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Solving the Water Problem of the Middle East

INTRODUCTION

This paper describes the Israeli part of a coordinated regional study which sets out to formulate, appraise and evaluate alternative development programmes. It is a contribution to an international effort, led by the World Bank, to achieve sustainable development in the region, on the premise that coordination between neighbouring countries in water development and usage could increase the total amount of usable water for all. The net result of such coordination would thus be a 'positive-sum game' in which all players stand to gain. Political issues, and the principles of allocating resources between countries, are, however, beyond the terms of reference.

Geographically, the study relates to land and populations between the Mediterranean and the Jordan River, that is, areas in Israel within the 'green line', and the West Bank and the Gaza Strip. The study takes into full account the implications of urbanization processes, water quality and environmental considerations and, especially, water environment considerations. Although the work was done with reference to a specific zone, the issues which it raises are common to many parts of the world; hence the suggested solutions could serve as a model for areas where water shortage exists or is anticipated.

Based on a review of water supply and demand projections for Israel over the period 2000–2040, the study puts forward technical programmes for future water development in Israel and throughout the Jordan Basin. The alternative programmes are discussed in the light of their relative contributions to an overall solution of problems relating to water quality, quantity, supply reliability, transport and costs. Proposed solutions to the problems of closing the water supply gap will clearly tend towards programmes incorporating waste water reclamation and desalination of both brackish water and sea water. It is estimated that, up to the year 2010, the gap could be closed primarily by increased use of reclaimed waste water. After this, the main solution to the deficiency problem would be the gradual introduction of sea water desalination projects.

The anticipated growth in population of urban regions will bring about an increase in the demand for fresh water and increased production of sewage water. Population growth will also raise the demand for agricultural produce. However, increasing efficiency in agriculture will enable supply to expand

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without significant addition of water, and the process will be aided by utilizing reclaimed waste water. Hence agriculture will be able to spare some fresh water for urban use. Consequently, the main utilization of fresh water will be in urban areas, while its use in farming will decrease as the dependence on purified waste water expands. That will be followed by a growing gap in the prices which the urban sector will be paying for the use of water, and for its removal, compared with the average price of waste water in agriculture.

Waste water reclamation, it will be seen, is considered not only as a water supply stopgap but also as a means of disposing of sewage in a manner appropriate to the ecological and environmental requirements of the twenty-first century. The choice of sea water desalination as the ultimate solution, rather than importation of water from other countries, was determined on the basis of the following considerations:

(1) The engineering/economic parameters of water importation programmes and evaluation of their cost are highly uncertain (except in the case of a canal from the Nile, on which engineering data are of a higher level).
(2) A downward trend is foreseen in the cost of erecting new water desalination projects and those currently operating, owing to technological improvements expected to appear in the next 20 years.
(3) Sea water is the only existing quantitatively unlimited source of water.
(4) Since importation of water depends on extraterritorial agreements, it may involve political dangers, as well as the possibility that the price charged for the water could be at least as high as the alternative cost of desalination.
(5) In future systems, exploiting water of different qualities, including reclaimed waste water, the mineral quality of the water will have to be ameliorated by dilution with high-quality desalinated water.

Although the assumptions in a study of this type are necessarily uncertain, should the main recommendations be accepted the course taken will be in the direction of immediate implementation of treatment and reclamation projects, and the beginning of desalination towards the year 2010. An error in assumptions may involve adjustment of the year for starting desalination, making it earlier or later than 2010. If, indeed, the assumptions lead to such an error, and if at the same time immediate preparations for entry into the desalination age are decided upon, the error can be corrected according to actual developments between the years 2000 and 2005.

Though the importance of neighbourly coordination regarding water use and sewage disposal may seem self-evident, it is, in fact, vital. A distinction has to be made, however, between the approach adopted regarding activities undertaken by Israel within the defined area between the Jordan and the Mediterranean Sea and activities undertaken involving coordination with Jordan. Clearly, integrated activity between Israel and the future Palestinian Autonomous Authority is inevitable since this region constitutes an almost unified hydrological unit. The progressing peace process in the area will enable a discussion with the Jordanians, based on a similar study done by them. This should result in the presentation of solutions based on the cooperation between all of the elements in the area.

Practical solutions to the problems of water in the region from a comprehensive viewpoint will call for heavy investments and the formation of suitable financial mechanisms to carry programmes forward.

THE GEO-URBAN OVERALL PLAN

According to projections and Israel's present planning concept, most of the country's population will continue to concentrate in the metropolitan area between Hadera and Gedera, with Tel Aviv at its centre. The heaviest concentration will be in Tel Aviv and its satellites, and will live in built-up areas. This concentration will be 'self-created' owing to the dynamics of metropolitan development, which may be encouraged by the government for transport reasons since no efficient system now exists for daily commuting into the city of a large part of the population living in the metropolitan outskirts.

In addition to Tel Aviv, other urban centres such as Haifa, greater Jerusalem and Gaza are expected to grow in population. In parallel, smaller urban concentrations will grow up throughout the country, in towns like Be'er Sheva, Carmiel, Kiryat Shmonah, Ramalla and Nablus. Population growth will alter the relationship between the amount of water supplied to the urban and to the agricultural sectors. With the increasing shift to urban concentrations, the problems of water quality and disposal of sewage will be accentuated.

WATER QUALITY

Population growth and density, water scarcity and heightened awareness in matters of health and environment will place water quality at the centre of the problems of the system in the years 2000–2040. Drinking water and supply for some industrial purposes will have to meet very high standards, demanding appropriate raw water treatment (as long as there is no desalination).

This study presumes that removal and conveyance of water that has served various urban uses will, in future, only be permitted in closed systems, unlike the present situation in which sewage (some of it totally untreated) flows into cesspits, wadis, river beds and the sea. The final stage of the treatment of waste water removed in closed systems would be irrigation use.

As part of the water system, agriculture will play an important role in determining water quality. Irrigation will form an integral part of the waste water treatment and removal system, and agriculture will have to adapt itself to a regime of balanced fertilization and controlled farming subject to soil and water source pollution prevention and food quality constraints.

METHODOLOGY OF THE STUDY

The study is not confined to locating water supply gaps and performing simplistic economic analyses of the feasibility of closing them. Water sources and uses have been examined along a time axis to take account of the projected developments bearing on the various parameters, including classification of water source according to geographical distribution and quality. The possibilities studied for closing gaps took into consideration existing sources, possible additional quantities from such sources, the whole subject of waste water and two main categories of unconventional sources: water imported from other countries and desalination. Although waste water reclamation has been practised for some time, and was stepped up in the late 1980s, it may still be seen as an unconventional source in the overall future context, since engineering problems remain to be solved and, above all, significant finance is required for its further development.

PLANNING ASSUMPTIONS

Four assumptions underlie the work:

(1) Israel's population is expected to increase from 4.9 million in 1990 to 7.7 million in 2010 and 12.8 million in 2040.
(2) The Arab population in the West Bank and the Gaza Strip is expected to increase from 1.6 million in 1990 to 3.2 million in 2010 and 6.3 million in 2040.
(3) Per capita water demand in the urban and industrial sectors is almost inflexible and is expected to remain at its present level of an annual 120 cu.m. at the beginning of the period and decrease to 110 cu.m. per capita by 2040. The annual per capita demand in the West Bank and Gaza Strip is at present 35 cu.m. and will increase to 100 cu.m. towards 2040.
(4) Demand for water in the agricultural sector is derived as a function of the projected development of agriculture and the role of agriculture in the water quality cycle.

FOOD SUPPLY FROM LOCAL AGRICULTURAL SOURCES AND THE AGRICULTURAL CROP PLAN

The root question here is with regard to the price which agriculture can afford to pay for water. A future agricultural crop plan will have to be established to withstand water prices stemming from future costs within the system of overall water supply to different users, and at the same time meet food demands.

The basis used in the study for designing a crop plan was the 1993–7 agricultural production forecast prepared by the Israel Ministry of Agriculture Planning Authority. Among the forecast's assumptions it was anticipated that supply of vegetables, fruit and milk would come mainly from local agricultural sources, though the possibility was foreseen that some vegetables, fruit and milk would be imported in the more distant future. This assumption, taken in parallel with the calculated return for water from Israel's total agricultural activity, implies that most irrigated farming would concentrate on vegetable and fruit production and supply of 25 per cent of the dry fodder requirement for milk production.

In the study it was assumed that during the planing period a rise in efficiency in agricultural production generally, and specifically in water exploitation, could be expected. In the years 1993–7 the cumulative rise in water use has been assumed at 15 per cent, and it is suggested that efficiency coefficients will rise even higher. This subject and the sensitivity of other basic assumptions are dealt with below.

BALANCE OF SOURCES AND USES (INCLUDING WEST BANK AND GAZA)

On the basis of the various assumptions about population growth and the associated urban and agricultural requirements, assessments of availability from conventional sources (Table 1) can be compared with the forecasts to derive an estimate of the cumulative gap in availability which will emerge in the years up to 2040 (Table 2). An indication is also provided of the way in which that gap might be met.

TABLE 1 *Conventional sources of water (MCM, millions of cubic metres)*

	2000	2010	2020	2040
Groundwater	1 090	1 100	1 100	1 100
Jordan Basin	670	670	670	670
Floods	50	70	80	70
Effluents	198	198	198	198
Gaza	87	87	87	124
Losses	(40)	(30)	(25)	(25)
Total	2 055	2 095	2 110	2 137

ADDITIONAL WATER DEVELOPMENT SOURCES

Possible sources of additional water are (1) additional waste water reclamation, (2) importing water by conveyance from a neighbouring country, (3) desalination (of brackish and/or sea water).

Waste water reclamation

Recycling water after suitable treatment serves several ends. First, it solves the sanitation problem of sewage removal, at the same time preventing environmental nuisance and hazard. Second, it prevents pollution of surface and ground water sources, thus safeguarding the water environment. This is particularly important in the West Bank because of the rate of expected urban

TABLE 2 *Forecast water demand for years 2000–2040 (cumulative MCM)*

Year	Population	Urban sector water demand	Agric. sector water demand	Total demand	Existing sources	Cumulative gap	New sources	
							Waste water	Other
2000	8 900	903	1 250	2 153	2 055	98	98	—
2010	10 900	1 151	1 317	2 468	2 095	373	288	85
2020	13 400	1 440	1 542	2 982	2 110	872	453	419
2040	19 100	2 041	2 017	4 058	2 137	1 921	873	1 048

development and the area's geological structure. Third, it is a reliable source for solving the water resource gap problem.

By the year 2000 an annual quantity of about 300 MCM of reclaimed waste water will be in use, derived from existing effluent treatment and some additional recycling (see the figures in Tables 1 and 2 above). Use over and above the base quantity is termed 'unconventional', since a leap will be required in the scope of activities, given an accelerated growth rate and given the fact that development of waste water treatment and irrigation technologies to combat agriculture-related health risks still have a long way to go. In line with Israel's policy, based on a long-range programme, all sewage will be transported to suitable reservoirs and treated to the appropriate level to enable its use for crop irrigation. The extent of investments needed to achieve this programme is $550 million up to year 2010, a further $450 million up to 2020 and another $770 million up to year 2040, amounting to a total of $1.8 billion in the next 40 years.

The water and sewerage system in Israel's non-agricultural sector is planned to be based on statutory authorities set up throughout the country, whose functions will include the general supply of water of the required quality, collecting sewage and raising it to a standard appropriate to environmental and irrigation quality demands. The cost of treating the water and conveyance of the effluent is estimated at between 26 and 52 cents per cubic metre. The authorities will function on a business basis and as a closed economy. Investments will come from the authority's profits and the capital market.

This subject must be regarded essentially as a matter of cooperation between Israel, the West Bank and Gaza in one system. The terrain, geographical distribution of population, environmental requirements and the distribution of agricultural areas justify coordination of use of water and reclaimed sewage between the three elements.

Importing water from neighbouring countries

The following possibilities for importing are discussed in the study:

- water import from Turkey by sea in vinyl sacks;
- water import from Turkey from the Seyhan–Cheyhan rivers, to Syria, Jordan and Israel, the West Bank, Gaza and the Arabian Peninsula;
- as above, but excluding the Arabian Peninsula;
- water import from the Litani River to Lake Kinneret by an overland carrier;
- water import from the Nile, by overland carrier.

The conclusion reached was that the prospects for water importation are not very promising. The necessary degree of economic/engineering knowledge required for such projects is lacking, and despite the peace process the political aspect may present a problem. All the countries involved, it should be remembered, may have their own water problems and it can be safely assumed that a country which plans to supply water to its neighbour will charge a price which, together with the cost of transport, may equal the cost of desalination. If the question of water quality and the rising necessity of diluting water in the system with high-quality desalinated water are also taken into account, the conclusion that the water importation solution is inferior to desalination is further strengthened.

Brackish and sea water desalination

The need for significant quantities of desalinated water will arise in 2010. The period until then allows time for development of technological solutions and preparations in the subject of water pricing. Water desalination is extremely important not only as an additional water source but also as a means of protecting water quality.

The intensive system of exploiting water from conventional sources to the last drop, treating waste water and conveying it for agricultural use calls for the improvement of water by adding high-quality water from an outside source. The most favourable source is desalination. Logistically, too, this source has obvious advantages. The large urban centres (Haifa, Tel Aviv, Gaza) lie along the coastal plains and the source of water for desalination will be the Mediterranean; hence the desalination installations can be erected close to the large consumer areas.

According to calculations starting from the year 2010, the gap between water demand and supply is about 375 MCM per year. The most favourable solution, at present, for closing it is desalination. The investment required in order to close this gap (excluding the needs of the Kingdom of Jordan) is about $900 million. The production cost per cubic metre of desalinated water is estimated at $0.72. An interim stage in respect of desalination is the use of brackish water, where the cost is only $0.25 to $0.40 per cubic metre.

Sea water desalination is essential to the solution of the region's water problem towards the year 2010. It demands timely preparedness, from the technological and planning aspects and in terms of cooperation agreements and sources of finance.

MARGINAL AND AVERAGE RETURNS FOR WATER AND CHARGING POLICY

The added production and conveyance cost of the extra water needed is $0.26 to $0.52 per cubic metre for waste water, and $0.72 for desalinated water. Analysis of the crop plan arranged in diminishing order of marginal returns to water shows a wide range of return, starting from $4.0 and decreasing to $0.10 per cubic metre of water. Taking average values (for the year 2010 for example), the picture represented in Table 3 emerges. The total gap for 2010 is 373 million cubic metres. Assuming that this gap withstands irrigation needs, and taking marginal return as against marginal cost, then the last 318 million cubic metres will yield an average return of $0.27 per cubic metre, while its cost is $0.72.

TABLE 3 *Returns to water use*

Marginal return for water ($.cu.m.)	Quantity of water (MCM)	Average (cumulative) return per cu.m.
> 1.0	593	1.58
1.0–0.5	285	0.38
<0.5	318	0.27
Total	1 196	1.11

From a purely economic viewpoint, it would seem unprofitable to produce 318 million cubic metres if there were importation alternatives for the same price. If the cost of the alternatives was higher, then the marginal return per unit would rise, making production of marginal water worthwhile. The decision affecting production of this quantity of water will have to be reached in the years 2000–2005, and by then the question of profitability will be clearer. Other considerations are also liable to appear regarding population composition and distribution, and prospective returns in agriculture. On this question, two important points should be noted. First, the average return per cubic metre is higher than one dollar; and second, all water deriving from waste water and supplied freely to agriculture – excluding conveyance costs – is water whose treatment costs the urban user would have to bear.

SENSITIVITY OF ASSUMPTIONS

In a study covering a planning horizon of 40 years, the question of validity of assumptions arises. Changes might occur over the years in each of the key parameters, namely, the rate of population growth, technological advance, trade conditions and the composition of the food basket.

From the study the main conclusion is that the solution to problems of quality and deficiency in water supply will be achieved through appropriate preparations for waste water reclamation and sea water desalination. An error in assumptions and in the model could, it seems, lead to erroneous decisions. However, further analysis shows that waste water use is not in question. The technological and physical infrastructure for sewage collection, reclamation and disposal has been established over the past decade in the Dan Sewage project and other local projects. Expanded activity on this subject is a function of resources to be budgeted year by year.

COOPERATION ON A REGIONAL LEVEL

Inter-state cooperation could in the future reach all the countries of the region (Turkey, Iraq, Syria, Lebanon, Jordan, Israel, the West Bank and Gaza, Egypt and the Gulf states). This study, however, in accordance with its terms of reference, deals with Israel, the West Bank, Gaza and Jordan only. That area appears in the calculations as one entity, regardless of political and institutional aspects.

With regard to cooperation with Jordan, the basic assumption is that, even in the analysis of sources and future uses, conclusions reached in Jordan as to the need for maximum use of waste water and seawater desalination will be similar to those in Israel, although their timing may be different. Population concentrations in Jordan are some distance from sources of sea water for desalination, but closer to the natural sources of the Jordan basin. Thus the Jordanians may be interested in joint projects such as the following:

(1) enabling Jordan to use sea water sources by cooperation with Israel in a joint 'Two Seas' (Mediterranean–Dead Sea, or Red Sea–Dead Sea) canal project;
(2) siting sea water desalination along the Mediterranean coast and conveying treated water to Jordan;
(3) the 'Two Seas' canal project could contribute to solving the water shortage problem if desalination plants were built along it in the Jordan Valley or the Dead Sea, exploiting the fall in water to below sea level as a source of hydroelectrical energy and/or a conservational source of energy in the reverse osmosis process.

RECOMMENDATIONS

Main points

In seeking solutions to water problems, Israel, the West Bank and the Gaza Strip should be regarded as one planning unit. The main technologies capable of meeting future water problems are waste water reclamation and desalination of brackish water and sea water. Solutions to shortage problems should ensure:

- compatibility of water sources and water supply with demands in the various periods by continued development of existing sources, development of unconventional sources, adoption of new and innovative technologies, implementation of innovative projects, demand management and an appropriate pricing policy;
- appropriate water standards for all types of use: drinking, industrial and agricultural;
- safeguarding of general environment quality and of water environment quality.

Existing water sources

The main conventional water sources should be exploited to the maximum, thereby increasing the area's annual water supply by 145 million cubic metres.

This will be achieved by *inter alia*, addressing the subjects of floodwater storage, reduction of water losses and, especially, demand management and pricing policy, to prevent water wastage generally and discourage use of water to irrigate crops which give a low return to water.

Other sources for closing the water gap

Water quality The 2000–2040 water development system should be seen as one entity, responsible both for supply of the required water and for the treating and disposal of the used water. Thus, at all points of the cycle, the quality of water supplied to urban and agricultural consumers and the treatment and removal of sewage can be scrutinized, ensuring prevention of any general environmental damage and, in particular, water environment damage.

Waste water reclamation The setting up of a sewage treatment and removal system, the first stage in environmental treatment, will mean that no untreated sewage will be allowed to drain off to cesspits, the sea, wadis and streams. The treated water will be used mainly for irrigation purposes, with irrigation acting as the final stage in the water reclamation cycle.

The subject of sewage, its treatment and removal has reached an advanced stage of development in Israel, but has not yet been applied sufficiently in the West Bank and the Gaza Strip. To advance the subject, about $550 million will be required until 2010. Up to the year 2020, a further $575 million will be needed and another $1050 million by 2040. Overall investments amounting to $2.2 million would yield an additional 970 million cubic metres of water per year. In view of the importance of this subject, it is recommended that the World Bank assist in the funding of these developments.

Desalination As the findings of the study show, a deficiency of water, exceeding the conventional sources, between the Mediterranean and the Jordan, will appear in 2010 (if until then the water used in agriculture is reclaimed waste water, as in the study assumptions). The answer to this deficiency, in addition to reclamation of all sewage water, will be provided by desalination plants.

If future desalination plants are to be reliable and their setting up, operation and maintenance not too expensive, applicable specific research must be carried out in both the basic technology and in the planning of the plants themselves. Subjects for more research include improvement of durability of membranes and other materials, problems of heat transfer (the problem of furring), improvement of pump efficiency and computerized control development. In order to be able to supply the reclaimed water at a reasonable price, starting from the year 2010, it is recommended that, parallel with the technological development work, desalination plants should go into operation from the year 2000, since the resulting feedback would stimulate and contribute to research and development.

The investment required in order to set up desalination plants up to the end of 2040 would amount to $3.3 billion. This investment would yield an additional 1.1 billion cu.m. of water per year by the end of the period.

Demand management and pricing policy Israel has amassed wide experience in the field of demand management. This should be exploited to the maximum by encouragement of methods of efficient and economical water use in agriculture, industry and for municipal purposes. Where pricing is concerned, a new approach will be needed. Users will be required to pay a price based on he following economic considerations:

(1) The main addition in water demand in the years 2000–2040 will arise from urban population growth, and it is this population which will have to pay for the cost of technological development of innovative water sources, as well as sewage removal and its reclamation to a standard suitable for agriculture.
(2) Agriculture will have to pay only the cost of conveyance of the reclaimed water, and the adoption of this policy will bring about a reduction in the average price of water intended for agricultural purposes.
(3) Agriculture will assume a new role of 'water treater' and 'environmental quality preserver' and this role will be reflected in the price paid by the agricultural sector for water.
(4) The price of water for agriculture will be determined, not on the basis of subsidies, but on the basis of an economic calculation, as shown above. The change in the price of water, and in its quality for agriculture, will call for changes in the agricultural production plan. An agricultural plan can be designed which would withstand water prices higher than those in force today.

CONCLUSION

The study examined urban and agricultural water requirements in areas west of the Jordan as a basis for providing appropriate answers to those requirements, and as a means of planning future coordination with the Jordanian government. It devoted careful thought to the subject of the quality of the water to be supplied to the population and the question of reclamation and disposal of waste water.

Regarding the water system as a whole, from the year 2000 gaps appear between water demand and supply which, up to year 2010, can be closed by reclaimed waste water. After 2010, the need arises for production of water from unconventional sources. The study proposes that desalination should be considered as the optimal source of this water.

Taking the urban sector water demand as inflexible, including the obligation to supply the treated effluent to consumers, and on the assumption that food requirements in vegetables, fruit and milk will be supplied by local agriculture, the urban sector appears able to and obliged to pay the costs of sewage treatment and desalination. Future coordination between all the areas west and east of the Jordan on the subject of water and economics is most important, if not vital.

NOTE

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