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PAPER 4

Water Supply to the Coastal Desert in Egypt

by

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In this paper a comprehensive analysis of pipeline and seawater desalination methods of supplying fresh water to coastal areas in Egypt is presented. The two methods are compared from the aspects of capital and running costs, reliability, maintenance and flexibility to load variation.

For the different methods of desalination a cost analysis was made using international and Egyptian energy costs both for single plants and for dual-purpose plants coupled to gas turbines.

INTRODUCTION

In Egypt a great quantity of fresh water is supplied by the River Nile. However, in spite of that, Egypt, generally, suffers from a shortage of fresh water, especially along the coasts of the Mediterranean sea, the Red sea and Sinai. This is mainly because of the small amount of rainfall in these coastal areas. Figure 1 shows the monthly rainfall at Daba which is on the Mediterranean coast.

Supplying water to coastal areas in the required quantity and quality is of vital importance to the improvement of the Egyptian national income, because of the revenue that will result from the establishment of new residential areas and the promotion of such activities as tourism, fishing, mining and petroleum exploration.

The estimated maximum amount of fresh water required by Egypt by the year 2000 in m^3 per day, excluding industrial activities in the different coastal zones, is given in the map in Figure 2.

There are two main alternatives for the supply of fresh water to the Egyptian coastal areas. The first is the use of a pipeline to pump the fresh water from the nearest Nile source to the required areas. The second is the desalination of the available underground and/or surface sea water. Supplying water to the Mediterranean coast by various ordinary methods of transport seems to be an impractical for economic and reliability considerations.

In this paper, the two alternatives for supplying fresh water to coastal areas in Egypt are analysed from both the economic and technical points of view according to the prevailing conditions.

THE PIPELINE METHOD

In estimating the cost per cubic meter for transporting Nile water from the nearest point to a given area using this method, the following data and assumptions were used:

The Nile water will be pumped from Alexandria to the Mediterranean-sea west coastal area, from Qena to the Red sea coast and from Ismailia to Sinai.

A 10% loss along the pipeline will be assumed as a result of possible illegal connections to the system, or by any leakage through cracks and faults in the pipeline.

Economic water velocity inside pipeline is 2.25 m/sec. (1).

Material of construction of the pipeline is ductile iron.

Capital cost per km length of 700-mm diameter ductile-iron pipeline is 160×10^3 LE/km (based on data available in May 1982).

This cost includes, the required booster-pump stations, connections and installations. (2).

Depreciation duration is 20 years.
Interest rate is 12%.
Cost exponent of pipeline (cost vs diameter squared) is 0.72. (1)
Cost of spare parts is 0.2 Pt/m^3.
Operating and maintenance cost is 0.019 Pt for each m^3 of water per km of the pipeline length (2).
Cost of the pumping power is 0.0022 Pt per m^3 of water for each km length of the pipeline (2).
Operating factor is 95%.

The main features of the different pipelines and the unit cost at different locations are shown in Table I.

The pipeline method of transporting fresh water has the additional advantages of high reliability and high flexibility with respect to load fluctuations, and its operation and maintenance do not need skilled labour. On the other hand, there are several drawbacks to this method, such as high initial capital investment, design and construction must be based on the full capacity estimated at the end of the lifetime of the pipeline, a large land area is required for the pipeline itself and for maintenance facilities and a relatively-long time is required for installation.

SALT-WATER DESALINATION METHODS

Unfortunately, the available data on the underground water in the coastal zones in Egypt are not sufficient and not satisfactory both from the point of view of quantity and salinity. For this reason this analysis will be concerned only with sea-water desalination.

The current commercial sea-water desalting processes include brine circulating multi-stage flash (MSF-BR), multiple effect horizontal falling film (ME-HFF), vapour compression (VC) and reverse osmosis (RO). In the course of defining the appropriate standard for comparing and selecting the most suitable desalination process to be used in Egypt, attention must be focussed not only on the overall cost per m^3 of fresh water but also on other factors:

Possibility of local production using the available Egyptian technology and raw materials of construction.

Standard of personnel required to operate and maintain the plant.

Process reliability.

Process flexibility with respect to variation in demand.

Dependance of the plant operation and maintenance on the foreign market.

Energy Consumption

Energy requirements, for prevailing sea-water desalting processes, cannot be expressed by a unique figure for each process, since location and design conditions have a considerable effect upon the actual energy consumption.

The energy used for distillation sea-water processes (MSF-BR), (ME-HFF) and (thermal VC), is mainly "low grade", usually low-pressure steam, together with a considerable amount of shaft power to drive pumps and other auxiliaries. Reverse osmosis plant required "high-grade" energy for shaft power only, normally provided by electric motors. To enable a true comparison between the different sea-water desalination processes to be made, the energy required for each unit of fresh water must be referred back to the output energy from fuel needed at the boiler plant or the appropriate thermal power plant. Substantial energy savings of ten can be achieved by the use of exhaust-heat recovery from power or chemical plants in desalination processes. The most advantageous combination in such dual-purpose plants is obtained with gas turbines (3), where the waste heat can be recovered at a temperature high enough for the desalination plant to be operated over the normal range.

Assuming an efficiency of 30% in converting the thermal form of energy to electricity, the ranges of energy consumption per unit of fresh water for both single-and dual-purpose plants (gas turbine-desalination) are shown in Table II (4-7).

It should be pointed out that the energy requirements for typical sea-water (35,000 mg/litre) desalination by RO are approximately 94% of that required for the higher salinity Red Sea water.

Cost estimation

The cost of desalting sea water is made up of two major items viz, capital and annual operating costs. For a fair and accurate comparison, the following cost analysis was based on the following assumptions:

Plant capacity is 10,000 m^3/day.
Life of the plant is 20 years.
Interest rate is 12%.
International cost of oil is LE 250/ton.
Egyptian cost of oil is LE 15/ton.
One kilowatt-hour of energy requires 0.24 kg of oil.
Prices are related to the year 1982.
Plant factor for thermal processes is 70% and for RO is 90%.
Thermal performance for the different distillation processes is 9.
Costs of coupling the desalination units to a gas-turbine power plant are not included.

The cost components and the unit product cost for the different desalination processes according to the international and Egyptian energy prices are shown in Table III.

Other factors affecting desalination processes

Production flexibility of desalination plants to cope with the variations in daily and seasonable demand is very important, especially when a plant is coupled to a power-generation unit.

The RO units are most easily adaptable to varying production requirements because they are usually furnished in multiples of small-capacity units, each having a rapid start up time and a low brine-flow rate. The thermal desalination processes show a poor response to load variation because time is required to build up the operating vacuum and, usually, another requirement is a high brine-flow rate. The VC process is of good flexibility because it requires a small brine-flow rate as compared to the other distillation processes.

The RO process normally requires significantly more careful pretreatment than the distillation processes. The water quality that can be achieved by RO is very much dependent on the feed-water salinity, the working pressure, the water conversion factor and the ambient temperature. However, the quality of feed water has little effect on the complexity of the different thermal processes.

Due to the fact that the RO process typically involves the use of a number of small units, an increase in maintenance requirements can be expected. The maintenance of thermal plants using acid for water treatment is relatively high because of corrosion problems and the necessity to incorporate a pH control system.

CONCLUSIONS

From the investigation of the two methods of supplying fresh water to Egyptian coastal areas it was found that the most economical and technically efficient method which should be used is the pipeline method.

In the desalination method it was found that the cost of producing fresh water from the RO with energy recovery, VC and ME-HFF is nearly the same. However, in Egypt and ME-HFF method of desalination is recommended because it is relatively easy to establish and very suitable for coupling to gas-turbine power plants which are available in the coastal areas in Egypt where they are the main forms of power generation.

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TABLE I

Unit cost in different coastal areas

Area	Pipeline	Distance km	Capacity m³/day	Diameter mm	Capital invest. LE x 10^6	Cost Pt/m³
ElHammam	Alex/ElHam.	67	247850	1336	39.066	9.613
ElDaba	ElHam/ElDaba.	99	194450	1184	45.287	23.722
M.Matruh	ElDaba/Matr.	129	92950	837	29.538	42.786
S.Barani	Mat./Barani	183	13450	311	4.795	68.715
Salum	Bar./salum	66	1750	112	0.272	78.114
Safaga	Qena/safaga	165	74200	731	28.802	23.4
Quesier	Saf./Quesier	60	11130	283	1.571	32.04
Hardagha	Saf./Hardagha	65	32100	481	4.909	32.738
R.Gharb	Hard./R.Gharb	250	19840	387	12.219	60.16
ElArish	Ism./ElArish	195	77636	713	32.377	25.494
S.ElShi	Ism./S.ELshi	373	15945	339	13.991	52.645
Dahab	S.ElShi./Ism.	145	4465	179	0.746	66.40

TABLE II

Specific energy consumptions for different desalination processes; kJ/kg of water.

Distillation processes						Reverse Osmosis			
MSF-BR		ME-HFF		VC		With energy recovery		Without energy recovery	
single	dual	single	dual	single	dual	single	dual	single	dual
320	190	121	82	130	50	109	25	90	20
200	113	110	70	110	57	100	22	70	15

TABLE III

Cost components for different desalination processes

Cost		MSF-BR	ME-HFF	VC	RO with energy recovery	RO without energy recovery
Capital cost LEx10^6		16.13	13.07	14.5	16	16
Energy costs						
1-Energy (single)						
International		77.2	37.37	33.98	22.45	33.97
Egyptian		23.32	11.29	10.22	6.78	10.23
2-Energy (dual)						
International		46.32	22.86	16.99	4.77	8.2
Egyptian		13.99	6.9	5.11	1.48	2.4
Chemicals		2.3	2.3	2.3	10.3	10.3
spare parts		10.5	10.5	10.5	16.7	16.7
operating and maintenance		20.4	20.4	20.4	18.6	18.6
Unit cost						
single	Intern.	184.2	130.5	133.2	133.6	144.7
	Egypt.	130.3	104.4	109.9	117.6	121.0
dual	Intern.	153.3	125.9	116.7	115.6	119
	Egypt.	121.0	110.0	104.8	112.3	113.2

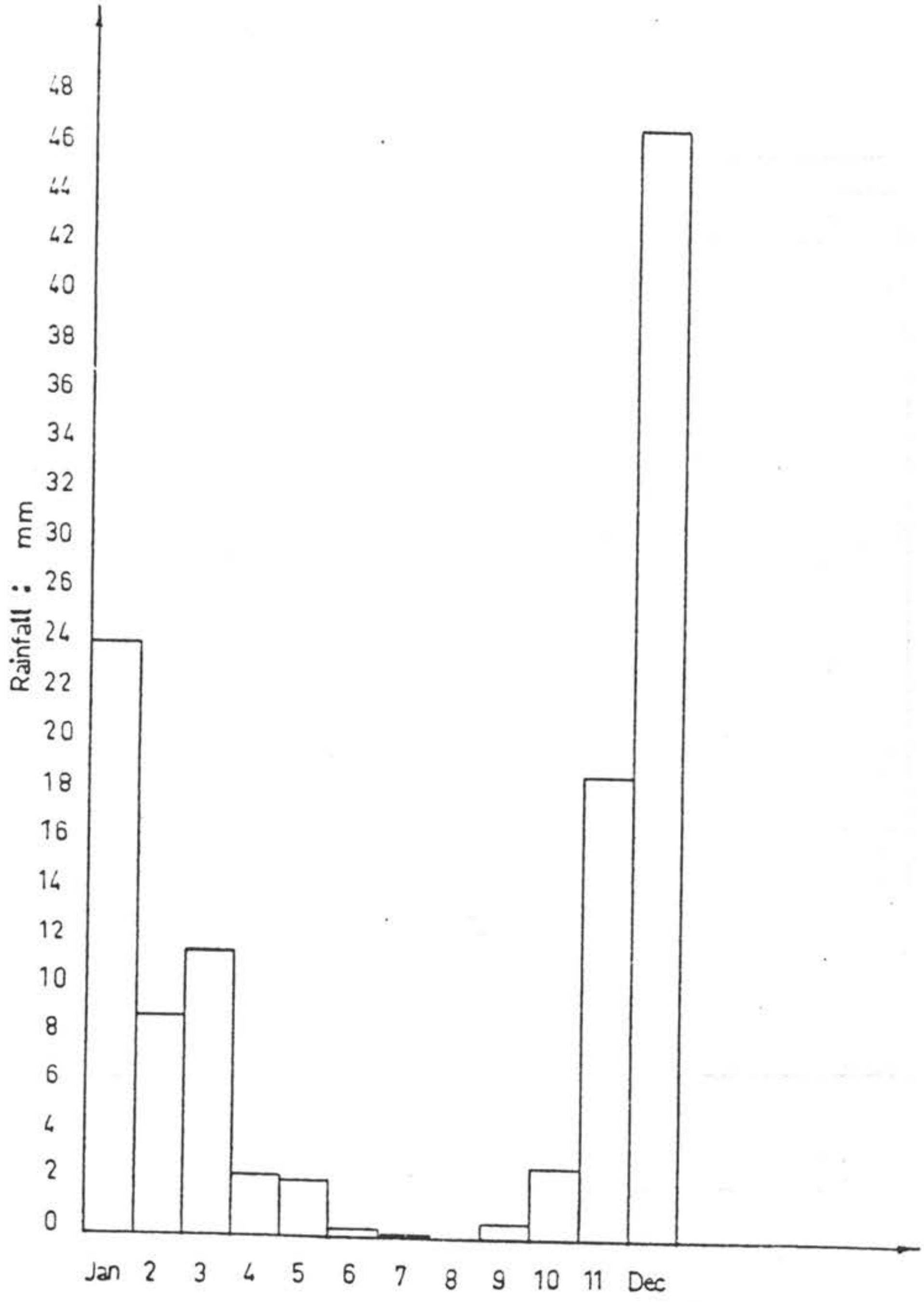

FIGURE 1. Monthly rainfall at Daba

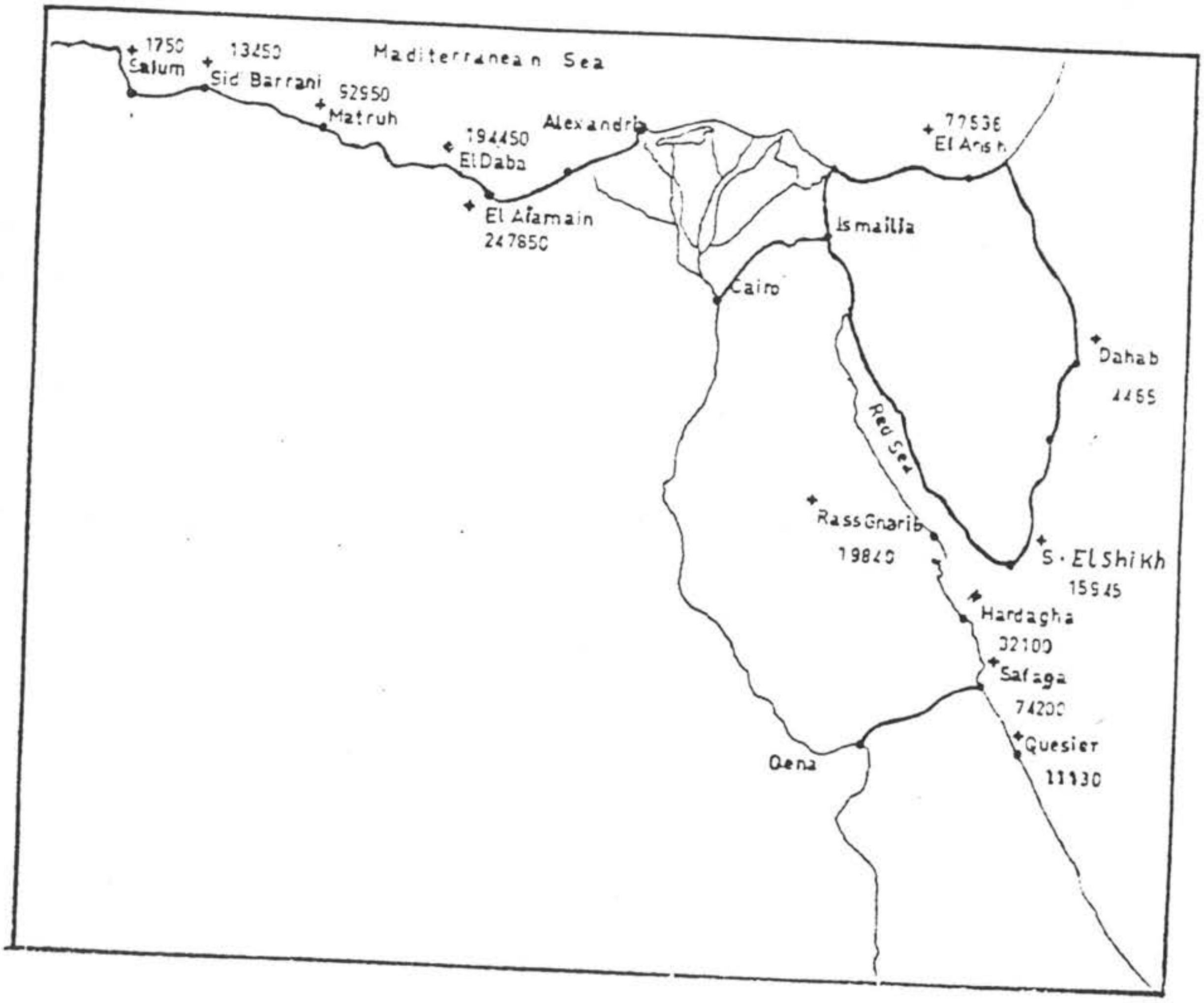

FIGURE 2. Map showing Egypt's requirements of fresh water estimated for the year 2000. Figures are in m³/day.