficient distance between the intake head and the outfall so that no occurrence of hot water re-circulation is ensured.

(4) Space for Future Extension

The space for the future extension is to be arranged in the east of the site for the following reasons;



ITEM NO.	FACILITY	REMARKS
POWER PLANT		
A-01	GAS TURBINE GENERATOR (GTG)	
A-02	HEAT RECOVERY STEAM GENERATOR (HRSG)	
A-03	STEAM TURBINE GENERATOR (STG)	
A-04	FUEL GAS RECEIVING UNIT	
A-05	FUEL OIL TANK	
A-06	SENDING OUT FACILITY	
A-07	SWITCH GEAR ROOM (GIS)	
A-08	CENTRAL CONTROL BUILDING	
DESALINATION PLANT		
B-01	DUAL MEDIA FILTER	
B-02	BACK WASH TANK	
B-03	FILTERED WATER TANK	
B-04	CARTRIDGE FILTER	
B-05	HIGH PRESSURE PUMP	
B-06	PRODUCT WATER TREATMENT	
B-07	PRODUCT WATER RESERVOIR	
B-08	PRODUCT WATER PUMPING STATION	
B-09	DESAL CONTROL BUILDING	
B-10	DESAL CHEMICAL INJECT BUILDING	
B-11	DESAL SWITCH GEAR BUILDING	
B-12	CHEMICAL STORE HOUSE	
COMMON FACILITY		
C-01	SEA WATER INTAKE & PUMP PIT	
C-02	SEA WATER INTAKE PIPE LINE	
C-03	SEA WATER OUTFALL	
C-04	CHLORINATION BUILDING	
C-05	SEA WATER PUMP CONTROL ROOM	
C-06	ADMINISTRATION BUILDING	
C-07	STORE	
C-08	WORK SHOP	
C-09	GATE HOUSE	
C-10	UTILITY SPACE	

HOUSING AREA			
1	A-TYPE HOUSE	8	CLUB HOUSE
2	B-TYPE HOUSE	9	LAUNDY ROOM
3	C-TYPE HOUSE	10	SOCCER GROUND
4	D-TYPE HOUSE	11	TENNIS COURT
5	MOSQUE	12	PARKING AREA
6	MARKET	13	PLAY GROUND
7	CANTEEN		

Figure 11.3.1 Plant Layout

THE SULTANATE OF OMAN
MINISTRY OF ELECTRICITY AND WATER
BARKA POWER AND DESALINATION PLANT PROJECT

FIGURE 11.3.1 PLANT LAYOUT

1) In addition to the space for future expansion shown in Figure 11.3.1, further land outsite the site may be required for the future expansion. The land to the east of the site belongs to the Royal Family and it is considered easier to acquire it rather than acquisition of private land.

2) From the environmental point of view, it is not preferable to extend the plant to the west of the site since there is Haradi in this direction.

(5) Administration Building

The layout of the administration building shall ensure efficient administration of the power station. The building shall be located in a position near the main entrance to the power station.

(6) Housing Area

A good living environment is necessary in the housing area for the welfare of the residents, thus it is arranged outside the plant area.

Furthermore, the location of the housing area is considered adequate from the following points of view;

1) The prevailing wind blows in the south-west direction in Seeb area, while the housing area is located to the south-east of the plant area. Therefore, the influence due to the exhaust gas from the power plant is considered small.

2) The distance to the plant area is not too far even by walking.

11.4 Selection of Water Intake Facility

Three types of water intake facility were studied.

(1) Open channel type
(2) Buried pipeline type
(3) Jetty type

The general features of these types are summarized in Table 11.4.1, Figures 11.4.1, 11.4.2 and 11.4.3.

Table 11.4.1 Comparison of Water Intake Systems

	Open Channel	Buried Pipeline	Jetty
1.Occupied area	Large	Small	Middle
2.Water Intake	Sufficient depth and width at the mouth to be secured for avoiding an inflow of surface water	Possible to take clean and low-temperature water from a depth below a layer of discontinuity	Inflow of surface water and bottom deposit is unavoidable
3.Littoral transport of sand	Due to construction of a dike projecting to the seaside, the shoreline feature generally changes.	Since an intake head is constructed at the sea bed level, littoral transport of sand is negligible.	Since an intake pit is constructed in the sea, some influence due to littoral transport of sand is expected.
4.Wave	Breakwater in front of the end of the channel is required.	Influence to intake head is negligible.	Since intake structures directly receive wave forces, due consideration is required in the structural design.
5.Inflow of suspended solids (sand)	Sedimentation in the channel and pump pits generally occurs.	Since the inflow velocity is low (approx. 20cm/s), the inflow rate of SS is small.	Since the inflow velocity is relatively high, the inflow rate of SS is high.
6.Volume of intake water	Easy to accommodate a large volume of water	Easy to accommodate a large volume of water	Not adequate for a large volume of water
7.Environment a. Aquatic biota	Since the occupied area is large, impacts are relatively high.	Relatively minor impacts	Relatively minor impacts
b. Scenery	Due to a waterway dike projecting to the seaside, impacts are high.	Since all structures are constructed at the sea bed level, no impacts are expected.	Due to a jetty structure and an intake head projecting to the seaside, impacts are high.
8.Obstruction for boats	Not possible to pass along the shoreline	Possible to pass across pipelines laid in the sea.	Not possible to pass along the shoreline
9.Maintenance	Dredging for a channel is generally necessary.	Inspection by divers is necessary.	Proper protection and maintenance are necessary for preventing steel / concrete structures from corrosion, rusting and deterioration.
10.Construction	Turbidity of sea water is high during construction.	Turbidity of sea water is high during construction.	Turbidity of sea water is relatively low during construction.
11.Others	Jellyfish, oil balls, etc. can be removed only by mechanical equipment. If the amount is quite big, operation may be disrupted.	Inflow rate of jellyfish, oil balls, etc. is generally small. If they flow into the intake, they can be removed by mechanical equipment.	Jellyfish, oil balls, etc. can be removed only by mechanical equipment. If the amount is quite big, operation may be disrupted.

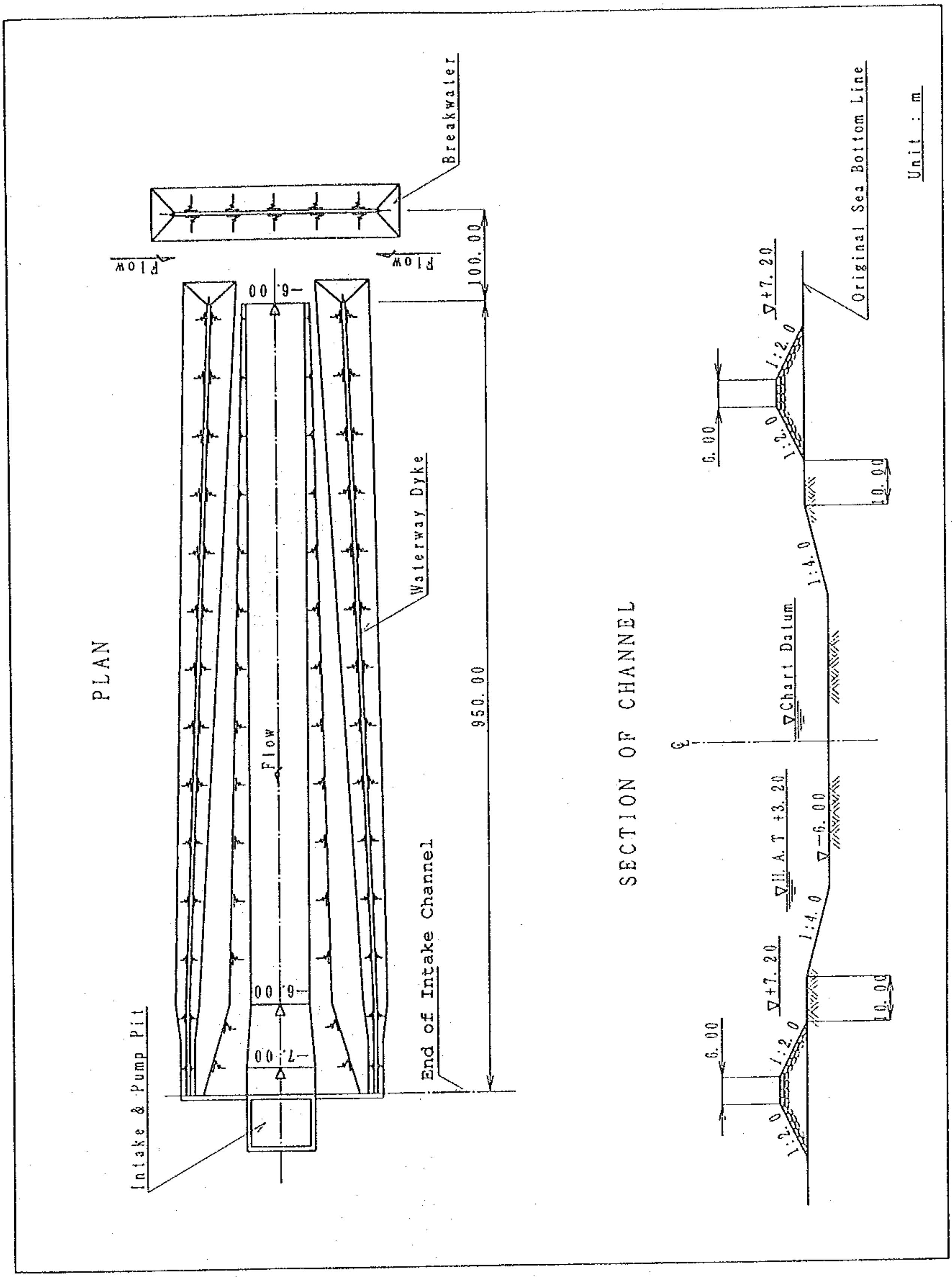


Figure 11.4.1 Sea Water Intake: Open Channel

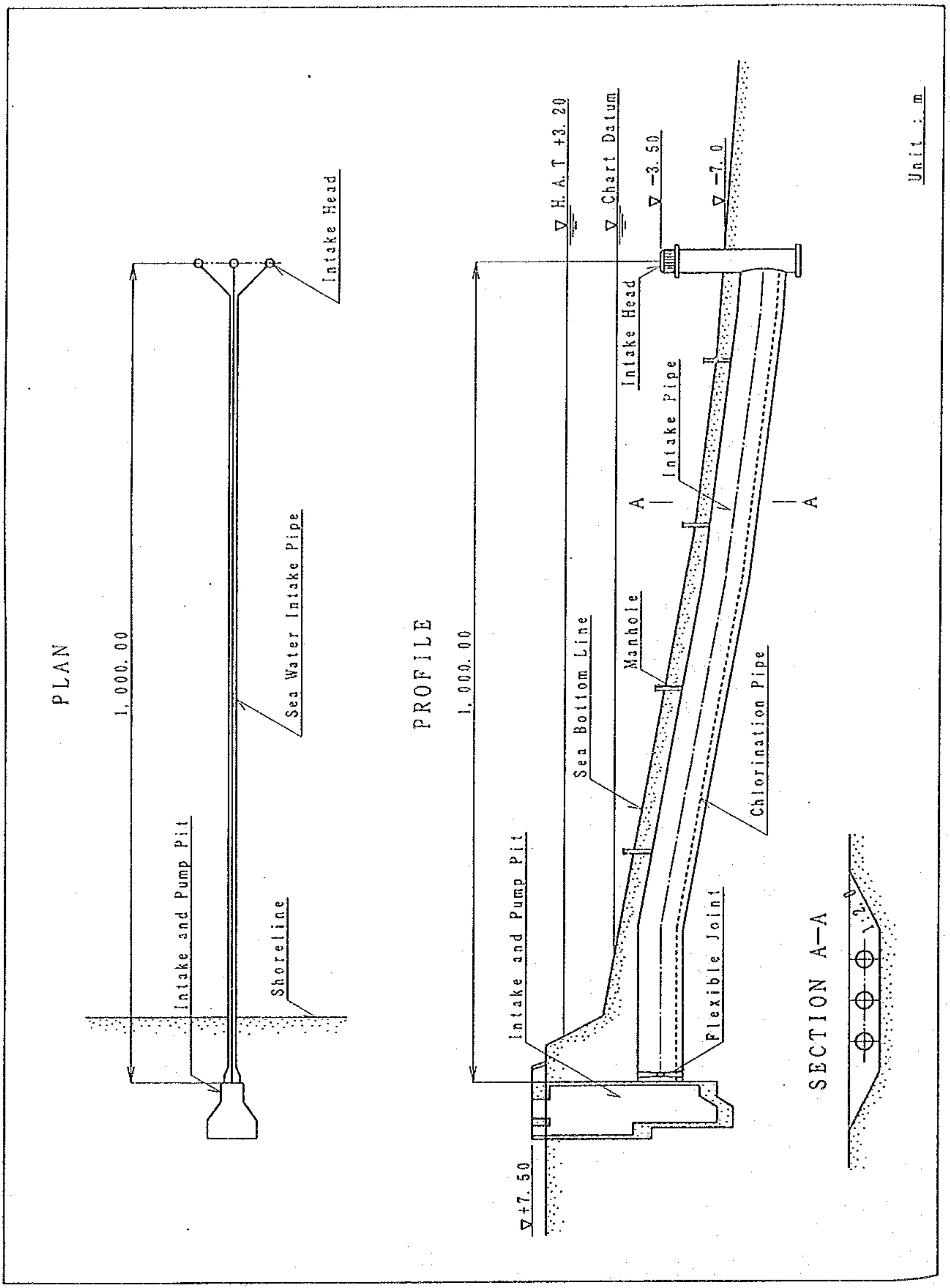


Figure 11.4.2 Sea Water Intake: Buried Pipeline

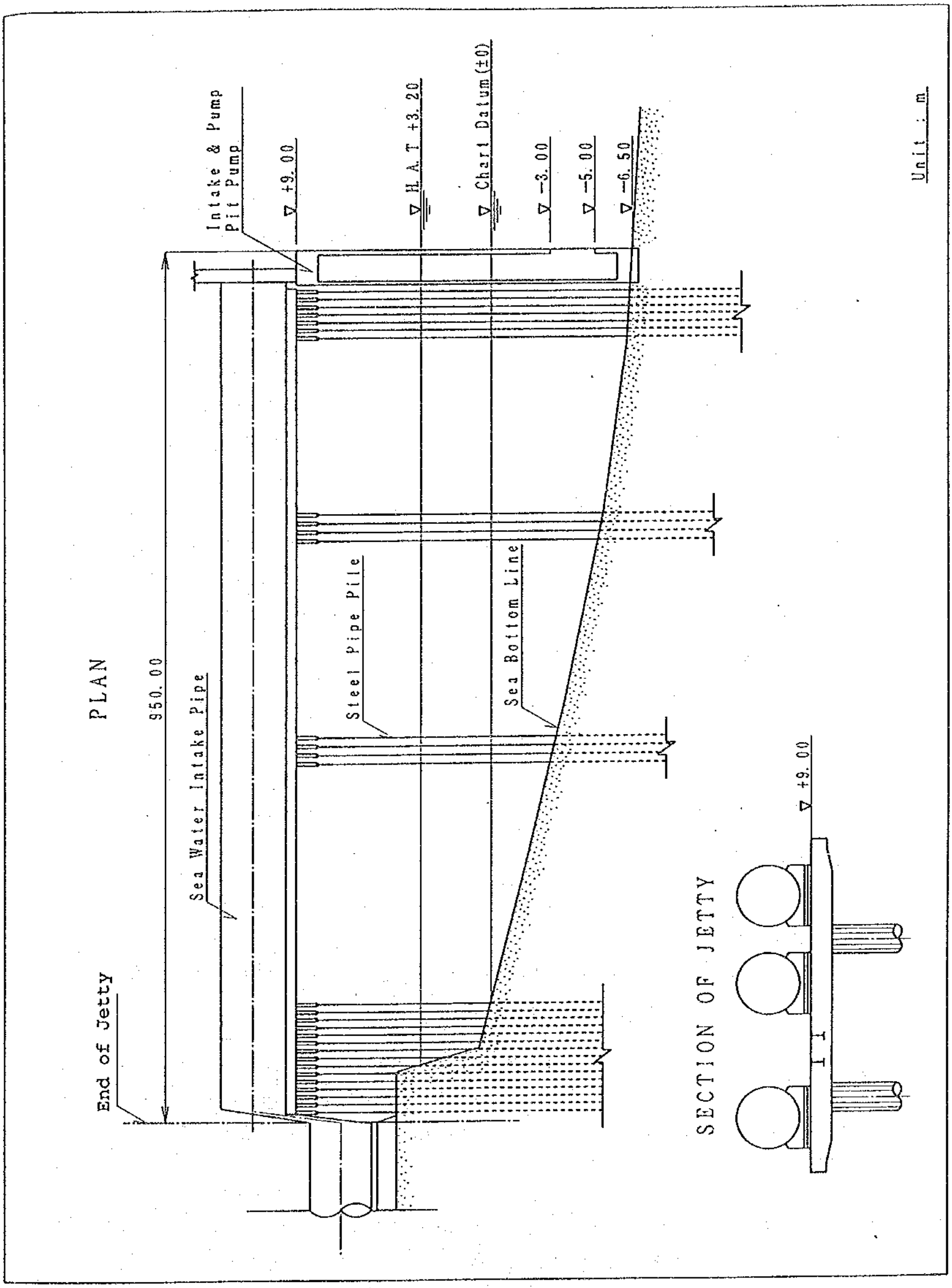


Figure 11.4.3 Sea Water Intake: Jetty

The jetty type was adopted for the water intake facilities of Phases 1 & 2 in Ghubrah Power and Desalination Plant (GPDP). However, the operation of the Phase 1 water intake facility has been stopped because of serious corrosion in the jetty structure (reinforced concrete) due to chloride. Although it is possible to take some countermeasures such as crack control and surface protection for preventing corrosion of reinforcement, it is, in fact, difficult and costly to undertake them properly. From such a background, the open channel type was selected in the Phase 3 construction of GPDP. We, therefore, intend to proceed, hereinafter, with the study on the open channel type and buried pipeline type only.

One of the important factors to be considered in the study is the fact that there is a possibility of oil leakage in the Gulf region due to an oil tanker accident. Generally speaking, oil leaked out to the sea drifts at the surface in the early stage, then sinks and floats repeatedly after forming oil balls. Once oil leakage occurs, there is the possibility of damage being caused to the intake facility, and, as a result, the supply of electricity and water could be stopped. This is a very serious consideration, since a lack of electricity and water causes considerable problems in social and economic activities. From this point of view, a comparison between open channel and buried pipeline types was made as shown in Table 11.4.2.

Both types are able to remove oil balls flowing into the intake pit by bar screens and traveling screens, provided that the amount of oil balls is small. The only way of preventing a large amount of oil from entering the intake is to minimize the possibility of inflow of oil into the intake pit. In this aspect, the buried pipeline type has an advantage.

The careful study is necessary for selecting the type of intake system from environmental points of view as well, which are studied in Table 11.4.1 by types of intake systems. It is apparent that the buried pipeline type will give less impacts to the environment than the other types.

The matter of construction and maintenance costs are also factors to be considered. However, advantage in environmented aspects takes precedence over costs considering that conservation of the environment is becoming more important in Oman as elsewhere in the world.

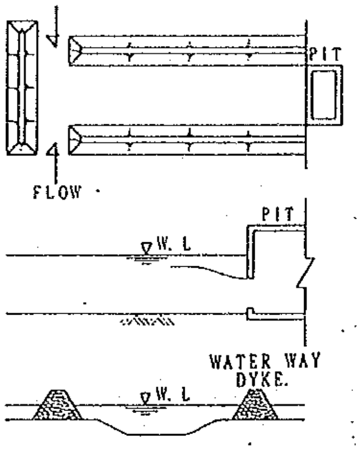
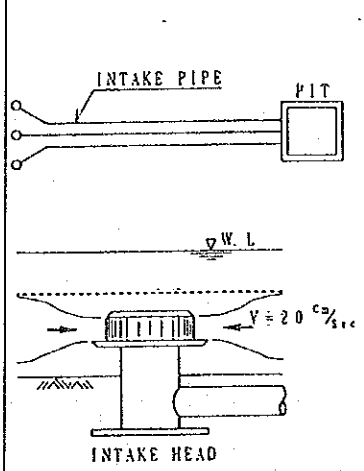
From the study herein, it is concluded that the water intake system with buried pipelines is to be adopted in the project. In order to ensure normal functioning, periodical monitoring and maintenance are of vital importance.

(1)	Measurement of head loss	:	every months
(2)	Measurement of volume and concentration of sodium hypochlolite	:	every week
(3)	Inspection of pipes and intake heads by divers for;	:	every 1 ~ 3 years

- coating
- chlorination pipe
- sedimentation
- attachment of aquatic biota
- buried conditions

(3)	Measurement of electric potential difference (inspection for cathodic protection)	:	every 3 years

Table 11.4.2 Comparison of Open Channel and Buried Pipeline Types

	Open Channel	Buried Pipeline
Outline		
Drifting of Oil at Sea Surface	Sea water with oil directly flows into the channel and oil adheres to the dyke. The intake facility may be damaged considerably. It is quite difficult to remove the oil adhered to the dyke.	Since it is possible to take water from the middle layer of sea as shown above, inflow of oil is very small.
Drifting of Oil at Middle Layer of Sea Water	Oil adheres to the dyke and in time percolates into the channel. A direct inflow of oil into the channel is relatively small.	Since the inflow velocity is almost same as the sea water current (max. 20 cm/s), inflow of oil may be small.
Drifting of Oil at Bottom Layer of Sea Water		Since it is possible to take water from the middle layer of sea as shown above, inflow of oil is very small.

11.5 Outlines of Civil and Architectural Facilities

11.5.1 Outlines of Major Plant Facilities

(1) Road

Width	:	8.0 m
Surface	:	Asphalt pavement

(2) Fence along the Site Boundary

2.0 m high chain-link fence with barbed wires at top.

(3) Seawater Intake Facilities (58 m^3/s)

Buried pipelines	:	∅3.4 m x 3 steel pipes with tar epoxy coating and cathodic protection
Intake and pump pit	:	Reinforced concrete

(4) Discharge Facilities

Discharge pit	:	Reinforced concrete
Discharge channel	:	Stone embankment and pitching

(5) Gas Turbine Generator Foundation (100 MW x 13 units)

Reinforced concrete with piles

(6) Steam Turbine Generator Foundation (100 MW x 6 units)

Reinforced concrete with piles

(7) Steam Turbine Generator Building (100 MW x 3 units x 2 buildings)

Foundation : Reinforced concrete with piles

Building : Steel structure with;

- roof : metal sandwitch board
- wall : metal sandwitch board + reinforced concrete frame and hollow block
- floor : reinforced concrete + grating

(8) Heat Recovery Steam Generator Foundation (12 units)

Reinforced concrete with piles

(9) Oil Tank Foundation (2 units)

Tank foundation	:	Reinforced concrete with piles
Oil dyke	:	Reinforced concrete

(10) Power Plant Control Building (2 stories)

Foundation	:	Reinforced concrete with piles
Superstructure	:	Reinforced concrete with hollow block wall

(11) Desalination Plant Unit Foundation (8 units)

Reinforced concrete with piles

(12) Water Reservoir (63,600 m^3 x 4 units)

Reinforced concrete

(13) Desalination Plant Control Building (single story)

Foundation	:	Reinforced concrete with piles
Superstructure	:	Reinforced concrete with hollow block wall

(14) Administration Building (2 stories)

Foundation	:	Reinforced concrete with piles
Superstructure	:	Reinforced concrete with hollow block wall

(15) Store/Workshop (single story)

Foundation	:	Reinforced concrete with piles
Superstructure	:	Reinforced concrete with hollow block wall

(16) Switch Gear (GIS) Room (single story)

Foundation	:	Reinforced concrete with piles
Superstructure	:	Reinforced concrete with hollow block wall

(17) Other Facilities

1) Water treatment facilities
2) Fire pump house and fire fighting system
3) Lightning protection

4) Chlorination building
5) Chemical dosing building

11.5.2 Outlines of Housing Facilities

The housing facilities are planned as shown on Figure 11.3.1, which requires an area of about 75,000 m^2. All buildings are of reinforced concrete with reinforced concrete footings and hollow block walls.

(1) House

In order to minimize the area required for housing, 2 or 3-story buildings are planned. This height seems the maximum considering harmony with the surrounding environment. The details of the houses are as follows;

1) A-type : 140 m^2/flat x 1
For the plant manager

2) B-type : 120 m^2/flat x 5
For the deputy plant managers and the department chiefs

3) C-type : 80 m^2/flat x 24------- 2 stories x 3 units
For staff with family

4) D-type : 20 m^2/flat x 324 ----- 3 stories x 6 units
For unattended staff including operating staff in the housing area

(2) Others

Roads have 6.0 m width and are paved with asphalt. In order to keep harmony with the surrounding environment, trees are to be planted. Hollow block wall 1.5 m high is to be provided along the boundary.

CHAPTER 12 OPERATION AND MAINTENANCE PLAN

CHAPTER 12 OPERATION AND MAINTENANCE PLAN

The purpose of this Chapter is to plan for the safe and economic operation and maintenance of the entire plant by setting up a control system and the items needed to operate and maintain the Barka Power and Desalination Plant and by putting in place the necessary management organizations and personnel.

12.1 Basic Plans for Operation and Maintenance

Operation and maintenance of the plant will be based on the system shown in Figure 12.1. The details of control items are described below. Similar operation and maintenance shall also be carried out at the desalination plant.

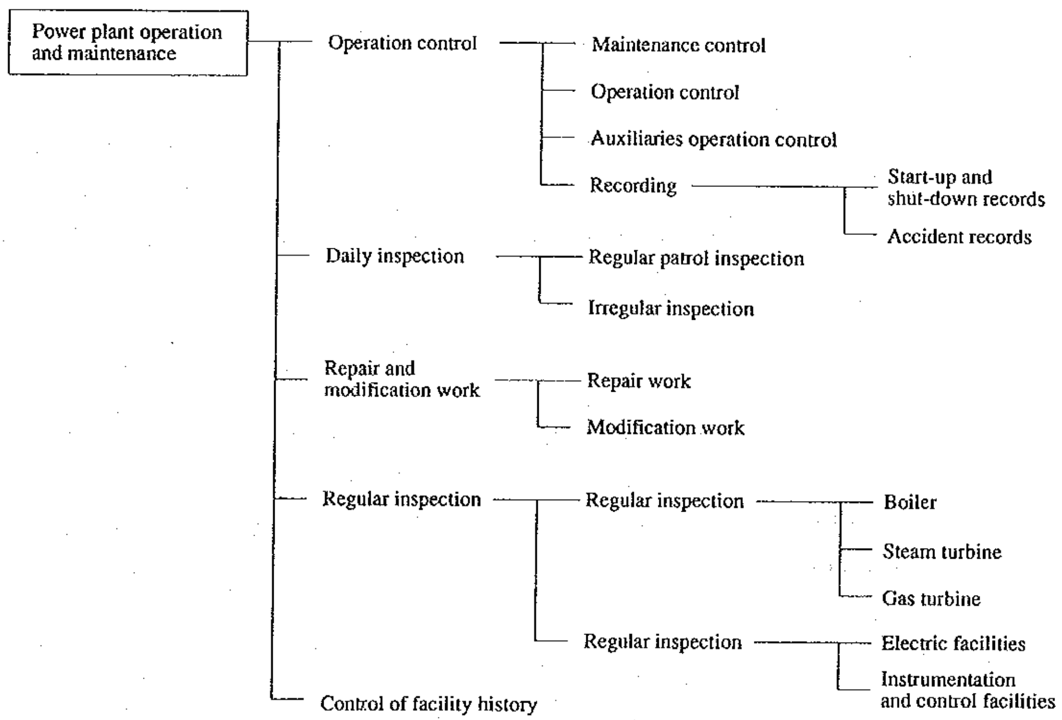


Figure 12.1 Power Plant Operation and Maintenance System

(1) Operation control

In operating the power plant, operation control shall be based on the operation control criteria prescribed prior to the commencement of operations.

1) Maintenance control

The safe operations of boilers, steam turbines and gas turbines shall be controlled. Secure records of important matters shall be kept.

2) Operation control

Appropriate operation control shall be conducted in accordance with the prescribed operating procedures prior to the commencement of operations. Records of principal operation shall be kept.

3) Operation control of auxiliaries

Operation control of principal auxiliaries for boilers, steam turbines and gas turbines shall be conducted. Records of operation control of auxiliaries shall be kept.

4) Operation records control

Records shall be kept on the plant's start up and shut down, accidents and other principal operations. These records shall serve as a reference during regular inspections, component replacement and facility modification works.

(2) Daily inspection

The status of operating equipment shall be regularly inspected, on a daily basis. If an abnormality is detected during the operation monitoring or operation patrol, an irregular inspection and maintenance shall be conducted.

1) Regular patrol inspection

The regular patrol inspection is an inspection conducted by cruising, based on the patrol inspection schedule set up for every day, every week and every month for boilers, steam turbines, gas turbines, electrical and instrumentation and control facilities. The objective of patrol inspections is to check the existence of abnormalities by watching, listening to and touching the equipment and recording the results of inspection.

If an abnormality is discovered, it must be classified by mode of detection, status, cause, repair details and countermeasures. Historical data shall then be recorded for use as basic maintenance data.

2) Irregular inspection and maintenance

Irregular inspection and maintenance refer to inspection and maintenance carried out when the inspection record is issued, as well as irregular inspections carried out when abnormalities, failures and accidents occur, after detection through operations monitoring or operations patrol. The results of irregular inspection and maintenance shall be kept as a record of control data. These records shall be used for reference in planning, including planning for daily inspections, regular inspections and repair and modification work.

(3) Repair and modification works

Repair and modification works refer to modification work to maintain functions necessitated by a facility abnormality or failure and repair work, including component replacements.

(4) Regular inspection

Figure 12.2 shows an example of the details of standard regular inspection. Where the law provides for regular inspection of boilers and turbines, inspection of these facilities shall be in accordance with the relevant regulations. Electrical and instrumentation and control facilities shall be inspected by the owner of the facilities. These facilities shall be inspected when the plant is shut down following regular inspection of boilers and turbines.

(5) Facility history control.

To ensure rational maintenance, a history of inspection of each facility and item of equipment, the existence of abnormalities, the exchange of components and the duration of operations and other matters shall be recorded.

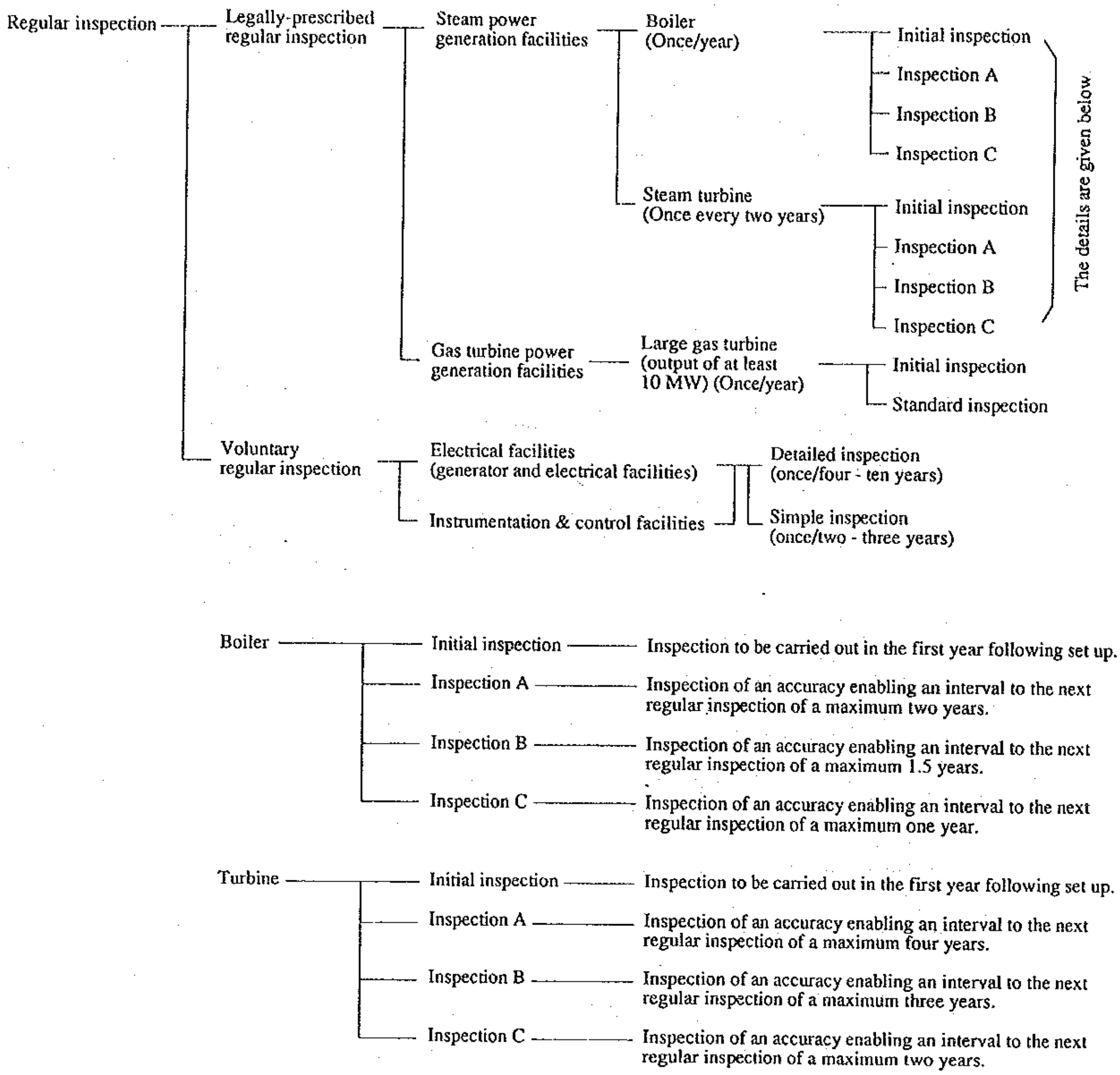


Figure 12.2 Types of Regular Inspections and Timing for Inspections

(6) Inventory control of equipment and components

Abnormalities, failure and end of useful life of facilities and equipment necessitate replacement of components, equipment and materials at regular annual inspections implemented. It is therefore necessary to constantly stock required quantities of spare parts and consumables. For this purpose, it is necessary to control the inventory of spare parts and consumables to respond to equipment maintenance control.

The power plant comprises many facilities, items of equipment and components. The plant includes boiler facilities, turbine facilities, electrical facilities and instrumentation and control facilities. Rational maintenance of these facilities and equipment can best be carried out using computerized inventory control. This requires the installation of a computer system in the project's implementation stage.

12.2 Management Organization and Assignment of Personnel

12.2.1. Management organization

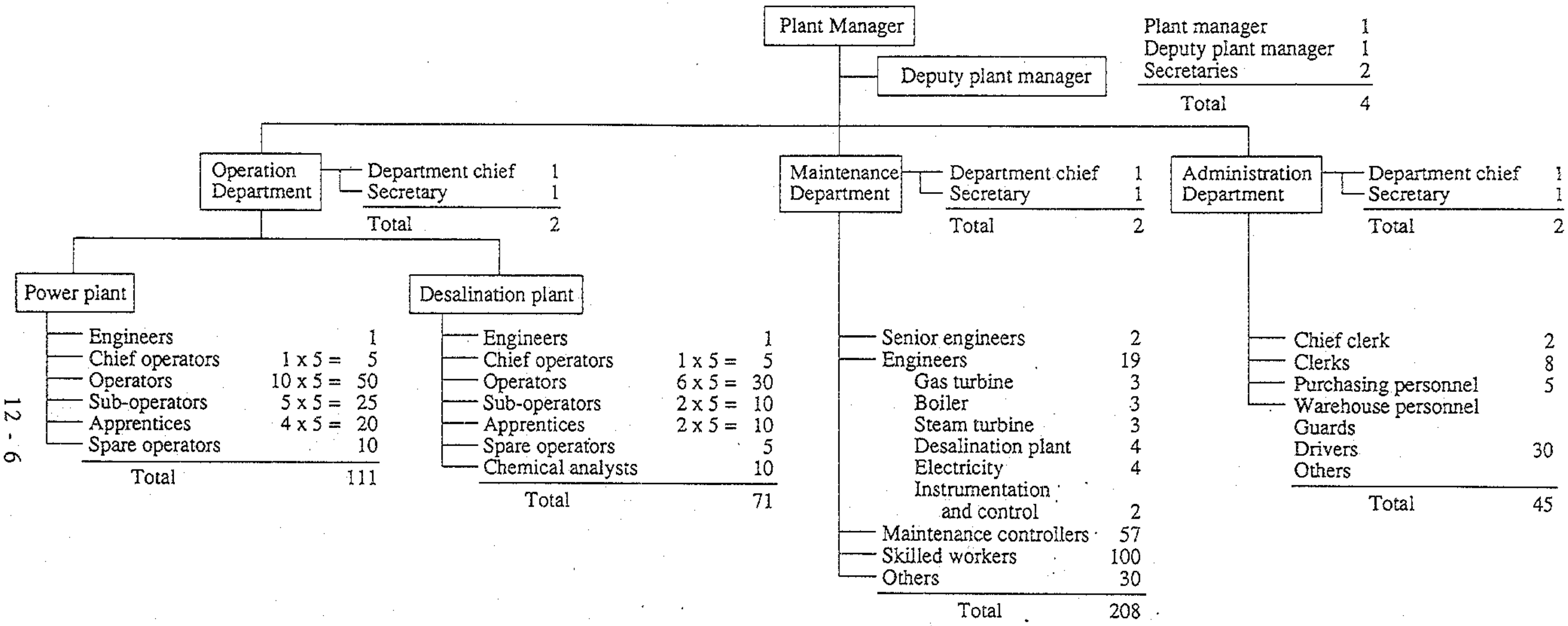
The effective and efficient operation, maintenance and control of the power and desalination plant demands a systematic management organization. It is also essential to build a rational organization by assigning appropriate personnel, and clarifying the scope of tasks, responsibilities, authority and duties, while establishing a chain of command within the management organization. In building such an organization, it is necessary to organically link the operations and maintenance functions with the control function. Figure 12.3 provides an example of a management organization set up with this objective.

The plant manager is at the pinnacle of the management organization. The operation, maintenance and administration departments are set up under the plant manager. Each department is headed by one department chief. The operations of each department are conducted under the direct control of these responsible personnel. The operation department is further classified into power plant and desalination plant operations divisions. Personnel are split into a four-shift system over a 24 hour period. It is therefore necessary to form five teams for each plant.

The total number of staff required at the plant will be 445. This total does not include personnel involved in miscellaneous daily tasks or personnel required for repair and modification works.

12.2.2 Personnel job assignments

The tasks of principal personnel, who form the core of the operations and maintenance of the power and desalination plant, are as follows.



Required personnel	
Plant Manager and Deputy Plant Manager Office	4
Operation Department	184
Maintenance Department	210
Administration Department	47
Total	445

Figure 12.3 Example of Management Organization and the Number of Required Personnel

(1) Plant Manager

The plant manager is the senior person at the plant site with responsibility for the safe and economical operation of the power and desalination plant.

(2) Deputy Plant Manager

One deputy plant manager is assigned to assist and act on behalf of the plant manager in his absence.

(3) Operation Department Chief

The operation department chief is responsible for the control of the overall operation of the entire power and desalination plant. Responsible for the safe and economical operation of the entire plant, the operation department chief must understand the basic theory and functions of the devices, equipment and systems of the plant.

(4) Operation Engineer

The operation engineers are directly engaged in the actual operations and also assist the operation department chief. Operation engineers must understand the structure and application of plant equipment, facilities and systems for which they are responsible. They must instruct chief operators to ensure safe and efficient functioning.

(5) Chief Operators

Chief operators guide operators who work on their shifts. They also operate and monitor particular plant, and regularly record monitoring and operational data. Chief operators must fully understand the structure and functions of equipment and systems.

(6) Maintenance Department Chief

The maintenance department chief is responsible for supervising maintenance of the entire power and desalination plant. The chief must understand the structure and functions of each item of plant equipment, each facility and all systems. The chief is responsible for producing basic policies regarding regular inspections, repair work and modifications, plans for daily inspections and maintenance, and corrective action procedures for accidents or failures. The maintenance department chief must ensure safe operations and maintenance in the plant.

(7) Maintenance Senior Engineer and Maintenance Engineer

The maintenance senior engineer must assist the maintenance department chief by responsibly carrying out plant maintenance. Maintenance engineers are assigned to operate one of the following facilities:

1) Gas turbine facilities
2) Steam turbine facilities
3) Boiler facilities
4) Desalination facilities
5) Electrical facilities
6) Instrumentation and control facilities

Each maintenance engineer shall provide direct guidance to maintenance personnel in that area, under the guidance of the maintenance senior engineer. Maintenance engineers must undertake daily maintenance operations and repairs after accidents or failure. These engineers must fully understand the structure and function of equipment and systems, and have extensive experience with equipment repair, disassembly and assembly.

(8) Chemical Analysts

Chemical analysts principally conduct regular chemical analysis on boiler make-up water, feed water and drum water, and on water produced by the desalination plant to ensure safe operations of the plant.

(9) Administration Department Chief

Apart from supervising personnel directly involved in plant operations, the administration department chief is responsible for controlling and guiding personnel from general affairs, procurement, warehousing, and other ancillary personnel such as guards and drivers. The administration department chief instructs the chief clerk to perform daily operations.

12.2.3 Personnel qualifications and experience

Regulations in Oman for qualifications required for the personnel involved in the operations and maintenance of the power and desalination plant are not known.

Therefore, the educational level and number of years of experience required for the personnel are given below for reference.

(1) Plant Manager's Office

	Education	Minimum job experience
1) Plant Manager	University graduate	20 years
2) Deputy Plant Manager	University graduate	15 years
3) Secretary	High school graduate	3 years

(2) Operation Department

	Education	Minimum job experience
1) Operation Department Chief	University graduate	15 years
2) Operation Engineer	University graduate	10 years
3) Chief Operator	High school graduate	5-10 years
4) Operator	High school graduate	2-3 years
5) Chemical analyst	High school graduate	3 years

(3) Maintenance Department

	Education	Minimum job experience
1) Maintenance Department Chief	University graduate	15 years
2) Maintenance Senior Engineer	University graduate	10 years
3) Maintenance Engineer	High school graduate	5-10 years
4) Maintenance Controller	High school graduate	3-5 years
5) Skilled maintenance personnel	High school graduate	1-3 years

(4) Administration Department

	Education	Minimum job experience
1) Administration Department Chief	University graduate	5 years
2) Chief Clerk	High school graduate	5 years
3) Clerk	High school graduate	2-3 years
4) Warehouse Controller	High school graduate	3 years
5) Guards, drivers, etc.	--	--

12.2.4 Personnel employment plan

The personnel employment plan considers the plant's staged completion timing and training schedules. The plant manager, deputy plant manager, operation department chief, operation engineer, maintenance department chief and maintenance senior engineer form the core plant personnel. These staff shall commence project participation about 12 months prior to starting of No. 1 unit commissioning. All these personnel should increase their understanding of the plant through involvement in a series of project stages, including plant design, manufacturing, factory tests, construction, personnel training and commissioning. Other staff for each unit, including chief operators, operators, maintenance engineers and maintenance controllers shall be trained and added about six months prior to the commencement of each unit's commissioning, depending on the unit's operational and maintenance requirements.

The administration department chief and other core personnel should be appointed one month prior to commencing No. 1 unit commissioning. All the required staff should be recruited before completion of the final unit.

It is recommended that personnel should be involved in the operations and maintenance of existing facilities such as Rusail Power Plant and Ghuburah Power and Desalination Plant. This will ensure smooth commencement of plant operations and maintenance, and effective and continuous plant operation during the subsequent period. Personnel with accumulated knowledge, experience and expertise should be transferred to the Barka Power and Desalination Plant.

12.2.5 Training plans

Training plans will target the MEW-employed operation engineers, chief operators, operators, senior maintenance engineers, maintenance engineers and maintenance controllers. Training and instruction will begin in concert with plant commissioning, about six months prior to commencing No. 1 unit commissioning. The guarantee engineers will supervise education and training during the period between the commencement of No. 1 unit commercial operations and expiration of the final unit guarantee period.

While the education and training curriculum will vary depending on the equipment that person will be responsible for, the facility type, job type and existing qualifications, most programs will include the following items:

(1) Basic technical lectures for each facility

(2) Lectures on equipment specifications, functions, construction, systems, etc.

(3) Lectures on operating and handling procedures for individual equipment

(4) Lectures on maintenance and inspection procedures for individual equipment

(5) On the job training at the manufacturer's factory as required

(6) Training at existing plants

(7) Training at the new plant

(8) Safety procedure lectures and practice sessions

(9) Follow up operating and maintenance activities provided by guarantee engineers

Education and training should have a practical focus, incorporating plant models, photos, color slides and videos, in addition to instruction manuals, documents and drawings which will be transferred at the time of plant completion.

CHAPTER 13 ENVIRONMENTAL STUDY

CHAPTER 13 ENVIRONMENTAL STUDY

13.1 Site Investigation

The investigation was carried out by the following methods.

(1) Site reconnaissance

(2) Examination of the existing data

(3) Interviews with the relevant organizations and local residents

The environmental conditions are summarized in Tables 13.1.1 and 13.1.2.

Table 13.1.1 Social Conditions of the Project Area

Item	Description	Source
Land Use (Land Ownership)	Land of the Royal Family and not used at present	MEW, MH, S
Water Use (Marine)	Fishing/Recreation	S, DCM(1), R
Economic Activity around the area	The major activities are fishing and the planting of date palm. The fishing is carried out in the area around the islands which are located about 15 km off-shore. The palnting of data palm is observed to the south of the project site and the surroundings.	S, R, DCM(1)
Property Rights/Local Customs	It seems that there are no property rights applied in the vicinity of the site (fishery rights, water rights, etc.). Final confirmation needs to be taken from the relevant organizations before the implementation of the project. The coastal area including the site is designated as "Coastal Reserve Area". For any development work in this area, approval from the relevant organizations such as MRME, MH etc. is needed	S, DCM(1), MAF, MH, MRME, MNHC MCI
Local Residence Population	There are no residents in the project site. There are several towns and villages within 5 km of the site. Barka is the largest town among them and its population in 1993 was 61,164. The others are much smaller than Barka and their populations are estimated as 1,000~2,000.	S
Public Health	The facilities for drinking water supply (piped supply) and waste water treatment were not observed.	S
Transportation	The national road, Route 1, runs in the east-west direction at approx. 3.7 km southward from the project site. There is a secondary road, nearby the site, which is a branch of Route 1 and leads to Barka.	S
Public Facilities	There are no facilities in the project site.	S
Pollution Complaints	None	S
Others	- The site is located about 60 km westward from Muscat. - There are no reports indicating the existence of cultural heritage.	MNHC

R : Residents S : Site Reconnaissance

DCM : Document/Book/Map

DCM(1) : Coastal Zone Management Plan - Greater Capital Area

Table 13.1.2 Natural Conditions of the Project Area

Item	Description	Source
Weather	The rainy season is generally from November to April and the annual rainfall is approx. 100 mm around the proposed site. The maximum humidity and ambient temperature in summer (June ~ August) is more than 90 % and 45°C respectively.	DCM(1)
Natural Disasters	There are records of 10 cyclones which caused some damage to the coastal area of Oman in the years from 1963 to 1993. According to the records, no cyclones have intruded the area around the site, and the courses of cyclones generally pass in the area between Masirah Island and India.	MC
Air Condition	There is no source of air pollution around the proposed site.	S
Landscape (Typical Shapes)	The proposed site is generally flat and with quite gentle undulations.	S
Soil Condition (Soil Contamination)	There is a sandy layer at the surface and the firm strata with SPT-value ≧ 50 are distributed at 5.0~11.0 m below the ground surface. The soils and underground water contain both sulphate and chloride.	S
Rivers	There is a small "wadi" about 200 m westward from the site.	S
Sea Data (Temperature, Currents)	The slope of the sea bed is gentle (1/100~1/200) and the water depth is about 7.0 m from CD at the location about 1 km offshore. The sea water temperature in December, 1993 was about 26°C. It is estimated to be about 30°C at the surface in the summer. The current velocity is estimated as 0.2 m/sec. or lower according to the measurement at Ghubrah by MEW.	DCM(2) S
Ground Water (Water Level, Uses)	The ground water table in the site was about GL-3 m (December, 1993). In Hayyasim, the ground water (saline water) is pumped up for the irrigation of plantation, but not used for drinking.	S
Vegetation	There are several kinds of trees, shrubs and other plants in and around the site.	S
Animals, Birds	There are traces of activities by some animals. Some goats and camels were seen in and around the site. Birds such as crows, sea gulls, etc. were also seen.	S
Aquatic Biota	Activities by pagurians, crabs, lugworms, etc. were observed. There are no coral reefs, breeding colonies of marine turtles or mangroves around the proposed site.	S, R, MRME
Endangered Species/Fragile Nature	No endangered species of fauna and flora exist around the site. Generally speaking, the endangered species are distributed in the mountainous area.	MRME, QU, S

DCM(1) : Statistical Year Book, 1992
DCM(2) : Hydraulic Study for the Sea-Water Intake Ghubrah Power and Desalination Plant Extension Phase III

13.2 Predictions for Hot Water Diffusion and Exhaust Gas Dispersion

Among the various items which are anticipated to give some impact to the natural and social environment, the matters of hot water diffusion and exhaust gas dispersion are to be numerically analyzed. The detailed analyses for them require various kinds of meteorological or marine data as described in Sections 13.2.1 and 13.2.2, however, some data is not available in Oman. Therefore, the analyses in this F/S were carried out by using simplified methods and the results were evaluated referring to the standards in Oman.

13.2.1 Prediction of Hot Water Diffusion

(1) The analysis of hot water diffusion was carried out under the following conditions.

1) Discharged hot water

Volume	:	$Q = 55\ m^3/s$
Temperature rise	:	$\Delta T = 6.4\ °C$
Density	:	$pd = 1.024\ t/m^3$

2) Ambient seawater

Temperature	:	$Te = 30\ °C$
Density	:	$pe = 1.025\ t/m^3$

3) Marine conditions

① Case 1 : Stationary and unbounded

② Case 2 : Current of 0.2 m/s parallel to the shoreline

4) Other assumptions

① Case 1 : No heat radiation and diffusion take place until the discharged hot water reaches 200 m offshore from the outfall exit. The depth of water subject to the diffusion is 1.5 m.

② Case 2 : Dimensions of the outfall are 20.0 m wide x 1.5 m deep.

5) Model of analysis

① Case 1 : Hirano's formula

② Case 2 : CORMIX model which is released by EPA

(2) Results of Analysis

Figures 13.2.1 and 13.2.2 show the results of the analyses. The computer outputs are exhibited in Appendix 13.1.

According to the results, the diffusion area corresponding to a 1 °C rise is estimated as follows:

Case 1 : approx. 1.5 km offshore from the outfall
Case 2 : approx. 2.6 km downstream from the outfall

The results do not satisfy the standard in Oman which specifies that the temperature rise shall not exceed 1 °C beyond a 300 m radius. This standard seems very strict. For instance, the matter of temperature rise in Japan is evaluated by project from overall points of view considering compensation, an environmental impact, site conditions and so forth, and the standard in Taiwan specifies that the temperature rise shall not exceed 4 °C beyond a 500 m radius.

On the other hand, since the diffusion area varies depending on several factors such as a discharge volume, current and so forth, it is not adequate to assess the impact to the marine environment based on the above results. It is, therefore, necessary to assess the impact by undertaking a numerical simulation or a model test in the detailed design stage after obtaining more data as listed below.

- Vertical distribution and seasonal change of seawater temperature
- Current
- Geographical features of seabed
- Diffusion coefficient
- Meteorological data such as wind speed, ambient temperature, humidity, cloud cover, solar radiation and so forth

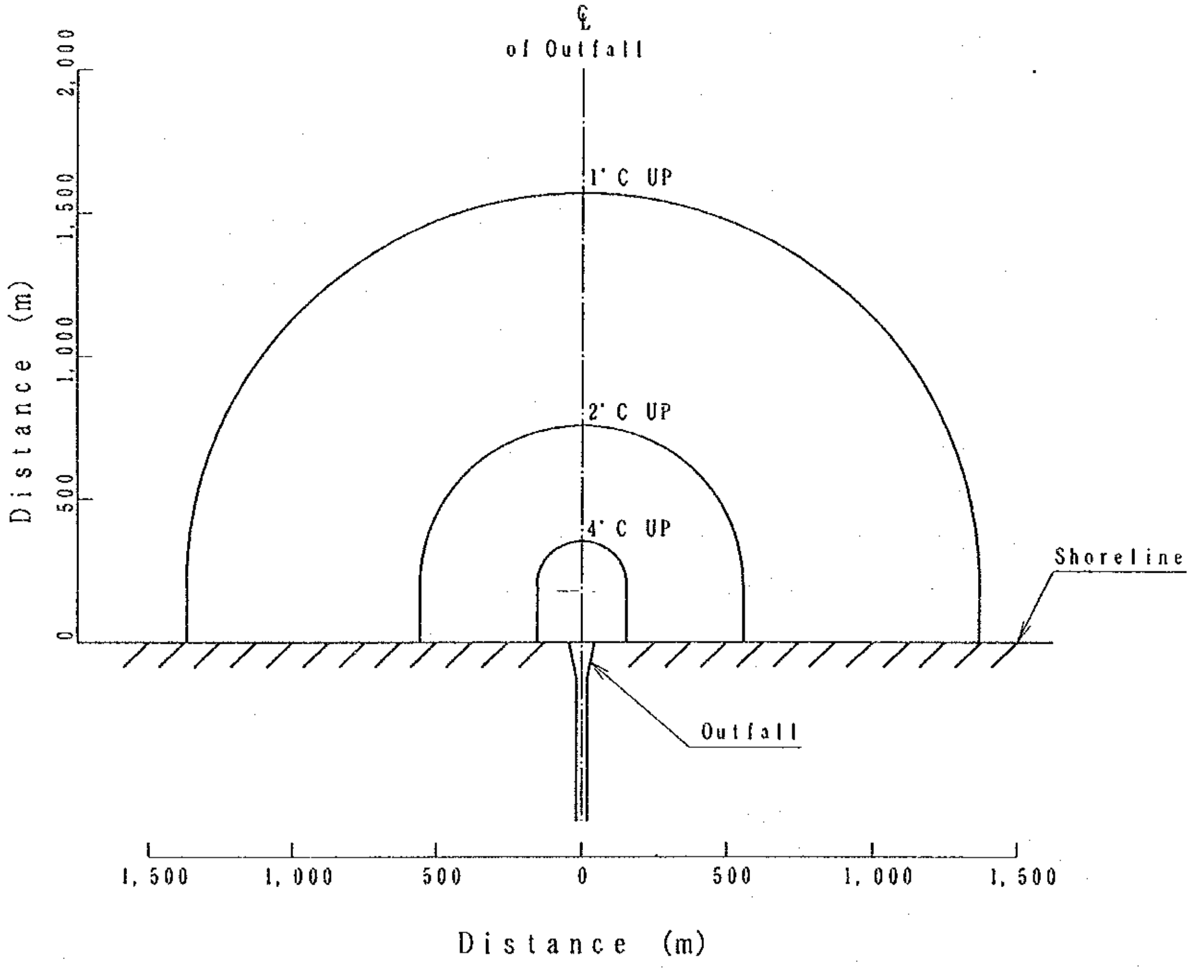


Figure 13.2.1 Hot Water Diffusion (Case-1)

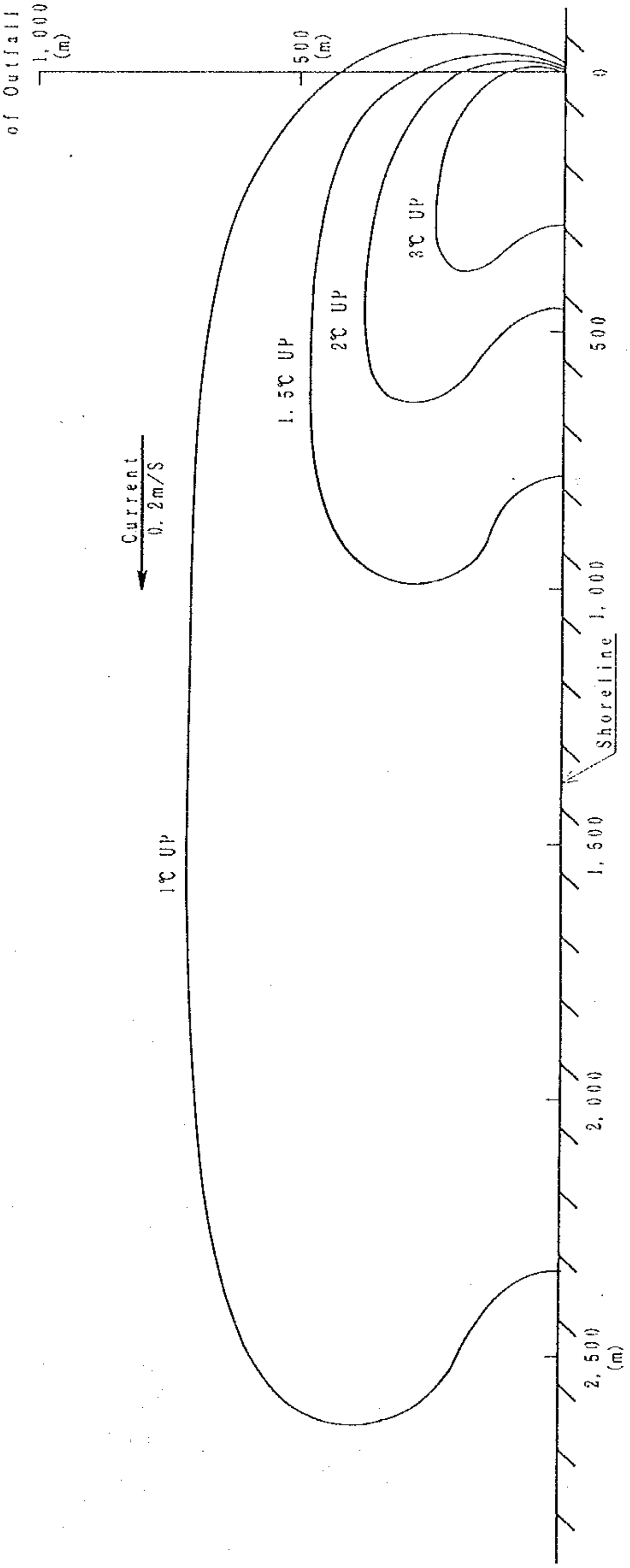


Figure 13.2.2 Hot Water Diffusion (Case-2)

13.2.2 Prediction of Exhaust Gas Dispersion

(1) Pollutants in Exhaust Gas

Representative pollutants causing air pollution in the project are SOx and NOx. SOx is generated by combustion of distilled oil during an emergency. NOx consists of "fuel NOx" caused by nitrogen in the fuel and "thermal NOx" caused by oxidization of nitrogen in the air. The analyses for dispersion of SOx and NOx were carried out assuming that a gas turbine generator with a unit capacity of 100 MW (combined cycle) is operated.

(2) Exhaust Gas Conditions

The exhaust gas conditions are assumed as shown in Table 13.2.1 and Appendix 13.2.

Table 13.2.1 Exhaust Gas Conditions

	SOx (Distillated Oil)	NOx (Natural Gas)
Flue Gas Volume (Nm^3/s)	280	280
Pollutant Emission Rate (Nm^3/s)	0.0225	0.028
(g/Nm^3)	0.229	0.2
Flue Gas Temperature (°C)	90 (Note)	90 (Note)

Note: Flue gas temperature at HRSG end.

(3) Equation of Analysis

The plume and puff equations are used for the analyses under wind and no-wind conditions respectively. In general, the analysis of dispersion is to be undertaken to obtain an average concentration in a year considering hourly combination of wind speed, wind direction, stability of ambient air, etc. and a frequency of occurrence for each combination. However, this report introduces a simplified method to predict a higher concentration in a short period of time since some meteorological data is not available at present. The assumptions and method of calculation are shown in Appendix 13.3.

In the analysis under wind conditions, the prevailing wind speed is assumed as 2.6 m/s which is obtained from the data at Seeb as indicated in Table 13.2.2 and Figure 13.2.3.

(4) Results of Analysis

The results of the analysis are exhibited in Appendix 13.3 and summarized in Tables 13.2.3 ~ 13.2.4.

1) Emission rate

The emission rate of SOx exceeds the standard in Oman (80 $\mu g/m^3$). It seems, however, that this does not create a serious impact to the environment since SOx is generated during an emergency only. The emission rate of NOx is almost equal to or lower than the standard (refer to Table 13.2.5).

2) Ground level concentration

Since the environmental quality standards are still under preparation in Oman, the results were examined comparing with the Japanese standards. SOx and NOx concentrations under the no-wind condition exceed the standards, while both under the wind condition satisfy the standards. Considering the fact that the frequency of occurrence for the no-wind condition is quite small, it is estimated that a high concentration as calculated may not occur as a long-range average.

In the detailed design stage, it is necessary to undertake a study taking into consideration the following factors.

- Hourly data such as wind speed, wind direction, solar radiation, cloud cover, cloud height and ambient temperature
- Lid height during the daytime and night
- Stack height, location and number
- Configurations of plant facilities
- Topographical features

3) Stack height

Since natural gas or distillated oil (during an emergency) is used for the operation, it is considered that a stack height of 50 m is sufficient.

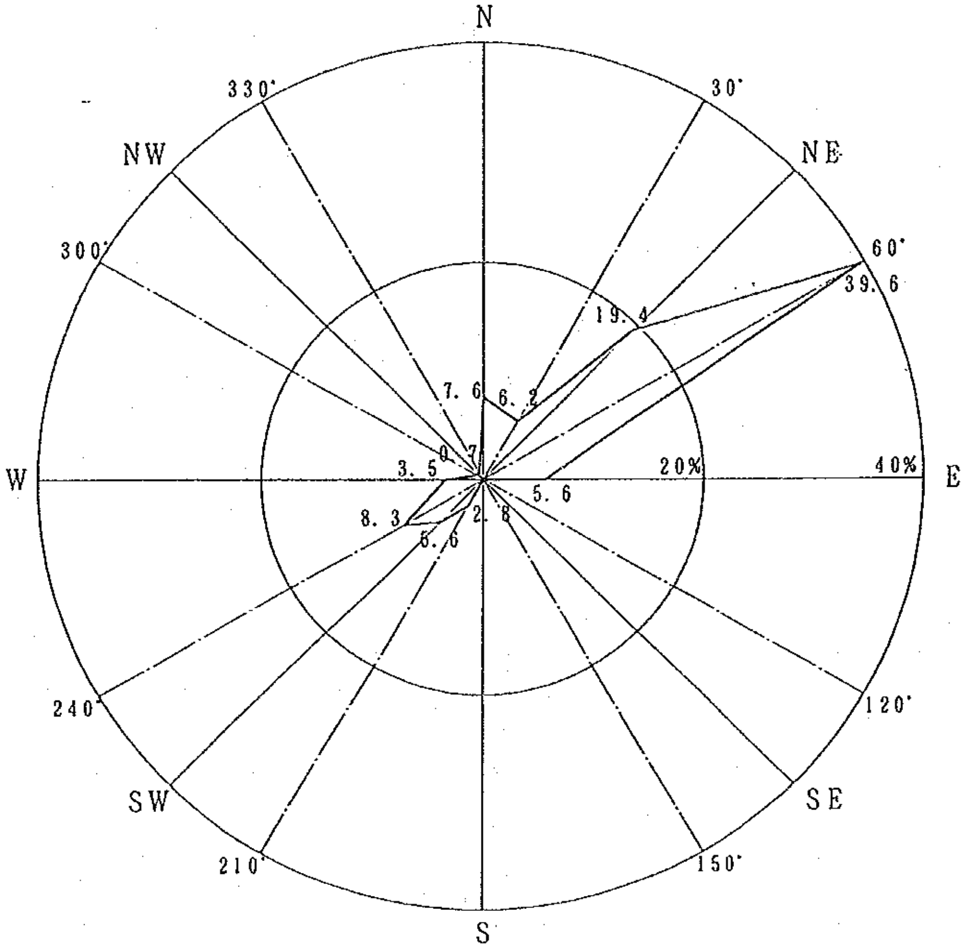
Table 13.2.2 Mean Wind Speed at Seeb

Sultanate of Oman
Ministry of Communications
Directorate General of Civil Aviation & Meteorology
Department of Meteorology

Station : Seeb
Parameter : Surface wind * prevailing direction with mean speed [knots]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1980	225	045	045	225	360	045	045	045	045	045	045	225	
	05	10	10	09	10	09	10	11	09	09	12	05	
1981	225	045	360	045	045	360	045	045	045	045	360	045	
	05	10	09	10	09	09	09	11	09	11	10	11	
1982	225	270	360	360	360	045	045	045	045	045	045	225	
	08	09	09	09	09	10	11	10	08	09	10	05	
1983	225	270	045	360	225	045	045	045	045	360	045	360	
	06	08	10	09	12	08	08	10	07	08	07	07	
1984	240	060	060	240	060	030	060	060	060	030	060	060	
	05	05	05	05	06	04	05	05	06	04	04	05	05
1985	060	240	240	270	060	060	060	060	060	060	240	240	
	04	05	05	06	05	05	05	05	05	05	05	05	05
1986	210	060	060	060	060	060	060	060	060	240	060	060	
	05	06	06	05	07	05	06	05	05	05	05	06	06
1987	210	060	060	330	060	060	060	060	060	030	030	030	
	04	05	05	04	06	05	06	05	05	04	04	04	05
1988	210	240	060	060	060	060	060	060	060	360	060	210	
	05	06	06	05	05	06	06	05	05	04	04	04	05
1989	240	030	060	060	060	030	060	030	090	270	060	300	
	05	05	05	05	05	04	06	04	04	05	04	05	05
1990	240	240	090	090	090	090	090	090	090	060	030	060	
	04	05	05	05	04	06	06	05	04	04	04	04	05
1991	060	060	060	270	060	060	060	060	060	060	060	240	
	05	05	05	05	04	05	05	05	04	04	04	04	

WIND DIRECTION (1980~1991)



WIND MEAN SPEED (1980~1991)

min 4 knots max 12 knots

knots	4	5	6	7	8	9	10	11	12
%	18.7	38.2	12.5	2.8	4.2	10.4	8.3	3.5	1.4

Figure 13.2.3 Wind Rose

Table 13.2.3 Prediction for Dispersion of SOx (100 MW GTG)

		Wind (Us = 2.6 m/s)				No Wind			
		Daytime		Night		Daytime		Night	
Output	(MW)	100				100			
Efficiency	(%)	30				30			
Fuel Consumption	(T/hr)	26.3				26.3			
Flue Gas Volume	(Nm^3/s)	280				280			
SOx Emission Rate	(Nm^3/s)	0.0225 (0.229 g/Nm^3)				0.0225 (0.229 g/Nm^3)			
Pasquill Stability		B		D		A		D	
Stack Height	(m)	50	100	50	100	50	100	50	100
Effective Stack Height	(m)	227	264	207	238	158	208	119	169
Max. Ground Level Concentration	(ppm)	0.0135	0.0091	0.0048	0.0029	0.0365	0.0211	0.8960	0.4439
Distance from Stack	(km)	1.4	1.6	7.9	10.5	0.0	0.0	0.0	0.0

Table 13.2.4 Prediction for Dispersion of NOx (100 MW GTG)

		Wind (Us = 2.6 m/s)				No Wind			
		Daytime		Night		Daytime		Night	
Output	(MW)	100				100			
Efficiency	(%)	30				30			
Fuel Consumption	(T/hr)	30.3				30.3			
Flue Gas Volume	(Nm^3/s)	280				280			
NOx Emission Rate	(Nm^3/s)	0.028 (0.2 g/Nm^3)				0.028 (0.2 g/Nm^3)			
Pasquill Stability		B		D		A		D	
Stack Height	(m)	50	100	50	100	50	100	50	100
Effective Stack Height	(m)	227	264	207	238	158	208	119	169
Max. Ground Level Concentration	(ppm)	0.0168	0.0114	0.0059	0.0036	0.0454	0.0262	1.1151	0.5520
Distance from Stack	(km)	1.4	1.6	7.9	10.5	0.0	0.0	0.0	0.0

Table 13.2.5 Emission Quality Standards in Oman and Japan

Air Pollutant	Oman	Japan
1. SO_2	80 $\mu g/m^3$ (Note 1)	Note 3 (1 day)
2. NO_2	0.20 g/m^3 (Note 2)	60 ~ 130 ppm (1 day) (Note 4)

Notes:

1. This value was verbally given by MRME. The method of measurement and relation to time span are unknown.
2. The method of measurement and relation to time span are unknown.
3. The permissible emission rate is to be calculated by the following formula.
   $Q\ (Nm^3/hr) = K \times 10^{-3} \times He^2$
   where,
   K : constant depending on the region
   He : effective stack height (m)
4. These values are applicable for a gas burning or a liquid fuel burning boiler, of which the nominal volume of exhaust gas is more than $5 \times 10^5\ Nm^3/hr$.

(6) Environmental Standards for Air Quality in Various Countries

Table 13.2.6 shows the environmental standards for air quality in various countries. It is to be noted that these standards shall not be simply compared since they are not enacted under common conditions.

Table 13.2.6 Environmental Standards for Air Quality

(Unit : ppm)

	SO_2	NO_2	Remarks
Japan	Daily Average 0.04 1-hour Value 0.1	To be in a range from 0.04 to 0.06 or less.	For protection of human health.
U.S.A.	Primary Standard Annual Average 0.03 Daily Average 0.14	Annual Average 0.05 Standard over a short period not yet specified	For protection of human health.
	Secondary Standard Average in 3 hours 0.5	Same as the above.	For protection of public welfare from the known or predicted impacts.
Germany	Long-term 0.05 Short-term 0.15	0.04 0.11	One of the conditions to obtain a permit for construction/installation proposal of a certain facility. Once the permit is granted, any claims by inhabitants to request suspension of the proposal may not be accepted.
Canada	Max Desirable Level Annual Average 0.01 Daily Average 0.06 1-hour Value 0.17	Annual Average 0.03	Long-range objectives to be considered as fundamentals of pollution prevention policies for clean areas and development of anti-pollution technologies.
	Max Acceptable Level Annual Average 0.02 Daily Average 0.11 1-hour Value 0.34	Annual Average 0.05 Daily Average 0.11 1-hour Value 0.21	Practical level of standards at present. To be observed from protection of living environment.
	Max Tolerable Level Daily Average 0.31	Daily Average 0.16 1-hour Value 0.53	Critical level of pollution. Prompt countermeasures to be taken.

13.3 Summary of the Environmental Impact Study

13.3.1 Matrix Table

The environmental matrix table (Table 13.3.1) was prepared to summarize the results of the environmental study in this F/S including the recommendations on mitigation measures and suggestions on monitoring for environmental protection.

It is concluded, from the matrix table, that no strong impacts due to the project are expected, and impacts to the environment can be limited to the minimum ranges by designing adequately and by adopting proper construction methods.

13.3.2 Major Study Items

(1) Type of Water Intake Facility

The sea is shallow for some distance from the shore at the site. For such a site, it is, in general, necessary to construct a water intake facility protruding far from the shore so as to secure a sufficient depth of water. Accordingly, it can be expected that this facility may cause some impact to the natural environment, such as a change of landscape due to the structures and a change of shoreline features due to the littoral transportation of sand. MRME and MCI also advised us to study this point carefully and to suggest some countermeasures. Therefore, a water intake facility with buried pipelines is recommendable from an environmental point of view.

(2) Hot Water Discharge

It is considered, at this stage, that there is no serious impact to aquatic biota, fisheries and so forth from the following points of view:

1) No mangroves or coral reefs exist around the site.

2) The marine environment along the coast is very similar, and accordingly, it is considered that a hot water discharge into a limited area will not cause a serious impact to the overall ecology.

3) Fishing is carried out mainly in the area around the islands which are located about 15 km offshore.

4) The impact area can be limited to a certain range by adopting a fan-shaped open discharge channel with adequate width and depth.

The above is to be confirmed, in the detailed design stage, by conducting a baseline survey for collecting meteorological, ecological and social data, then undertaking a detailed analysis.

(3) Waste Water Discharge

Waste water such as oily water, chemicals-mixed water and so forth will be produced by the plant operations. This is to be discharged outside the plant after treatment to the allowable levels specified in the standards in Oman.

On the other hand, concentrated saline water, and chemicals such as flocculating agents and so forth will be directly discharged from the desalination plant to the sea together with the cooling water. As described below, it is anticipated that no serious impact to the existing environment will be caused by this discharge.

1) Concentrated saline water

The concentration of salinity of the discharged water from the desalination plant is generally 12 ~ 14 % higher than that of the sea-water. This discharged water is mixed with the cooling water from the power plant and diluted to a concentration of about 1 % higher than that of the sea-water. After being discharged to the sea, it is promptly diluted by the sea-water to its original concentration.

2) Chemicals (flocculating agents, etc.)

Only the excess of these chemicals is discharged after the treatment of sea-water. Since their concentrations in the discharged water are very low and they are diluted promptly to negligible levels, it is considered that they do not cause any environmental problems.

(4) Air Pollution

It is expected that the exhaust gas from the plant will not have a serious impact on the surrounding environment. However, a detailed study in the detailed design stage is to be conducted with sufficient data as mentioned in Section 13.2.2.

(5) Other than the above, some impact to the surrounding environment is anticipated due to noise and contamination of sea-water during construction, increase of traffic, etc. These problems can be solved by selecting adequate construction methods which will minimize the impacts and making the best effort to explain to the local residents the necessity and advantages of the project.

13.3.3 Necessity of a Supplementary EIA in the Detailed Design Stage

The area around the proposed site is designated as a "Coastal Reserve Area" and its natural environment is controlled. Therefore, detailed investigations and a supplementary EIA in the detailed design stage are of vital importance to ensure that the project does not have a serious impact on the social and natural environment around the site. MRME also requires a detailed EIA prior to the implementation of the project in accordance with the T.O.R prepared by them.

(1) Baseline Survey

Figure 13.3.1 shows the outline of a baseline survey to identify the present conditions of the physical, biological and human environment. For preparing the detailed EIA report to be submitted to the relevant organizations in Oman, it is necessary to carry out this baseline survey.

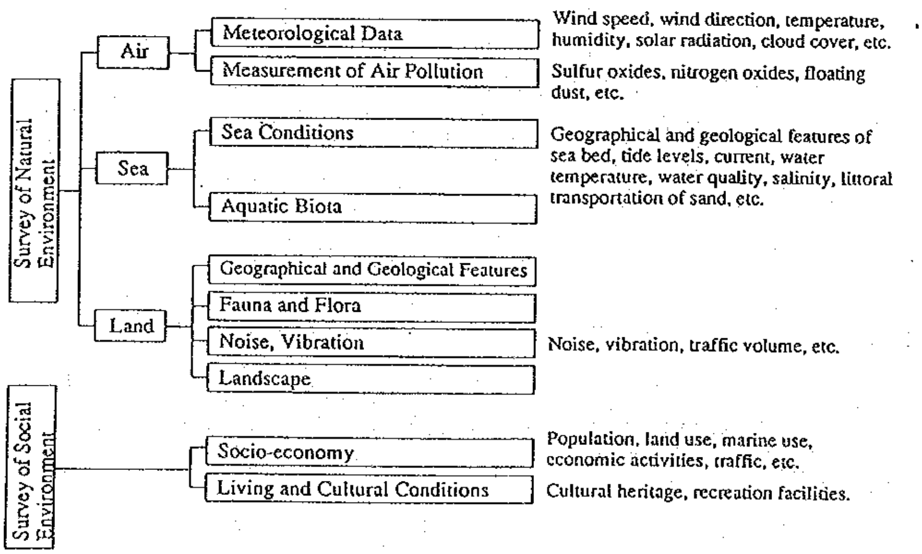


Figure 13.3.1 Outline of Baseline Survey

(2) Environmental Protection Measures

Environmental protection measures to be considered in the detailed design stage are shown in Figure 13.3.2.

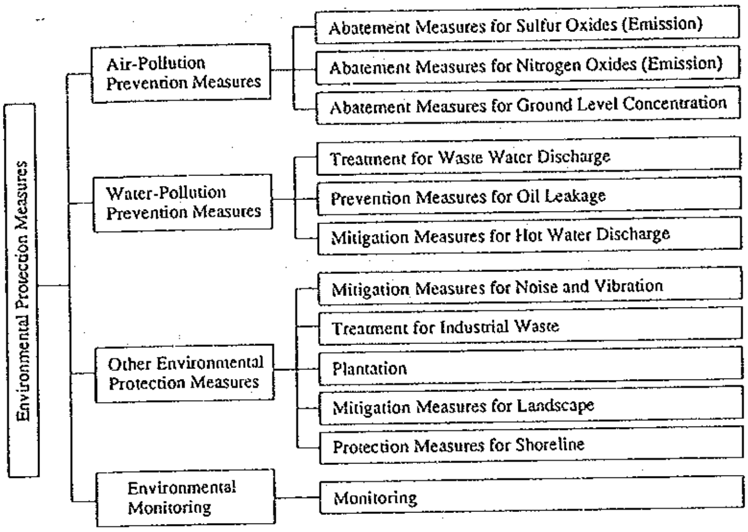


Figure 13.3.2 Environmental Protection Measures

Table 13.3.1 Environmental Matrix

Environmental Item	Description	Survey Item	Survey Method	Evaluation		Basis of Judgement	Mitigation/Protection Measures	Monitoring	Specific Survey Items in Detailed EIA
				During Construction	During Operation				
1. Resettlement	Relocation triggered by the project	Land location, land owner	Interview Access to land use map	D	D	No resettlement is required.	-	-	-
2. Split of Societies	Split due to presence of the project	Locations of towns/ villages	Interview Access to land use map	D	D	Splitting of present societies is not expected.	-	-	-
3. Aborigines	Impact to aborigines, minorities	Presence of aborigines or minorities	Site reconnaissance	D	D	No aborigines or minorities are present in the site.	-	-	-
4. Friction	Increase of friction among people	Inhabitants' opinions of project	-	C	C	Unknown.	• The outline of the project to be open to the public before implementation.	-	• Inhabitants' opinions.
5. Economic Activities	Impact to local economy, loss to the production basis	Major economic activities	Interview Examination of data	C	C	Impacts to fishing are unknown.	• Provision of an opportunity for employment. • Proper reimbursement if found necessary.	-	• Economic activities around the site, fisheries.
6. Public Facilities	Impact to schools, hospitals, etc.	Distribution of public facilities	Site reconnaissance	D	C	A housing area for plant operators will be located near the existing village.	-	-	• Use of public facilities.
7. Traffic	Increase of congestion, accidents	Road and traffic volume	Site reconnaissance Examination of data	B	C	Increase of traffic volume is expected especially during construction.	• Traffic signs to be arranged properly. • Traffic volume for construction to be well controlled.	-	• Present traffic volume, future plan for traffic system.
8. Common Rights	Loss of fishing rights, common rights	Fisheries and fishing rights	Interview Examination of data	C	C	Confirmation of the fisheries by MAF is necessary.	• The outline of the project to be open to the public before implementation. • Proper reimbursement if found necessary.	-	• Fisheries, fishing rights.
9. Cultural Heritage	Impact to historic monuments, etc.	Locations of cultural heritage sites	Interview Examination of data	C	C	Confirmation by MNHC is necessary.	• To consult MNHC and take countermeasures, if found.	-	• Site investigation with MNHC.
10. Change of Views	Drastic change of panoramic views	Present conditions in the surrounding area	Interview Examination of data Site reconnaissance	C	C	The plant will be built on the beach where the natural features are preserved.	• To maintain harmony with the surrounding views by plantation, consideration to colour of structures, etc.	-	• Inhabitants' opinions. • Opinions of the relevant authorities regarding details of the project.
11. Precious Nature	Collapse of wetlands, tropical forests, wildlands, mangroves, etc.	Present conditions in the surrounding area	Interview Examination of data Site reconnaissance	C	C	The beach around the site is designated as a "Coastal Reserve Area".	• To maintain harmony with the surrounding views by plantation, consideration to colour of structures, etc.	-	• Opinions of the relevant authorities regarding details of the project.
12. Endangered Animals, Plants	Impact to endangered species, original animals, plants, etc.	Presence of endangered species in and around the site	Interview Examination of data Site reconnaissance	C	C	It seems that there are no endangered species in the project area. However, a detailed survey is required especially for aquatic biota.	-	-	• Detailed survey for fauna, flora, aquatic biota.
13. Vegetation	Impact to vegetation	Present conditions	Site reconnaissance	B	D	Some trees and shrubs will be removed during construction.	• Plantation	-	-
14. Landscape	Change of landscape (Change of shoreline)	Geographical features	Site reconnaissance Examination of data	B	B	The natural features will change due to filling and construction of plant facilities (marine structures).	• To adopt an appropriate type of water intake (buried pipeline). • Due consideration to be taken in the detailed design of marine structures.	• Survey for change of shoreline twice a year.	• Volume of sediment flowing into the sea from the wadi (littoral transportation).
15. Groundwater	Change of groundwater level	Present conditions of groundwater	Site reconnaissance Examination of data	D	D	Groundwater around the site will not be used for the project.	-	-	-
16. Surface Water	Change of route, volume, etc.	Present conditions	Site reconnaissance	C	C	A wadi exists to the west of the site.	• Rain water drainage around the site to be considered in the design.	• Visual inspection during and after rainfall.	-
17. Surface Water	Change of temperature	Water quality, water temperature, aquatic biota	Site reconnaissance Examination of data Measurement and analysis for pollution	D	B	Hot water will be discharged into the sea.	• To design a fan-shaped outfall with proper dimensions for minimizing the impact area.	• Regular measurement of water temperature at the water intake and outfall. • Regular measurement of salinity at the outfall. • Survey for water temperature, water quality and aquatic biota in the sea around the site. (twice a year)	• Meteorological data, sea conditions. • Detailed analysis for hot water diffusion.
18. Air Pollution	Caused by factories and cars	Meteorological conditions, distribution of living facilities, standards	Examination of data Analysis for pollution	C	B	Emission of exhaust gases.	• To use natural gas for operation. • Due consideration to be taken in the design of the stack for promoting dispersion. (especially for stack height)	• Regular monitoring for concentration of NOx, SOx, etc. at the stack and at ground level.	• Meteorological and geographical data. • Detailed analysis for dispersion of pollutants.
19. Water Pollution	Caused by factories and land construction/ excavation	Fisheries, water quality, recreation use	Site reconnaissance Examination of data Interview	B	D	Turbidity of sea water during construction.	• To adopt proper construction methods for minimizing contamination. (use of silt-protector, etc.)	• Monitoring at appropriate points during construction.	• Sea conditions • Fisheries.
20. Soil Contamination	Caused by toxic waste disposal	Present conditions	Site reconnaissance Interview	D	D	No disposal without treatment is expected.	• Industrial wastes to be treated if necessary. • To check chemicals in filling material.	• Regular measurement of discharged water quality.	-
21. Noise/Vibration	Caused by traffic and factories	Distribution of living facilities, standards	Site reconnaissance Examination of data	B	C	Increase of traffic volume is expected especially during construction.	• Equipment generating noise to be arranged at a sufficient distance from the site boundary or to be housed. • To adopt low-noise equipment.	• Regular measurement of noise at the boundary.	-
22. Ground Subsidence	Caused by overuse of groundwater	Underground conditions	Soil investigation	D	D	Groundwater around the site will not be used for the project.	-	-	-
23. Offensive Odor	Caused by exhaust gas, wastes	Standards	Examination of data	D	D	No facilities causing offensive odor.	-	-	-

Evaluation Grade:

A: Strong impact is expected
B: Little impact is expected
C: Unknown (Not clear at this moment, but needs to be examined in detail)
D: Impact is insignificant, and no need to be a scope of EIA

CHAPTER 14 IMPLEMENTATION PLAN

CHAPTER 14 IMPLEMENTATION PLAN

14.1 Project Implementation Plan

The implementation plan for the power and desalination complex plant proposes the quick completion of the first unit in order to respond to the already pressing demand for power and water. Afterwards, the other power and desalination units will be constructed in accordance with the increase of each demand. The facilities must meet expected demand without requiring excessive capital investment. This plan considers these factors to determine the optimum size of the facility.

Figure 14.1 shows the implementation plan for the Power and MSF desalination plant and Figure 14.2 shows the same for the Power and RO desalination plant.

14.2 Selection of Contractor and Project Contract

The outline of the steps required from the conclusion of this feasibility study up to the completion of the complex plant is given below:

(1) Design
(2) Preparation of technical specifications and bidding documents
(3) Bidding
(4) Bid evaluation and negotiations
(5) Selection of contractor and contract
(6) Implementation design
(7) Manufacture of equipment and procurement of materials
(8) Construction
(9) Commissioning
(10) Commercial operations

It is necessary to appoint a Consultant, for the engineering services, to accomplish steps (1) ~ (5).

To complete the urgent first phase of the implementation plan, smooth and short-term engineering services are considered to be vital.

14.3 Plant Construction

The Contractor is fully responsible for the control of the plant delivery schedule which will be approved later. However, MEW is requested to expediently approve the contractors' operations in order to facilitate the process. MEW is also requested to assist in the Contractors' negotiations with the government authorities concerning the approval on legal matters of this project. Major issues of the construction work schedule are as follows:

(1) Detailed Design, Manufacture of Equipment and Procurement of Materials

1) Power Plant

For the gas turbine power plant a standard construction method was adopted, in which it takes about 12 months to design, manufacture and deliver one unit to site. Due to the large dimensions of the boiler, the steam turbine power generation unit is prefabricated by segmented panels which are manufactured at the factory and assembled at site. This will require about 17 months to design, manufacture and deliver one unit to site.

2) Desalination Plant

Under the MSF method, the evaporator which takes the longest manufacturing period, uses a prefabricated method in which modules manufactured at the factory are assembled at the site. This will require about 18 months to manufacture and deliver one unit to site.

Using the RO method, it will take about 14 months to manufacture and deliver one unit to site. Under the RO method, the high-pressure feed pump and the RO module requires a long manufacturing period and the RO module will be manufactured in the factory and assembled at the site.

(2) On-Site Work

1) Civil/Architectural Construction Work

① Survey and Preparation

Immediately after concluding the contract, civil-engineering works for survey purposes, including a geological survey of land and sea and sounding of the sea bottom, must be carried out in order to finalize the design criteria for the plant foundations, water intake and outfall facilities, buildings and structures. This survey work will require about 4 months.

Furthermore, preparatory works including construction of an access road leading from the main road to the site and clearing of the plant site will commence. These preparatory civil works will require about 3 months.

② Water Intake and Outfall Facilities

Commissioning for the first unit of the desalination plant by the MSF and RO methods is scheduled for October 1998. Therefore, the water intake and outfall facilities must be completed by May 1998 assuming that it requires about 5 months for the installation of the seawater pumps including the piping to the plant. Most of the civil work for the water intake channel will adopt an underwater buried pipeline system. The dredging works for the channel and embeddment works for the pipes will require about 23 months. Constructing the intake structure and pump pit will require about 16 months, and the outfall channel will take about 12 months. These works will be carried out simultaneously with the water intake channel work.

③ Plant Foundations

The foundations for the major items of plant, such as for the gas turbine power generation plant, the steam turbine power generation plant and the desalination plant, will be constructed in stages and completed before installation work commences.

④ Building Construction Work

The Administration and Control buildings must be completed before the commissioning commences for the 2 units of gas turbine power generation plant, which is scheduled at the end of 1997. The construction of these structures will require about 18 months. Furthermore, the main building containing the steam turbine power generation plant and buildings used for the desalination plant must be completed before the commissioning of those plants.

2) Power Transmission and Substation Facilities

Substation construction includes the Barka Substation, which will meet the capacity requirements for the first phase of Barka Power Plant, and expansion of the existing Bait Barka and Madinat Qaboos Substations.

Power transmission line construction is to be between Barka and Bait Barka Substations and between Barka and Madinat Qaboos Substations. These must be completed by the end of 1997, when commissioning of the gas turbine power generation plant is scheduled. The construction work for these liens is considered to be on the critical path of the plant construction schedule.

3) Water Transmission Facilities

Water transmission facilities are expected to be completed 20 months after the signing of the contract. Therefore, this construction period will not affect the plant construction schedule severely. However, the finalization of the transmission route for the pipeline and negotiations with government authorities and local residents must be carried out swiftly.

4) Power Generation Plant

Installation of the gas turbine power generation plant is relatively simple, since all of the equipment comes as a package. The entire process, from installation to commissioning, requires about 8 months per unit. The steam turbine power generation plant requires on-site assembly of the auxiliary equipment and piping. Furthermore, since the boiler is prefabricated, it requires a great deal of welding and pipe installation. Therefore it takes about 13 months to complete the entire process for one unit.

5) Desalination Plant

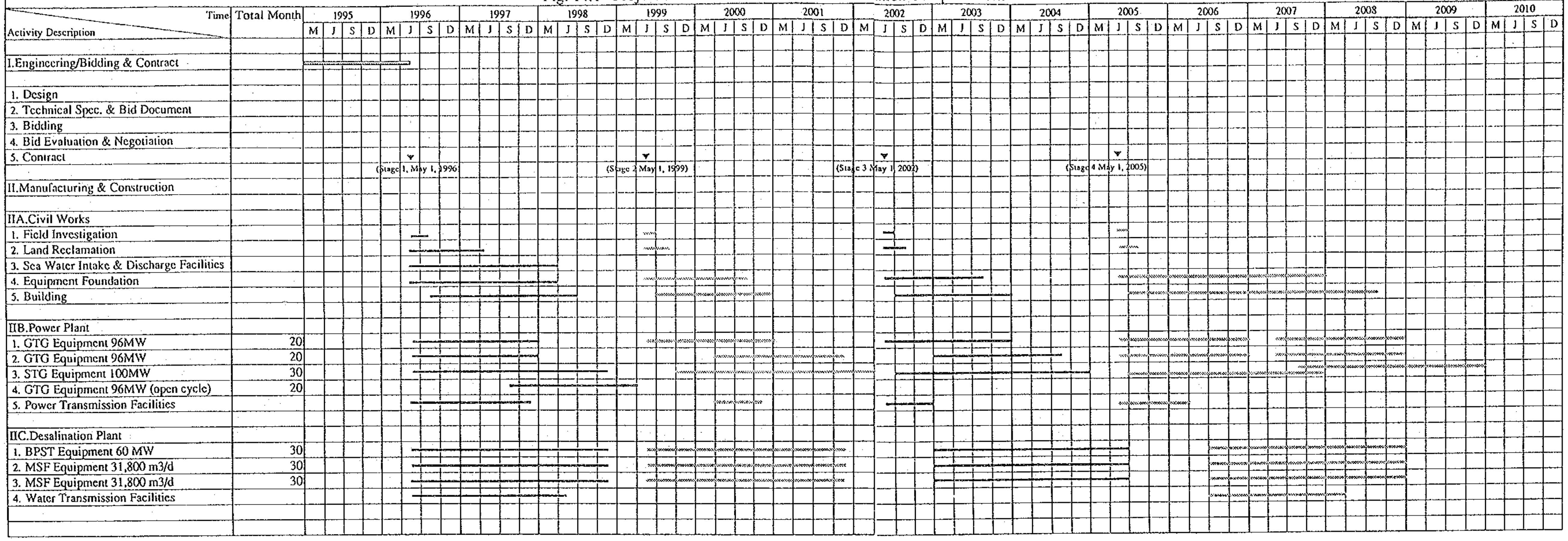
A total of 8 desalination plants will be constructed. The 2 units to be constructed in the first phase and to coincide with the completion of the power generation plant are scheduled for completion at the end of 1998. The remaining units will be constructed in stages by considering the growth in demand and economic factors. Each stage shall consist of 2 units each.

6) Commissioning

To confirm the reliability of the power and desalination plants, performance tests will be carried out for one month prior to the taking over.

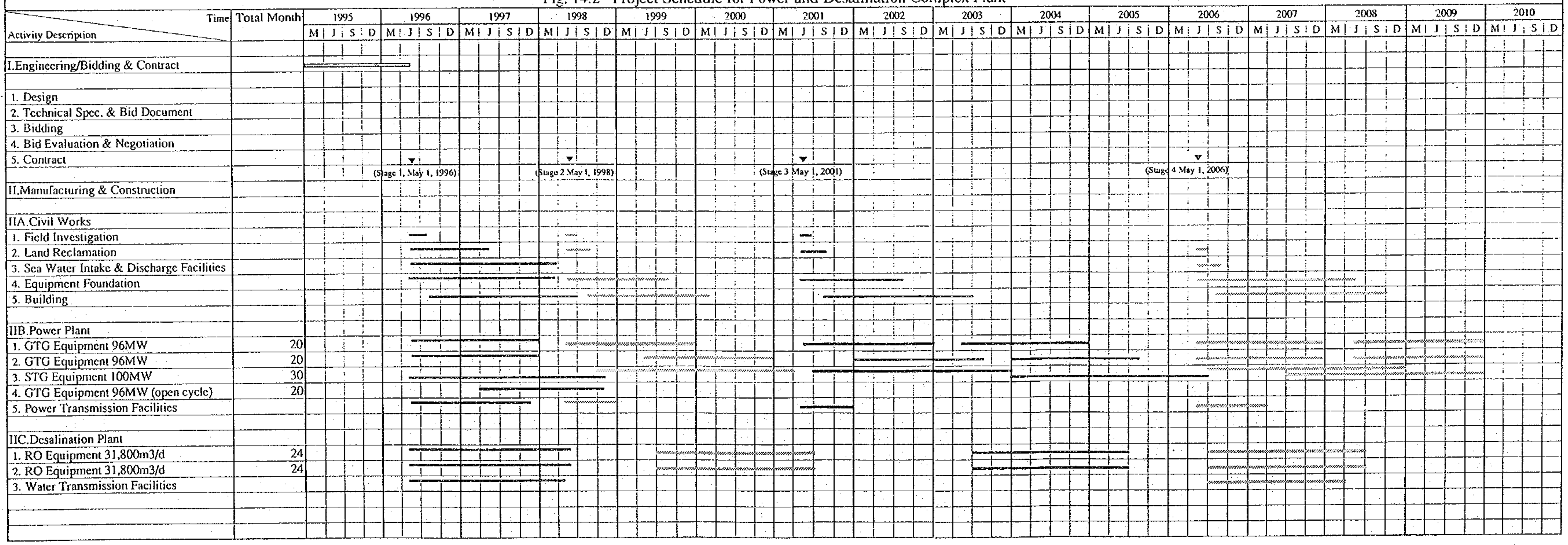
Alternative A (MSF Process)

Fig. 14.1 Project Schedule for Power and Desalination Complex Plant



Alternative B (RO Process)

Fig. 14.2 Project Schedule for Power and Desalination Complex Plant



CHAPTER 15 CONSTRUCTION COST ESTIMATE

CHAPTER 15 CONSTRUCTION COST ESTIMATE

15.1 Basic Conditions

The construction cost was estimated for both Alternative A (Power and MSF Plant) and Alternative B (Power and RO Plant).

The construction cost estimate was broken down into local currency portion and foreign currency portion, covering the following facilities. (The amounts were expressed in terms of Rial Oman. For foreign currency portion, amounts converted to US$ were also given in parentheses).

(1) Electric Power Portion

- Generating facilities
- Transmission and substation facilities
- Sea water intake and out-fall facilities

(2) Desalination Portion

- Desalination facilities
- Sea water intake and out-fall facilities
- Product water transmission facilities

(3) Other Portion

- Physical contingencies
- MEW's administration expenses
- Engineering fee

The annual disbursement of the construction cost was made according to the construction schedule described in Chapter 14. The estimate was made at 1994 prices.

The foreign currency portion includes costs of imported equipment and materials, ocean freight and insurance, and salaries for foreign personnel, while the local currency portion includes costs for inland transportation, locally available construction machines and materials such as cement, aggregates, etc., as well as salaries and wages for local personnel.

15.2 Conditions for Estimate

The physical contingencies, MEW's administration expenses, engineering fee, and exchange rates of currencies were estimated under the following conditions:

(1) Physical contingencies

Physical contingencies are to cover mainly unforeseen additional works. In the light of experiences in projects of similar nature, 10 % for the civil works and electrical/mechanical equipment of their respective base direct costs was included as physical contingencies.

(2) MEW's administration expenses

In general, administration expenses of MEW are estimated around 0.5 % of the base direct construction cost annually.

(3) Engineering fee

Engineering fee is the expense for engineering services such as definite design and preparation of tender documents, evaluation of tenders, construction supervision, etc. In consideration of magnitudes of this Project, the amount was estimated at 1.5 % of the base direct construction cost.

(4) Exchange rates of currencies

The following foreign exchange rate is applied in the study;

US$1.00 = 0.3845 Rial Omani (R.O.) (as of June 1994)

15.3 Conditions for Annual Disbursement

The construction cost was disbursed annually under the following conditions:

(1) Costs of equipment

Advance payment - 10 % of the CIF price upon signing of the contract

- 80 % of the CIF price upon shipment of the equipment

Retention money - 10 % of the CIF price to be released upon issue of the acceptance certificate by MEW

(2) Costs of civil works and buildings

Advance payment	-	10 % of the contract price upon signing of the contract
Monthly payment	-	According to the amount of works done
Retention money	-	10 % of the contract price to be released upon issue of the acceptance certificate by MEW

(3) Erection and installation cost

Same conditions as for civil works.

15.4 Estimated Construction Cost

On the basis of the conditions stated above, the construction cost at 1994 prices including physical contingencies, MEW's administration expenses and engineering fee were estimated as follows:

(1) Alternative A (MSF type)

a. Electric power portion:	563.90 million R.O.
b. Desalination portion:	332.26 million R.O.
Total	896.16 million R.O.

(2) Alternative B (RO type)

a. Electric power portion:	564.18 million R.O.
b. Desalination portion:	262.02 million R.O.
Total	826.20 million R.O.

The construction cost for both Alternative A and Alternative B at 1994 prices is summarized in Table 15.1 ~ 15.6. The annual disbursement of the construction cost is shown in Table 15.7 ~ 15.10.

15.5 Estimated Stage Construction Cost

The estimated cost at 1994 prices of each stage of the best alternative, namely, Alternative B is as follows;

(1) First Stage Construction (May 1996 ~ Dec. 1998)

a. Electric power portion:	145.10 million R.O.
b. Desalination portion:	113.19 million R.O.
Total	258.29 million R.O.

(2) Second Stage Construction (May 1998 ~ Dec. 2001)

a. Electric power portion:	101.29 million R.O.
b. Desalination portion:	49.61 million R.O.
Total	150.90 million R.O.

(3) Third Stage Construction (May 2001 ~ Dec. 2006)

a. Electric power portion:	157.17 million R.O.
b. Desalination portion:	49.61 million R.O.
Total	206.78 million R.O.

(4) Fourth Stage Construction (May 2006 ~ Dec. 2009)

a. Electric power portion:	160.62 million R.O.
b. Desalination portion:	49.61 million R.O.
Total	210.23 million R.O.

Table 15.1 Summary of Construction Cost (Alternative A, MSF)

(Million R.O.)

Alternative	Alternative A MSF			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
Electric Power Portion				
A. Power Plant Facilities	421.47	(1,096.15)	29.56	451.03
B. Power Transmission Facilities	40.91	(106.40)	11.54	52.45
Sub Total (Base Direct Cost)	462.38	(1,202.56)	41.09	503.48
Physical Contingencies	46.24	(120.26)	4.11	50.35
MEW Admi. Expense	-	(-)	2.52	2.52
Engineering Fee	7.55	(19.64)	-	7.55
Total (1994 Price)	516.17	(1,342.45)	47.72	563.89
Desalination Portion				
A. Desalination Facilities	199.78	(519.59)	50.94	250.72
B. Water Transmission Facilities	32.60	(84.79)	13.34	45.94
Sub Total (Base Direct Cost)	232.38	(604.37)	64.28	296.66
Physical Contingencies	23.24	(60.44)	6.43	29.67
MEW Admi. Expense	-	(-)	1.48	1.48
Engineering Fee	4.45	(11.57)	-	4.45
Total (1994 Price)	260.07	(676.38)	72.19	332.26
Grand Total (1994 Price)	776.24	(2,018.83)	119.92	896.16

Table 15.2 Summary of Construction Cost (Alternative A, Electric Power Portion)

(Million R.O.)

Alternative	Alternative A MSF			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
A. Power Plant Facilities				
1. Civil Work				
1.1 Land Reclamation	0.83	(2.17)	2.00	2.83
1.2 Water Intake and Outfall	3.27	(8.51)	7.68	10.95
1.3 Common Buildings	1.41	(3.68)	3.34	4.75
1.4 Foundation	3.10	(8.07)	7.23	10.34
1.5 Power House	2.86	(7.44)	6.64	9.50
2. Power Plant				
2.1 GTG Equipment	164.14	(462.89)	-	164.14
2.2 GTG Erection	28.62	(74.43)	0.36	28.98
2.3 STG Equipment	136.28	(354.43)	-	136.28
2.4 STG Erection	22.38	(58.21)	1.67	24.05
2.5 BPST Equipment	50.01	(130.08)		50.01
2.6 BPST Erection	8.55	(22.25)	0.63	9.18
B. Power Transmission Facilities	40.91	(106.40)	11.54	52.45
Total (A - B) (1994 Price)	462.38	(1,202.56)	41.09	503.48
C. Other Cost				
1. Physical Contingencies (10 %)	46.24	(120.26)	4.11	50.35
2. MEW Admi. Expense (0.5 %)	-	(-)	2.52	2.52
3. Engineering Fee (1.5 %)	7.55	(19.64)	-	7.55
Grand Total (1994 Price)	516.17	(1,342.45)	47.72	563.89

Table 15.3 Summary of Construction Cost (Alternative A, Desalination Portion)

(Million R.O.)

Alternative	Alternative A MSF			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
A. Desalination Facilities				
1. Civil Work				
1.1 Land Reclamation	0.83	(2.17)	2.00	2.83
1.2 Water Intake and Outfall	3.27	(8.51)	7.68	10.95
1.3 Common Buildings	1.41	(3.68)	3.34	4.75
1.4 Foundation	6.93	(18.02)	16.14	23.07
1.5 Desal. Building	0.80	(2.08)	1.81	2.61
2. Desalination Plant				
2.1 BPST Equipment	33.34	(86.72)	-	33.34
2.2 BPST Erection	5.70	(14.83)	0.42	6.12
2.3 MSF Equipment	139.11	(361.79)	-	139.11
2.4 MSF Erection	8.38	(21.79)	19.55	27.93
B. Water Transmission Facilities				
1. Muscat Line				
1.1 Pipeline	18.40	(47.85)	4.60	23.00
1.2 Barka Reservoir & Pumping Station	1.40	(3.64)	5.60	7.00
2. South Batinah Line	12.80	(33.29)	3.14	15.94
Total (A - B) (1994 Price)	232.4	(604.37)	64.3	296.66
C. Other Cost				
1. Physical Contingencies (10 %)	23.24	(60.44)	6.43	29.67
2. MEW Admi. Expense (0.5 %)	-	(-)	1.48	1.48
3. Engineering Fee (1.5 %)	4.45	(11.57)	-	4.45
Grand Total (1994 Price)	260.07	(676.38)	72.19	332.26

Table 15.4 Summary of Construction Cost (Alternative B, R.O.)

(Million R.O.)

Alternative	Alternative B R.O.			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
Electric Power Portion				
A. Power Plant Facilities	427.3	(1,111.39)	23.9	451.28
B. Power Transmission Facilities	40.9	(106.40)	11.5	52.45
Sub Total (Base Direct Cost)	468.24	(1,217.80)	35.49	503.73
Physical Contingencies	46.8	(121.78)	3.5	50.37
MEW Admi. Expense	-	(-)	2.5	2.52
Engineering Fee	7.6	(19.65)	-	7.56
Total (1994 Price)	522.62	(1,359.23)	41.56	564.18
Desalination Portion				
A. Desalination Facilities	141.9	(368.93)	46.2	188.01
B. Water Transmission Facilities	32.60	(84.79)	13.34	45.94
Sub Total (Base Direct Cost)	174.45	(453.71)	59.49	233.95
Physical Contingencies	17.4	(45.37)	5.9	23.39
MEW Admi. Expense	-	(-)	1.2	1.17
Engineering Fee	3.5	(9.13)	-	3.51
Total (1994 Price)	195.41	(508.21)	66.61	262.02
Grand Total (1994 Price)	718.03	(1,867.44)	108.17	826.20

Table 15.5 Summary of Construction Cost (Alternative B, Electric Power Portion)

(Million R.O.)

Alternative	Alternative B R.O.			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
A. Power Plant Facilities				
1. Civil Work				
1.1 Land Reclamation	0.83	(2.17)	2.00	2.83
1.2 Water Intake and Outfall	3.13	(8.13)	7.28	10.41
1.3 Common Buildings	1.41	(3.68)	3.34	4.75
1.4 Foundation	1.57	(4.08)	3.66	5.22
1.5 Power House	2.23	(5.79)	5.21	7.44
2. Power Plant (C/C)				
2.1 GTG Equipment	193.99	(504.53)	-	193.99
2.2 GTG Erection	33.81	(87.92)	0.44	34.24
2.3 STG Equipment	163.52	(425.28)	-	163.52
2.4 STG Erection	26.84	(69.81)	2.03	28.87
B. Power Transmission Facilities	40.91	(106.40)	11.54	52.45
Total (A - B) (1994 Price)	468.24	(1,217.80)	35.49	503.73
C. Other Cost				
1. Physical Contingencies (10 %)	46.82	(121.78)	3.55	50.37
2. MEW Admi. Expense (0.5 %)	-	(-)	2.52	2.52
3. Engineering Fee (1.5 %)	7.56	(19.65)	-	7.56
Grand Total (1994 Price)	522.62	(1,359.23)	41.56	564.18

Table 15.6 Summary of Construction Cost (Alternative B, Desalination Portion)

(Million R.O.)

Alternative	Alternative B R.O.			
Item	Foreign Currency	(US$ Million)	Local Currency	Total
A. Desalination Facilities				
1. Civil Work				
1.1 Land Reclamation	0.83	(2.17)	2.00	2.83
1.2 Water Intake and Outfall	2.16	(5.63)	4.95	7.11
1.3 Common Buildings	1.41	(3.68)	3.34	4.75
1.4 Foundation	6.93	(18.02)	16.14	23.07
1.5 Desal. Building	0.94	(2.45)	2.18	3.12
2. Desalination Plant				
2.1 RO Equipment	122.02	(317.36)	-	122.02
2.2 RO Erection	7.54	(19.62)	17.56	25.10
B. Water Transmission Facilities				
1. Muscat Line				
1.1 Pipeline	18.40	(47.85)	4.60	23.00
1.2 Barka Reservoir & Pumping Station	1.40	(3.64)	5.60	7.00
2. South Batinah Line	12.80	(33.29)	3.14	15.94
Total (A - B) (1994 Price)	174.5	(453.71)	59.5	233.95
C. Other Cost				
1. Physical Contingencies (10 %)	17.45	(45.37)	5.95	23.39
2. MEW Admi. Expense (0.5 %)	-	(-)	1.17	1.17
3. Engineering Fee (1.5 %)	3.51	(9.13)	-	3.51
Grand Total (1994 Price)	195.41	(508.21)	66.61	262.02

Table 15.7 Annual Disbursement of Construction Cost (Alternative A, MSF/Electric Power Portion)

(R.O. Million)

Item	Total			1996			1997			1998			1999			2000			2001			·	2002			2003			2004			2005			2006			2007			2008			2009			2010		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC		LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Power Plant Facilities																																																	
1 Civil Work																																																	
1.1 Land Reclamation	0.83	2.00	2.83	0.17	0.20	0.37	0.67	1.80	2.47																																								
1.2 Water Intake and Outfall	3.27	7.68	10.95	0.33	0.77	1.10	1.96	1.54	3.50	0.98	5.38	6.36																																					
1.3 Common Buildings	1.41	3.34	4.75	0.42	0.33	0.75	0.99	3.00	3.99																																								
1.4 Foundation	3.10	7.23	10.33	0.06	0.14	0.20	0.56	1.30	1.86							0.06	0.14	0.20	0.56	1.30	1.86	0.06		0.14	0.20	0.56	1.30	1.86				0.06	0.14	0.20	0.56	1.30	1.86	0.06	0.14	0.20	0.56	1.30	1.86						
1.5 Power Houses	2.86	6.64	9.50	0.17	0.13	0.30	0.40	1.20	1.60							0.17	0.13	0.30	0.40	1.20	1.60	0.17		0.13	0.30	0.40	1.20	1.60				0.17	0.13	0.30	0.40	1.20	1.60	0.17	0.13	0.30	0.40	1.20	1.60						
2 Power Plant (C/C)																																																	
2.1 GTG Equipment	164.14		164.14	1.49	0.00	1.49	13.43	0.00	13.43				1.49	0.00	1.49	13.43	0.00	13.43				1.49		0.00	1.49	13.43	0.00	13.43				1.49	0.00	1.49	13.43	0.00	13.43	1.49	0.00	1.49	13.43	0.00	13.43						
2.2 GTG Erection	28.62	0.36	28.98	0.26	0.00	0.26	2.34	0.03	2.37				0.26	0.00	0.26	2.34	0.03	2.37				0.29		0.00	0.29	2.34	0.03	2.37				0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37						
				1.49	0.00	1.49	13.43	0.00	13.43	1.49	0.00	1.49	13.43	0.00	13.43	1.49	0.00	1.49	13.43	0.00	13.43					1.49	0.00	1.49	13.43	0.00	13.43	1.49	0.00	1.49	13.43	0.00	13.43	1.49	0.00	1.49	13.43	0.00	13.43						
				0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37					0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37						
2.3 STG Equipment	136.28		136.28	2.73	0.00	2.73	19.08	0.00	19.08	5.45	0.00	5.45				2.73	0.00	2.73	19.08	0.00	19.08	5.45		0.00	5.45							2.73	0.00	2.73	19.08	0.00	19.08	5.45	0.00	5.45									
2.4 STG Erection	22.38	1.67	24.05	0.45	0.03	0.48	3.13	0.07	3.20	0.90	0.23	1.13				0.45	0.03	0.48	3.13	0.07	3.20	0.90		0.23	1.13							0.45	0.03	0.48	3.13	0.07	3.20	0.90	0.23	1.13									
																						2.73		0.00	2.73	19.08	0.00	19.08	5.45	0.00	5.45							2.73	0.00	2.73	19.08	0.00	19.08	5.45	0.00	5.45			
																						0.45		0.03	0.48	3.13	0.07	3.20	0.90	0.23	1.13							0.45	0.03	0.48	3.13	0.07	3.20	0.90	0.23	1.13			
2.5 BPST Equipment	50.01		50.01	1.25	0.00	1.25	10.00	0.00	10.00	1.25	0.00	1.25	1.25	0.00	1.25	10.00	0.00	10.00	1.25	0.00	1.25					1.25	0.00	1.25	10.00	0.00	10.00	1.25	0.00	1.25	1.25	0.00	1.25	10.00	0.00	10.00	1.25	0.00	1.25						
2.6 BPST Erection	8.55	0.63	9.18	0.21	0.02	0.23	1.71	0.02	1.73	0.21	0.13	0.34	0.21	0.02	0.23	1.71	0.02	1.73	0.21	0.13	0.34					0.21	0.02	0.23	1.71	0.02	1.73	0.21	0.13	0.34	0.21	0.02	0.23	1.71	0.02	1.73	0.21	0.13	0.34						
B. Power Transmission Facilities	40.91	11.54	52.45	4.09	1.15	5.24	28.64	3.46	32.10	8.18	6.92	15.10			0.00			0.00																															
Total (A - B) (1994 Price)	462.38	41.09	503.47	13.39	2.79	16.18	98.69	12.44	111.13	18.73	12.66	31.39	18.99	0.05	19.04	32.64	0.36	33.00	40.41	2.72	43.13	11.51		0.55	12.06	42.16	2.61	44.77	33.83	0.28	34.11	8.38	0.44	8.82	56.18	2.64	58.82	24.97	0.57	25.54	56.18	2.75	58.93	6.35	0.23	6.58	0.00	0.00	0.00
C. Other Cost																																																	
1 Physical Contingencies (10%)	46.24	4.11	50.35	1.34	0.28	1.62	9.87	1.24	11.11	1.87	1.27	3.14	1.90	0.00	1.90	3.26	0.04	3.30	4.04	0.27	4.31	1.15		0.05	1.20	4.22	0.26	4.48	3.38	0.03	3.41	0.84	0.04	0.88	5.62	0.26	5.88	2.50	0.06	2.56	5.62	0.28	5.90	0.63	0.02	0.65	0.00	0.00	0.00
2 MEW Admi. Expense (0.5%)		2.52	2.52		0.08	0.08		0.56	0.56		0.16	0.16		0.10	0.10		0.17	0.17		0.22	0.22			0.06	0.06		0.22	0.22		0.17	0.17		0.04	0.01		0.29	0.29		0.13	0.13		0.29	0.29		0.03	0.03		0.00	0.00
3 Engineering Fee (1.5%)	7.55		7.55	0.24		0.24	1.67		1.67	0.47		0.47	0.29		0.29	0.50		0.50	0.65		0.65	0.18			0.18	0.67		0.67	0.51		0.51	0.13		0.13	0.88		0.88	0.38		0.38	0.88		0.88	0.10		0.10	0.00		0.00
Grand Total (1994 Price)	516.17	47.72	563.89	14.97	3.15	18.12	110.23	14.24	124.47	21.07	14.09	35.16	21.18	0.15	21.33	36.40	0.57	36.97	45.10	3.21	48.31	12.84		0.66	13.50	47.05	3.09	50.14	37.72	0.48	38.20	9.35	0.52	9.87	62.68	3.19	65.87	27.85	0.76	28.61	62.68	3.32	66.00	7.08	0.28	7.36	0.00	0.00	0.00
Annual Total			563.89			18.12			124.47			35.16			21.33			36.97			48.31				13.50			50.14			38.20			9.87			65.87			28.61			66.00			7.36			0.00
Stage Total																																																	

Table 15.8 Annual Disbursement of Construction Cost (Alternative A, MSF/Desalination Portion)

(R.O. Million)

Item	Total			1996			1997			1998			1999			2000			2001			2002			2003			2004			2005			2006			2007			2008			2009			2010		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Desalination Facilities																																																
1. Civil Work																																																
1.1 Land Reclamation	0.83	2.00	2.83	0.17	0.20	0.37	0.67	1.80	2.47																																							
1.2 Water Intake and Outfall	3.27	7.68	10.95	0.33	0.77	1.10	1.96	1.54	3.50	0.98	5.38	6.36																																				
1.3 Common Buildings	1.41	3.34	4.75	0.42	0.33	0.75	0.99	3.00	3.99																																							
1.4 Foundation	6.93	16.14	23.07	0.17	0.40	0.57	1.39	3.23	4.62	0.17	0.40	0.57	0.17	0.40	0.57	1.39	3.23	4.62	0.17	0.40	0.57				0.17	0.40	0.57	1.39	3.23		0.17	0.40	0.57	0.17	0.40	0.57	1.39	3.23	4.62	0.17	0.40	0.57						
1.5 Desal. Building	0.80	1.81	2.61	0.24	0.18	0.42	0.56	1.63	2.19																																							
2. Desalination Plant																																																
2.1 BPST Equipment	33.34		33.34	0.83	0.00	0.83	6.67	0.00	6.67	0.83	0.00	0.83	0.83	0.00	0.83	6.67	0.00	6.67	0.83	0.00					0.83	0.00	0.83	6.67	0.00		0.83	0.00	0.83	0.83	0.00	0.83	6.67	0.00	6.67	0.83	0.00	0.83						
2.2 BPST Erection	5.70	0.42	6.12	0.14	0.01	0.15	1.14	0.01	1.15	0.14	0.08	0.22	0.14	0.01	0.15	1.14	0.01	1.15	0.14	0.08					0.14	0.01	0.15	1.14	0.01		0.14	0.08	0.22	0.14	0.01	0.15	1.14	0.01	1.15	0.14	0.08	0.22						
2.3 MSF Equipment	139.11		139.11	3.48	0.00	3.48	27.82	0.00	27.82	3.48	0.00	3.48	3.48	0.00	3.48	27.82	0.00	27.82	3.48	0.00	3.48				3.48	0.00	3.48	27.82	0.00		3.48	0.00	3.48	3.48	0.00	3.48	27.82	0.00	27.82	3.48	0.00	3.48						
2.4 MSF Erection	8.38	19.55	27.93	0.29	0.49	0.78	0.63	1.47	2.10	1.17	2.93	4.10	0.29	0.49	0.78	0.63	1.47	2.10	1.17	2.93	4.10				0.29	0.49	0.78	0.63	1.47		1.17	2.93	4.10	0.29	0.49	0.78	0.63	1.47	2.10	1.17	2.93	4.10						
B. Water Transmission Facilities																																																
1. Muscat Line																																																
1.1 Pipeline	18.40	4.60	23.00	1.84	0.46	2.30	14.72	2.76	17.48	1.84	1.38	3.22																																				
1.2 Barka Reservoir & Pumping Station	1.40	5.60	7.00	0.14	0.56	0.70	1.12	3.36	4.48	0.14	1.68	1.82																																				
2. South Batinah Line	12.8	3.14																																	1.28	0.31	1.59	10.24	1.88	12.12	1.28	0.94	2.22						
Total (A - B) (1994 Price)	232.38	64.28	296.66	8.05	3.41	11.46	57.66	18.79	76.45	8.76	11.86	20.62	4.92	0.90	5.82	37.64	4.71	42.35	5.80	3.42	9.22	0.00	0.00	0.00	4.92	0.90	5.82	37.64	4.71	42.35	5.80	3.42	9.22	6.20	1.22	7.42	47.88	6.59	54.47	7.08	4.36	11.44	0.00	0.00	0.00	0.00	0.00	0.00
C. Other Cost																																																
1. Physical Contingencies (10%)	23.24	6.43	29.67	0.81	0.34	1.15	5.77	1.88	7.65	0.88	1.19	2.07	0.49	0.09	0.58	3.76	0.47	4.23	0.58	0.34	0.92	0.00	0.00	0.00	0.49	0.09	0.58	3.76	0.47	4.23	0.58	0.34	0.92	0.62	0.12	0.74	4.79	0.66	5.45	0.71	0.44	1.15	0.00	0.00	0.00	0.00	0.00	0.00
2. MEW Admi. Expense (0.5%)		1.48	1.48		0.06	0.06		0.38	0.38		0.10	0.10		0.03	0.03		0.21	0.21		0.05	0.05		0.00	0.00		0.03	0.03		0.21	0.21		0.05	0.05		0.04	0.04		0.27	0.27		0.06	0.06		0.00	0.00		0.00	0.00
3. Engineering Fee (1.5%)	4.45		4.45	0.17		0.17	1.15		1.15	0.31		0.31	0.09		0.09	0.64		0.64	0.14		0.14	0.00		0.00	0.09		0.09	0.64		0.64	0.14		0.14	0.11		0.11	0.82		0.82	0.17		0.17	0.00		0.00	0.00		0.00
Grand Total (1994 Price)	260.07	72.19	332.26	9.03	3.81	12.84	64.58	21.05	85.63	9.95	13.15	23.10	5.50	1.02	6.52	42.04	5.39	47.43	6.52	3.81	10.33	0.00	0.00	0.00	5.50	1.02	6.52	42.04	5.39	47.43	6.52	3.81	10.33	6.93	1.38	8.31	53.49	7.52	61.01	7.96	4.86	12.82	0.00	0.00	0.00	0.00	0.00	0.00
Annual Total			332.26			12.84			85.63			23.10			6.52			47.43			10.33			0.00			6.52			47.43			10.33			8.31			61.01			12.82			0.00			0.00
Stage Total																																																

Table 15.9 Annual Disbursement of Construction Cost (Alternative B, R.O./Electric Power Portion)

(R.O. Million)

Item	Total			1996			1997			1998			1999		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Power Plant Facilities															
1 Civil Work															
1.1 Land Reclamation	0.83	2.00	2.83	0.17	0.20	0.37	0.67	1.80	2.47						
1.2 Water Intake and Outfall	3.13	7.28	10.41	0.31	0.73	1.04	4.88	1.46	6.34	0.94	5.10	6.04			
1.3 Common Buildings	1.41	3.34	4.75	0.42	0.33	0.75	0.99	3.00	3.99						
1.4 Foundation	1.57	3.66	5.23	0.03	0.06	0.09	0.24	0.55	0.79						
1.5 Power House	2.23	5.21	7.44	0.11	0.09	0.20	0.26	0.78	1.04						
										0.03	0.06	0.09	0.24	0.55	0.79
										0.11	0.09	0.20	0.26	0.78	1.04
2 Power Plant (C/C)															
2.1 GTG Equipment	193.99		193.99	1.49		1.49	13.43		13.43	1.49		1.49	13.43		13.43
2.2 GTG Erection	33.81	0.44	34.25	0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37
				1.49		1.49	13.43		13.43				1.49		1.49
				0.26	0.00	0.26	2.34	0.03	2.37				0.26	0.00	0.26
2.3 STG Equipment	163.52		163.52	2.73		2.73	19.08		19.08	5.45		5.45			
2.4 STG Erection	26.84	2.03	28.87	0.45	0.03	0.48	3.13	0.07	3.20	0.89	0.24	1.13			
										2.73		2.73	19.08		19.08
										0.45	0.03	0.48	3.13	0.07	3.20
B. Power Transmission Facilities	40.91	11.54	52.45	4.09	1.15	5.24	28.64	3.46	32.10	8.18	6.92	15.10			
Total (A - B) (1994 Price)	468.24	35.49	503.73	11.81	2.60	14.41	86.42	11.18	97.60	20.53	12.44	32.97	40.23	1.43	41.66
C. Other Cost															
1 Physical Contingencies (10%)	46.82	3.55	50.37	1.18	0.26	1.44	8.64	1.12	9.76	2.05	1.24	3.29	4.02	0.14	4.16
2 MEW Admi. Expense (0.5%)		2.52	2.52		0.07	0.07		0.49	0.49		0.16	0.16		0.21	0.21
3 Engineering Fee (1.5%)	7.56		7.56	0.22		0.22	1.46		1.46	0.49		0.49	0.62		0.62
Grand Total (1994 Price)	522.62	41.56	564.18	13.21	2.93	16.14	96.52	12.79	109.31	23.07	13.84	36.91	44.87	1.78	46.65
Annual Total			564.18			16.14			109.31			36.91			46.65
Stage Total			564.18									145.10			

Item	2000			2001			2002			2003			2004		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Power Plant Facilities															
1 Civil Work															
1.1 Land Reclamation															
1.2 Water Intake and Outfall															
1.3 Common Buildings															
1.4 Foundation							0.03	0.06	0.09	0.24	0.55	0.79			
1.5 Power House							0.11	0.09	0.20	0.26	0.78	1.04			
													0.03	0.06	0.09
													0.11	0.09	0.20
2 Power Plant (C/C)															
2.1 GTG Equipment				1.49		1.49	13.43		13.43	1.49		1.49	13.43		13.43
2.2 GTG Erection				0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37
	13.43		13.43				1.49		1.49	13.43		13.43	1.49		1.49
	2.34	0.03	2.37				0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26
	1.49		1.49	13.43		13.43									0.00
	0.26	0.00	0.26	2.34	0.03	2.37									0.00
2.3 STG Equipment							2.73		2.73	19.08		19.08	5.45		5.45
2.4 STG Erection							0.45	0.03	0.48	3.13	0.07	3.20	0.89	0.24	1.13
	5.45		5.45										2.73		2.73
	0.89	0.24	1.13										0.45	0.03	0.48
B. Power Transmission Facilities															
Total (A - B) (1994 Price)	23.87	0.27	24.14	17.52	0.03	17.55	20.83	0.22	21.05	40.23	1.43	41.66	27.18	0.45	27.63
C. Other Cost															
1 Physical Contingencies (10%)	2.39	0.03	2.42	1.75	0.00	1.75	2.08	0.02	2.10	4.02	0.14	4.16	2.72	0.05	2.77
2 MEW Admi. Expense (0.5%)		0.12	0.12		0.09	0.09		0.11	0.11		0.21	0.21		0.14	0.14
3 Engineering Fee (1.5%)	0.36		0.36	0.26		0.26	0.32		0.32	0.62		0.62	0.41		0.41
Grand Total (1994 Price)	26.62	0.42	27.04	19.53	0.12	19.65	23.23	0.34	23.57	44.87	1.78	46.65	30.31	0.64	30.95
Annual Total			27.04			19.65			23.58			46.65			30.95
Stage Total						101.29									

Item	2005			2006			2007			2008			2009			2010		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Power Plant Facilities																		
1 Civil Work																		
1.1 Land Reclamation																		
1.2 Water Intake and Outfall																		
1.3 Common Buildings																		
1.4 Foundation				0.03	0.06	0.09	0.24	0.55	0.79									
1.5 Power House				0.11	0.09	0.20	0.26	0.78	1.04									
	0.24	0.55	0.79				0.03	0.06	0.09	0.24	0.55	0.79						
	0.26	0.78	1.04				0.11	0.09	0.20	0.26	0.78	1.04						
2 Power Plant (C/C)																		
2.1 GTG Equipment				1.49		1.49	13.43		13.43	1.49		1.49	13.43		13.43			
2.2 GTG Erection				0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37			
	1.43		1.43	1.49			13.43			1.49			13.43					
	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37	0.26	0.00	0.26	2.34	0.03	2.37			
2.3 STG Equipment				2.73		2.73	19.08		19.08	5.45		5.45						
2.4 STG Erection				0.45	0.03	0.48	3.13	0.07	3.20	0.89	0.24	1.13						
	19.08		19.08	5.45			2.73			19.08			5.45		5.45			
	3.13	0.07	3.20	0.89	0.24	1.13	0.45	0.03	0.48	3.13	0.07	3.20	0.89	0.24	1.13			
B. Power Transmission Facilities																		
Total (A - B) (1994 Price)	38.47	1.43	39.90	13.16	0.43	13.59	57.56	1.64	59.20	32.55	1.64	34.19	37.89	0.30	38.19			
C. Other Cost																		
1 Physical Contingencies (10%)	3.85	0.14	3.99	1.32	0.04	1.36	5.76	0.16	5.92	3.26	0.16	3.42	3.79	0.03	3.82			
2 MEW Admi. Expense (0.5%)		0.20	0.20		0.07	0.07		0.30	0.30		0.17	0.17		0.19	0.19			
3 Engineering Fee (1.5%)	0.60		0.60	0.20		0.20	0.89		0.89	0.51		0.51	1.57		1.57			
Grand Total (1994 Price)	42.92	1.77	44.69	14.68	0.54	15.22	64.21	2.10	66.31	36.32	1.97	38.29	43.25	0.52	43.77			
Annual Total			44.69			15.22			66.31			38.29			43.77			
Stage Total						157.17									160.62			

Table 15.10 Annual Disbursement of Construction Cost (Alternative B, MSF/Desalination Portion)

(R.O. Million)

Item	Total			1996			1997			1998			1999		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Desalination Facilities															
1. Civil Work															
1.1 Land Reclamation	0.83	2.00	2.83	0.17	0.20	0.37	0.67	1.80	2.47						
1.2 Water Intake and Outfall	2.16	4.95	7.11	0.22	0.19	0.41	1.30	0.99	2.29	0.65	3.46	4.11			
1.3 Common Buildings	1.41	3.34	4.75	0.42	0.33	0.75	0.99	3.00	3.99						
1.4 Foundation	6.93	16.14	23.07				0.17	0.40	0.57	1.56	3.63	5.19			
1.5 Desal. Building	0.94	2.18	3.12				0.28	0.22	0.50	0.86	1.96	2.82			
2. Desalination Plant															
2.1 RO Equipment	122.02		122.02				4.58		4.58	25.93		25.93			
2.2 RO Erection	7.54	17.56	25.10				0.19	0.44	0.63	1.70	3.95	5.65			
B. Water Transmission Facilities															
1. Muscat Line															
1.1 Pipeline	18.40	4.50	22.90				1.84	0.46	2.30	16.56	4.14	20.70			
1.2 Barka Reservoir & Pumping Station	1.40	5.50	6.90				0.04	0.17	0.21	0.32	1.26	1.58			
2. South Batinah Line	12.8	3.14					1.28	0.31		11.52	2.83				
Total (A - B) (1994 Price)	174.45	59.49	233.94	0.81	1.03	1.84	11.33	7.76	19.09	58.89	21.23	80.12	0.00	0.00	0.00
C. Other Cost															
1. Physical Contingencies (10%)	17.45	5.95	23.40	0.08	0.10	0.18	1.13	0.78	1.91	5.89	2.12	8.01	0.00	0.00	0.00
2. MEW Admi. Expense (0.5%)		1.17	1.17		0.01	0.01		0.10	0.10		0.40	0.40		0.00	0.00
3. Engineering Fee (1.5%)	3.51		3.51	0.03		0.03	0.29		0.29	1.20		1.20	0.00		0.00
Grand Total (1994 Price)	195.41	66.61	262.02	0.92	1.14	2.06	12.75	8.64	21.39	65.98	23.75	89.73	0.00	0.00	0.00
Annual Total			262.02			2.06			21.39			89.73			0.00
Stage Total			262.02									113.19			

Item	2000			2001			2002			2003			2004		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Desalination Facilities															
1. Civil Work															
1.1 Land Reclamation															
1.2 Water Intake and Outfall															
1.3 Common Buildings															
1.4 Foundation	0.17	0.40	0.57	1.56	3.63	5.19							0.17	0.40	0.57
1.5 Desal. Building															
2. Desalination Plant															
2.1 RO Equipment	4.58		4.58	25.93		25.93							4.58		4.58
2.2 RO Erection	0.19	0.44	0.63	1.70	3.95	5.65							0.19	0.44	0.63
B. Water Transmission Facilities															
1. Muscat Line															
1.1 Pipeline															
1.2 Barka Reservoir & Pumping Station	0.04	0.14	0.18	0.32	1.26	1.58							0.04	0.14	0.18
2. South Batinah Line															
Total (A - B) (1994 Price)	4.97	0.98	5.95	29.50	8.84	38.34	0.00	0.00	0.00	0.00	0.00	0.00	4.97	0.98	5.95
C. Other Cost															
1. Physical Contingencies (10%)	0.50	0.10	0.60	2.95	0.88	3.83	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.10	0.60
2. MEW Admi. Expense (0.5%)		0.03	0.03		0.19	0.19		0.00	0.00		0.00	0.00		0.03	0.03
3. Engineering Fee (1.5%)	0.09		0.09	0.58		0.58	0.00		0.00	0.00		0.00	0.09		0.09
Grand Total (1994 Price)	5.56	1.11	6.67	33.03	9.92	42.95	0.00	0.00	0.00	0.00	0.00	0.00	5.56	1.11	6.67
Annual Total			6.67			42.94			0.00			0.00			6.67
Stage Total						49.61									

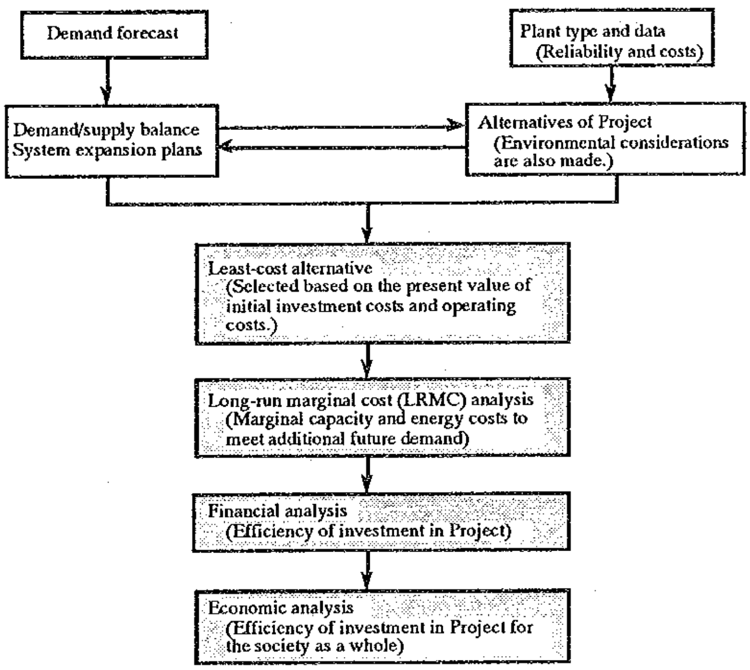
Item	2005			2006			2007			2008			2009			2010		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. Desalination Facilities																		
1. Civil Work																		
1.1 Land Reclamation																		
1.2 Water Intake and Outfall																		
1.3 Common Buildings																		
1.4 Foundation	1.56	3.63	5.19				0.17	0.40	0.57	1.56	3.63	5.19						
1.5 Desal. Building																		
2. Desalination Plant																		
2.1 RO Equipment	25.93		25.93				4.58		4.58	25.93		25.93						
2.2 RO Erection	1.70		1.70				0.19	0.44	0.63	1.70	3.95	5.65						
B. Water Transmission Facilities																		
1. Muscat Line																		
1.1 Pipeline																		
1.2 Barka Reservoir & Pumping Station	0.32	1.26	1.58				0.04	0.14	0.18	0.32	1.26	1.58						
2. South Batinah Line																		
Total (A - B) (1994 Price)	29.50	8.84	38.34	0.00	0.00	0.00	4.97	0.98	5.95	29.50	8.84	38.34	0.00	0.00	0.00	0.00	0.00	0.00
C. Other Cost																		
1. Physical Contingencies (10%)	2.95	0.88	3.83	0.00	0.00	0.00	0.50	0.10	0.60	2.95	0.88	3.83	0.00	0.00	0.00	0.00	0.00	0.00
2. MEW Admi. Expense (0.5%)		0.19	0.19		0.00	0.00		0.03	0.03		0.19	0.19		0.00	0.00		0.00	0.00
3. Engineering Fee (1.5%)	0.58		0.58	0.00		0.00	0.09		0.09	0.58		0.58	0.00		0.00	0.00		0.00
Grand Total (1994 Price)	33.03	9.91	42.94	0.00	0.00	0.00	5.56	1.11	6.67	33.03	9.91	42.94	0.00	0.00	0.00	0.00	0.00	0.00
Annual Total			42.94			0.00			6.67			42.94			0.00			0.00
Stage Total						49.61									49.61			

CHAPTER 16 ECONOMIC AND FINANCIAL EVALUATION

CHAPTER 16 ECONOMIC AND FINANCIAL EVALUATION

This chapter consists of five sections. The first section describes briefly the electricity generation and water production costs in recent years. We compare the actual production costs with the current tariffs of these utilities. In the second section, selection of the least cost solution is made among the alternatives for this project. These alternatives differ primarily in the type of desalination system (i.e., MSF and RO systems), as well as in the phasing. In the third section, discussions are made regarding the prices of the Project's outputs which are based on the concept of the Long-Run Marginal Cost (LRMC). Since our study is limited to the Barka Project, which includes the proposed power and desalination complex and related transmission facilities, it does not extend to such level of discussion as new tariffs, which may require the cost analysis of distribution facilities, production at other plants, and so on. Financial analysis of the Project is made in section four. Basically, two types of analysis are performed. In one type, the internal rate of return (IRR) is computed without considering inflation, debt services, or taxes. In the other, cash flow tables are prepared in nominal prices, taking into account inflation as well as the impact of debt financing. In the final section, economic analysis is performed and alternatives to the Project are discussed. Economic rates of return are calculated by two approaches; a revenue-based one and one that estimates the costs saved by carrying out the Project instead of its alternatives. Figure 16.1 exhibits the procedure of our economic evaluation. This chapter is concerned only with the study components which are shaded in the figure.

Figure 16.1 Procedure of Economic Evaluation



16.1 Current Power Generation and Water Production Costs

In its annual reports, MEW statistically analyzes production costs of electricity and water. Production costs are broadly classified into two, costs within plants and those outside plants. Fuel costs accounts for more than half of the total cost. The average consumer-end cost of electricity in the Northern Sector was 21.5 baiza/KWH in 1993. Approximately one-third of the total cost was subsidized by the Government.

16.1.1 Power Generation Costs

MEW defines costs inside plants as generation costs, and classifies them into five components: fuel, manpower, spares, equipment depreciation, and others. Manpower, in the case of the Muscat and Wadi Jizzi Systems, is a commission to a commune named SOJEX for operating power stations.

Costs outside plants are classified into three, transmission and distribution costs, MEW administration cost, and billing charges. The first cost item is further divided into equipment depreciation, operation and maintenance (O&M), and spares.

Table 16.1 exhibits total generation costs and unit generation costs (per KWH) for MEW's Northern Sector during the last three years. The Northern Sector consists of the Muscat and Wadi Jizzi Systems as well as some rural stations. Rural stations use diesel gas, and chiefly because of this, the unit cost is grossly higher than the counterfigures of the Muscat and Wadi Jizzi Systems. The average generation cost for the two systems in 1993 is calculated at 12.26 baiza (bz).

Table 16.1 Power generation costs (million R.O.)

	Fuel	Manpower	Spares	Equipment depreciation	Others	Total cost	Total power generated (GWH)	Cost of generation (BZ/KWH)
Northern Sector								
1991	50.10 (76.9%)	2.88 (4.4%)	3.11 (4.8%)	7.85 (12.1%)	1.18 (1.8%)	65.12 (100%)	4,182.0	15.57
1992	53.79 (76.1%)	3.37 (4.8%)	4.38 (6.2%)	7.78 (11.0%)	1.36 (1.9%)	70.68 (100%)	4,635.8	15.25
1993	58.62 (74.3%)	3.81 (4.8%)	6.48 (8.2%)	8.46 (10.7%)	1.51 (1.9%)	78.88 (100%)	5,301.4	14.88
Muscat System								
1991	28.92 (77.9%)	1.60 (4.3%)	1.34 (3.6%)	4.74 (12.8%)	0.51 (1.4%)	37.11 (100%)	3,083.5	12.04
1992	32.41 (77.5%)	1.79 (4.3%)	2.18 (5.2%)	4.74 (11.3%)	0.72 (1.7%)	41.84 (100%)	3,397.4	12.32
1993	35.87 (76.8%)	2.01 (4.3%)	2.75 (5.9%)	5.28 (11.3%)	0.77 (1.6%)	46.68 (100%)	3,862.5	12.09
Wadi Jizzi System								
1991	7.14 (79.2%)	0.38 (4.2%)	0.34 (3.8%)	1.12 (12.4%)	0.03 (0.3%)	9.01 (100%)	668.3	13.48
1992	8.09 (81.8%)	0.41 (4.1%)	0.24 (2.4%)	1.12 (11.3%)	0.03 (0.3%)	9.89 (100%)	755.8	13.09
1993	9.00 (79.2%)	0.53 (4.7%)	0.48 (4.2%)	1.28 (11.3%)	0.07 (0.6%)	11.36 (100%)	870.8	13.05
Rural stations								
1991	14.04 (74.0%)	0.89 (4.7%)	1.42 (7.5%)	1.99 (10.5%)	0.64 (3.4%)	18.98 (100%)	430.2	44.12
1992	13.28 (70.1%)	1.17 (6.2%)	1.97 (10.4%)	1.92 (10.1%)	0.61 (3.2%)	18.95 (100%)	482.7	39.26
1993	13.75 (65.9%)	1.27 (6.1%)	3.26 (15.6%)	1.91 (9.2%)	0.67 (3.2%)	20.86 (100%)	568.1	36.72

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

For the costs outside plants, systemwise breakdown figures are not available, whereas the total costs for the Northern Sector as a whole are known. It can be inferred that the costs for transmission and distribution, facilities and MEW administration are associated with the installed generation capacity and billing charges with the billed consumption. (Billing charges are subjected to the total amount of bills collected by the company in charge of metering and billing. For the rate of charges, see Appendix 1 of this chapter.) Table 16.2 shows the estimated systemwise outside-plant costs allocated according to this hypothesis.

Table 16.2 Outside-Plant Costs (Electricity)
1991 - 1993

(million R.O.)

	Transmission & distribution costs	MEW administration costs	Billing charges	Total costs	Installed capacity (MW)	Billed consumption (GWH)	Cost per KWH consumed (BZ)
Northern Sector							
1991	6.40	4.53	2.05	12.98	1,186	3,456.1	3.76
1992	6.10	5.97	2.23	14.30	1,186	3,814.4	3.75
1993	7.12	5.28	2.59	14.99	1,278	4,370.3	3.43
Muscat System*							
1991	4.25	3.01	1.52	8.77	787	2,557.1	3.43
1992	4.05	3.96	1.64	9.65	787	2,802.6	3.44
1993	4.55	3.38	1.89	9.82	817	3,195.4	3.07
Wadi Jizzi System*							
1991	1.05	0.74	0.33	2.12	194	558.1	3.80
1992	1.00	0.98	0.37	2.35	194	638.8	3.68
1993	1.24	0.92	0.43	2.59	222	728.8	3.55
Rural stations*							
1991	1.11	0.78	0.20	2.09	205	340.9	6.14
1992	1.05	1.03	0.22	2.30	205	373.0	6.18
1993	1.33	0.99	0.26	2.58	239	446.1	5.79

* Costs are estimated figures.

Table 16.3 exhibits the total costs including costs involved both inside and outside plants, and the consumer-end cost per KWH of energy. The consumer-end cost for the Northern Sector was 21.48 bz. per KWH in 1993, and was approximately 20 % higher than that for the Muscat System alone.

Table 16.3 Total Costs (Electricity)
1991 - 1993

(million R.O.)

	Costs within plants	Costs outside plants	Total costs	Power generated (GWH)	Billed consumption (GWH)	Total cost per KWH generated (BZ)	Total cost per KWH consumed (BZ)
Northern Sector							
1991	65.12	12.98	78.10	4,182.0	3,456.1	18.68	22.60
1992	70.68	14.30	84.98	4,635.8	3,814.4	18.33	22.28
1993	78.88	14.99	93.87	5,301.4	4,370.3	17.71	21.48
Muscat System							
1991	37.11	8.77	45.88	3,083.5	2,557.1	14.88	17.94
1992	41.84	9.65	51.49	3,397.4	2,802.6	15.16	18.37
1993	46.68	9.82	56.50	3,862.5	3,195.4	14.63	17.68
Wadi Jizzi System							
1991	9.01	2.12	11.13	668.3	558.1	16.65	19.94
1992	9.89	2.35	12.24	755.8	638.8	16.19	19.16
1993	11.36	2.59	13.95	870.8	728.8	16.02	19.14
Rural stations							
1991	19.00	2.09	21.09	430.2	340.9	49.02	61.87
1992	18.95	2.30	21.25	482.7	373.0	44.02	56.97
1993	20.84	2.58	23.42	568.1	446.1	41.23	52.50

Note: Systemwise costs are slightly different from those appearing on page 45 of the MEW's annual report for 1993. This difference may be attributed to the fact that the outside-plant costs in this table are not actual but estimated figures.

Regarding consumer costs, non-recurrent, initial expenses attributable to such items as meters and service drop lines are paid fully by the customers directly to private companies which are under contract to MEW. New customers are charged connection fees according to the following rates. Except for these connection fees, the sale of electricity is the only operating income for MEW.

	R.O. per connection
Domestic	
Single phase	10
3-phase	40
Other	
≤500 KVA	200
>500 KVA	500

16.1.2 Water Production Costs

The Ghubrah Desalination Plant has been equipped with a total capacity of 29 million gallons per day (or 131,818 m^3/d), since an additional capacity of 5 million gallons per day was developed in September 1992 by the plant's fifth-phase construction. Water production costs are classified into six categories, fuel (natural gas), manpower, spares, chemicals, depreciation, and others. Others include electricity consumed and consumables (see Table 16.4).

Table 16.4 Production Costs of Distillate 1990 - 1993

(million R.O.)

Year	Fuel (gas)	Manpower	Spares	Chemicals	Depreciation	Others	Total	Distillate produced (mil. m^3)	Cost per m^3 distillate produced (R.O.)
1989	10.56	1.10	0.30	0.41	4.59	1.96	18.92	32.77	0.58
1990	10.22	1.10	0.30	0.38	4.81	1.92	18.73	33.13	0.57
1991	10.98	1.10	0.60	0.39	4.81	2.04	19.92	34.85	0.57
1992	11.02	1.26	0.38	0.38	5.35	2.20	20.59	34.99	0.59
1993	13.22	1.34	0.63	0.45	6.96	2.60	25.20	42.22	0.60

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

Approximately 466.5 million m^3 of gas was consumed for the production of water at the Ghubrah station in 1993. This figure being multiplied by the price of gas at 0.028 R.O. per cubic meter gives the total fuel cost computed at 13.22 million R.O., as shown in Table 16.4. "Others" for that year consisted primarily of the electricity cost of 2.15 million R.O. and the consumables cost of 0.38 million R.O. The total power consumption was 153,836 MWH. Thus, the purchase price of electricity is calculated at 14 bz/KWH. Approximately 1.4% of the total water produced (0.60 million m^3) was consumed within the plant by both the electricity and water divisions. The production cost per cubic meter of water transmitted or delivered is thus computed at about 0.6053 R.O., which is equivalent to 0.00275 R.O. per gallon. Further, as the total billed consumption in the Muscat Area in 1993 was about 36.1 million cubic meter (or 7,941 million gallons), the production cost per cubic meter of water consumed was 0.6907 R.O. (i.e., 0.00317 R.O. per gallon).

Regarding outside-plant costs, the following expenditures are reported for 1993.

		R.O.
1	Operation of maintenance of transmission and distribution facilities*	548,000
2	MEW administration	939,986
3	Spares	50,000

* Some investment-related costs may be included.

The total of these outside-plant costs is approximately 1,538,000 R.O., which corresponds to 0.0426 R.O. per cubic meter of water consumed (or 0.000194 R.O. per gallon). (For reference, the current capital investment programmes for water transmission and distribution facilities are exhibited in Appendix 2.)

Thus, the consumer-end cost of water that includes both inside and outside plant costs in 1993 is calculated at 0.7333 R.O. per cubic meter or 0.0033 R.O. per gallon.

Similar to the case of electricity, non-recurrent initial consumer costs are fully paid by consumers. For the extension of an existing distribution line, 7 R.O. per meter is charged up to 20 meters, and actual cost over 20 meters. New consumers also have to pay the following connection fees.

Pipe diameter	R.O. per connection
For half inch	40
For 3/4 inch	50
For 1 inch	65

16.1.3 Existing Tariffs and Government Subsidies

Existing tariffs do not fully reflect the actual costs. In Tables 16.5 and 16.6, comparisons are made between the tariffs and the estimated costs for electricity and water. The power tariffs are designed to discourage high consumption and consumption during summer months, although tariffs hardly meet actual costs even at high slabs or for the peak season. The commercial tariff exceeds the actual (but in fact estimated) costs except for rural stations.[1] Introduction of capacity charges may be required to correct this potential cross subsidization.

Table 16.5 Comparison of Electricity Tariffs and Consumer-End Estimated Costs (1993)

(BZ/KWH)

Category	Type of consumer	Tariff	Consumer-end estimated cost
1. DG	Domestic & Government		
	Slab KWH		
	Up to 3,000	10	
	3,001 - 5,000	15	
	5,001 - 7,000	20	
	7,001 - 10,000	25	
	Above 10,000	30	Northern Sector:
2. C	Commercial	20	21.48
3. I	Industrial		
I-1	Within specified category		Muscat System:
	Summer (May - Aug.)	24	17.68
	Winter (Sep. - Apr.)	12	
I-2	Outside specified category		Wadi Jizzi System:
	Summer	24	19.14
	Winter	16	
4. AF	Agriculture & Fisheries		Rural stations:
	Slab KWH		52.50
	Up to 7,000	10	
	Above 7,000	20	
5. HT	Hotel & Tourism		
	Slab KWH		
	Up to 3,000	10	
	3,001 - 5,000	15	
	Above 5,000	20	

1 Accordingly to the MEW's annual report, 0.66% of the costs involved in commercial consumption in 1993 was subsidized by the Government.

Table 16.6 Comparison of Water Tariff and Consumer-End Estimated Costs (1993)

(BZ/gallon)

Tariff		Consumer-end estimated cost*
Domestic & Government	2	
Commercial & Industrial	3	
Government Tanker	2	3.3
Private Tanker		
≤700 gallon	1	
>700 gallon	3	

* Billing charges are unlikely to be included.

Table 16.7 shows the financial performance of the MEW Northern Sector's power division. The revenue consists of actual receipts from the sale of power to consumers, an equivalent revenue from the sale of power to the MEW's water division, and a share of the MEW's operating costs by Oman Mining Company whose generators at the Wadi Jizzi Station are operated by MEW. The total revenue accounts for approximately three-quarters of the total cost. The remaining one-quarter of the cost is subsidized by the Government.

Table 16.7 Summary of Financial Performance-MEW Electricity Sector, Northern Sector 1990 - 1993

(Million R.O.)

Description	1990	1991	1992	1993
1. Billed Amount	50.68	50.83	55.29	62.86
	66%	66%	72%	82%
2. Equivalent Revenue from Desalination Plants	1.98	2.46	2.18	2.56
	3%	3%	3%	3%
3. Total Revenue (1 + 2)	52.66	53.29	57.47	65.42
	68%	69%	75%	85%
4. Total Production Cost (MEW)	77.10	76.40	83.40	92.39
(Excluding OMCO Costs)	100%	100%	100%	100%
5. Total Subsidy (3 - 4)	24.44	23.11	25.93	26.97
	32%	30%	34%	35%

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

16.2 Least Cost Alternative

For a utility project, because its outputs are basically the same in quality and therefore in benefit among its alternatives, the best alternative can be determined on the basis of the total of the capital and operating costs for the project.[2] Four alternatives, the main features of which are depicted below, have been developed for the Project (for detailed information, see relevant discussions in Chapter 15). They differ in the project configuration, specifically, as to whether the type of the desalination plant selected is the MSF or RO system. Different types of desalination system require different types of generation equipment, and also their consumptions of energy to produce water differ. They also differ in project phasing or implementation schedule. All of them meet the same level of demand, and therefore they are the same as far as the operating income is concerned.

Alternative 1 (Option A-1):

Implementation	:	4 stages
Desalination system	:	MSF system
Total installed capacity (power)	:	1,796 MW
Total installed capacity (water)	:	254,560 m^3/d

Alternative 2 (Option B-1):

Implementation	:	4 stages
Desalination system	:	RO system
Total installed capacity (power)	:	1,848 MW
Total installed capacity (water)	:	254,560 m^3/d

Alternative 3 (Option A-2):

Implementation	:	2 stages
Desalination system	:	RO system
Total installed capacity (power)	:	1,796 MW
Total installed capacity (water)	:	254,560 m^3/d

2 As Figure 16.1 indicates, prior to this stage, alternatives are explored. All of them have found to satisfy the reliability and other technical requirements, so that the comparison of the alternatives can now be made solely in monetary terms.

Alternative 4 (Option B-2):

Implementation	:	2 stages
Desalination system	:	MSF system
Total installed capacity (power)	:	1,848 MW
Total installed capacity (water)	:	254,560 m^3/d

Among the capital cost components, the capacity costs for transmission facilities are the same for all the alternatives. The difference in cost comes from the cost for power generation and water production, and operating expenditures including fuel.

The least cost alternative is the one that has the lowest present value of discounted costs. We apply the assumed discount factor of 8 % to this present value calculation. Regarding the phasing or the timing of additional generating (or production) units, investment should be deterred to the extent possible, in order to reduce the present-worth costs. It is also true that even if its initial investment costs are high, an alternative with high efficiency of energy, and thus low operating costs may be a better alternative.

An issue of idle capacity vs. economies of scale is also involved. To attain a higher level of scales of economy, investment in a fewer number of phases and/or installment of larger capacity units are desirable, whereas this strategy may invite a loss due to overcapacity[3]. Capacity expansion plan should be determined so as to better fit the projected demand curve.

Costs have to be compared not only in financial terms but also in economic terms, so that it can be assured that the alternative selected is of the least cost in both financial and economic values. In the economic analysis, local cost components, if their market prices do not reflect their true economic values, have to be shadow-priced. Some detailed explanation concerning economic prices is provided in Appendix 3 of this chapter.

Based on the capital costs estimates provided in Chapter 15, tables of cost streams for all the four alternatives are prepared and presented in Appendix 16.4. The key

3 No alternatives were made for unit capacities, as have been discussed earlier in this report. Regarding power generators, appropriate choices of unit capacity are 60 MW, 100 MW, and 120 MW. The reliability is relatively low at the level at 120 MW. Between 60 MW and 100 MW, it is apparent that the latter is economically better. With regard to the unit production capacity of water, the level at 5 to 7 MGD is common in the Middle East. The current unit capacity at the Ghubrah plant is 6 MGD. For the Barka, the level of 7 MGD is sought, so that construction costs per gallon can be reduced.

assumptions and estimated unit costs for operation that are used are also exhibited. As a summary of the cost estimates, Tables 1 to 4 in Appendix 16.5 compare the discounted costs of the respective alternatives. A simplified conversion factor of 0.9 was used to shadow-price all the local currency components. (For a discussion regarding the conversion factor, see Appendix 16.3.) The least cost alternative was found to be Alternative 2, in which the RO system is used for the desalination process and the implementation is scheduled to be made in four stages. Instead of 8%, discount factors of 7%, 9%, and 10% were applied, to test for any change in the order of total costs among the four alternatives. No changes were observed. For Alternative 2, we perform financial and economic analysis later in this chapter.

16.3 Prices of the Project's Outputs

In order to measure the Project's benefit in quantitative and monetary terms, prices (shadow prices) of the Project's outputs must be determined. For this purpose, we employ the concept of long-run marginal cost (LRMC). The prices of the outputs are based on the costs involved in the Project, of which scope, it should be noted, is limited and does not cover the construction of power and water distribution facilities, nor consumer costs.

16.3.1 Concept of Long-Run Marginal Cost (LRMC)

Marginal cost is defined as the addition to total cost when one more unit of output is produced. In the long run planning, say, for the beginning of production ten years from now, a firm is able to vary all of its inputs, being unrestricted by its present resources. Long-run marginal cost is the marginal cost involved in such an environment.

For utility projects, marginal costs are usually classified into the following broad categories: capacity costs, energy costs, and customer costs. In the case of electricity, marginal capacity costs are basically the capital investments in generation, transmission and distribution facilities to supply the additional kilowatts. Marginal energy costs are the fuel and other operating costs required to supply additional kilowatt-hours. Marginal customer costs refer to hook-up, metering, billing, and other recurrent and non-recurrent costs directly attributable to customers. Figure 16.2 shows a typical cost classification. (The shaded components are those included in the Project.)

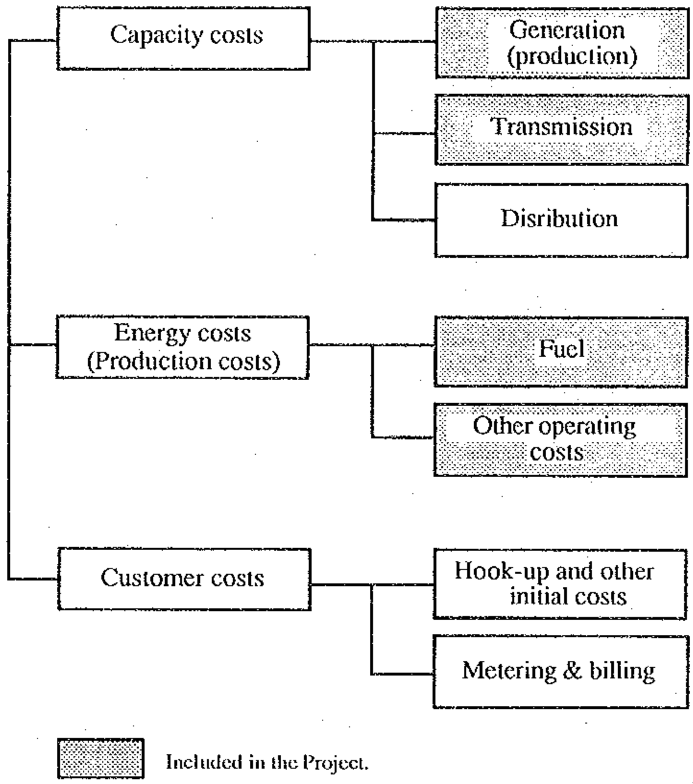


Figure 16.2 Cost Classification

As the above figure indicates, capacity costs for distribution facilities, as well as customer costs are not included in the Project. Transmission facilities that the Project intends to cover are limited to (1) those required to interconnect the existing substation in Madinat Qaboos and the proposed Barka Station for electricity and (2) those required to connect with the existing Muscat Water System at some points near its reservoirs, and to provide water to the concerned walayats in South Batinah for water. It should be noted that facilities that may be required in the future, as supply areas expand, but which are not foreseeable at the present time are not included in the scope of the Project. For the purpose of convenience, we classify in this report all the recurrent capacity costs (operation and maintenance, and administration and general) in the energy (production) costs.

Existing tariffs consist of energy charges alone. No fees such as capacity charges are collected, although it does not necessarily mean that capacity costs are covered by energy charges.