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ISRAEL WATER ECONOMY AN OVERVIEW

by

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Rehovot, Israel, P.O.B. 12

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INTRODUCTION

The first part of the paper introduces the water supply potential from natural sources. The expected future use of water by the urban and agricultural sectors is presented and the role of treated wastewater in the water balance of Israel is evaluated. Costs of water supply from different sources are compared.

The second part of the paper deals with major issues related to the pricing of water. The prevailing allocation and pricing system is presented and its positive and negative aspects are evaluated. Finally, several issues of current interest are briefly reviewed.

WATER POTENTIAL

There are several estimates of Israel's water potential; they range from 1517 to 1781 MCM per year, not including Gaza and the South Jordan Valley aquifers. The detailed estimates are presented in Table 1. The potential of water from natural sources includes about 160 MCM of brackish water, defined as water including more than 400 ppm chlorides, roughly equivalent to 1000 TDS (Total Dissolved Solids).

Note that the net potential takes into account conveyance losses of 4% of the gross quantity. The concept of water potential requires some clarification:

a. It depends on land use - the type of vegetation e.g. fallow vs. an orchard or a park, which affect natural replenishment via evapotranspiration. Another factor is the land area occupied by buildings and paved roads which prevent deep percolation of excess water to aquifers, and instead, allows the unabsorbed rainfall to fall into sewers and storm drains, and ultimately to wadis (dried river beds) and to the sea.

b. There is a difference between the hydrological potential which includes all the sources of water and the practical potential which represents the quantity of water practically available for use.

The practical potential available for use depends, of course, on the state of water supply alternatives and the economic conditions under given circumstances; prohibitively costly sources of water supply are not included in the practical potential. The distinction between the hydrological potential and the practical potential is not clear cut. An example is the saline water aquifer in the Negev southern highlands, the exploitation of which is expensive. The question arises which share of this aquifer should be included in the practical potential. If we expand the frame of reference to include water from artifical sources, e.g. reclaimed sewage and desalinated water, the theoretical potential of desalinated water being unlimited, nowadays the practical potential of desalination is restricted to a few locations only (e.g. Eilat). In the future, on the other hand, desalinated water may become one of the important components of the practical potential.

c. Speaking of potential, we refer, as in most publications, to the expected value (or perennial average). The expected value of water potential of a given aquifer depends on the relevant storage capacity (which is a limiting factor in Israel) and upon the long run use and inventory policy. Under conditions in which the storage capacity is not restricting, and the policy is to use all the quantity of water replenished in a particular year - the expected value of the potential and the standard deviation (SD) will be relatively high. On the other hand, under conditions of restricted storage capacity and a restrictive policy of water use in plentiful years, due to considerations of perennial storage, both the expected value and the standard deviation of the potential will be lower.

According to Schwartz (1990), the coefficients of variation (CV) of the natural replenishement of the major watersheds in Israel are:

Kinneret Basin	0.36
Coastal Plain	0.29
Yarkon Taninim (part of the Mountain Aquifer)	0.22
All three watersheds combined	0.27

The estimates of Schwartz relate to historical replenishment series and certain assumptions regarding the usage-inventory policy.

The above coefficients of variation are quite high. By way of illustration, let us assume, for simplicity, a normal distribution of the natural replenishment with a CV of 0.27 . Under these assumptions, in 16% of the years the overall natural replenishment of the above watersheds will be lower by 27% from the expected value (one SD towards the left tail of the distribution) and in 2.5% of the years, it would be lower by 54% from the expected value.

The policy options faced by the policymakers are either, to maintain a constant water supply from natural sources over the years with a low expected value and a low standard deviation, or to maintain a flexible water supply with a relatively higher water potential and higher standard deviation, as well. This issue is closely related to the structure of the agriculture and its crop mix.

Table 1. **WATER POTENTIAL FROM NATURAL SOURCES (EXCLUDING GAZA AND SOUTH JORDAN VALLEY) MCM/YEAR**

VERSION	(1)	(2)	(3)
SOURCE			
KINNERETH BASIN	660	600	660
GROUND & FLOW WATER 1)	1195	980	1063
TOTAL	1855	1580	1723
CONVEYANCE LOSSES	74	63	69
NET POTENTIAL	1781	1517	1654

VERSIONS: (1) Tahal Master Plan (1988)
(2) Nevo (1992)
(3) Based on Hydrological Service

Table 2. **URBAN WATER USE AND RESIDUAL FOR AGRICULTURE FROM NATURAL SOURCES**
MCM\YEAR

YEAR:	1990	2010	2030	2040
DOMESTIC 1)	482	700	980	1,160
INDUSTRY	105	140	150	150
TOTAL (A)	588	840	1,130	1,310
NET POTENTIAL 2)(B)	1,654	1,654	1,654	1,654
RESIDUAL 2) (B)-(A)	1,066	814	524	344
WASTEWATER POTENTIAL	240	400	540	630

FOOTNOTES:

1) 100 M^3/CAPITA BEYOND 1990
2) INCLUDING 160 MCM BRACKISH WATER

THE BALANCE OF WATER

The projected water use in Israel in the 21st century depends on the projection of population and water use per capita. The recent projection regarding population for the year 2010 is 6.9 million inhabitants in Israel including the settlements in the West Bank and South Gaza Strip. The quantity of water projected for domestic use is approximately 700 million MCM per year with an additional 140 MCM for industrial use. The projection for domestic use is based on the assumption of 100 CM per capita in 2010 and the years beyond. The current average use per capita is about the same.

The reason for using 100 CM per capita and not a higher figure which could reflect higher standards of living, implicitly assumes water policy aimed at lower use levels. In effect, in years of short supply, the use per capita can be even lower than 100 CM if proper administrative restrictions take place.

Table 2 shows the totals of the projected urban use of water, which, when compared with the potential of water from natural sources, gives the residual available to agriculture. Note that this residual includes about 160 MCM of brackish water. The last row of Table 2 presents the potential for reclaimed wastewater, which jointly with the residual in row 5 could be allocated to agriculture. The figures for the years 2030 and 2040 are extrapolations which illustrate the potential situation during the first part of the 21st century.

Table 2 suggests that an increased share of water supply to Israeli agriculture would be based on low quality water (brackish and reclaimed wastewater). According to this projection, already in the third and fourth decade of the 21st century, the shortage of fresh water to Israeli agriculture will be quite severe. Note that deviations from the projections in Table 2 are very likely, due to variation in the potential, and different rate of growth of population and use per capita. The table presents a general - simplified view. A real life planning should follow a probabilistic approach.

It should be emphasized that the above figures avoid, on purpose, the discussion of the claims for water by the Palestinian Authority, due to its sensitivity. Here we shall be satisfied with three comments: (a) The dispute over water between Israel, the Palestinian Authority and the State of Jordan should be resolved around a negotiation table, (b) data like those presented in Table 2 may serve as an input to the negotiations (see also: Yaron (1994)) and (c) any quantity of water transferred from the current or projected use in Israel to its neighbors will primarily affect the agriculture of Israel.

WATER SALINITY PROBLEM

There are two aspects of the salinity problem. The first one refers to local spots of brackish water in certain regions, which together amount to about 160 MCM/year.

The second, and considerably more important problem in the long run, is a strong trend faced by Israel of increasing salinity over time in most of its natural water sources. This process in the result of: (1) reduction of natural drainage and natural salt leaching to the sea, due to the very intensive exploitation of Israel's water sources; (2) intrusion of sea water in some locations along the coastal plain; (3) import of salts with irrigation water from Lake Kinneret to the regions served by the National Water Carrier (NWC). (Even though the salt content of the Kinneret, the source of NWC is relatively low (200 - 240 ppm Cl), the salt brought in by the National Water Carrier gradually accumulates in the soil and ultimately percolates to the groundwater; (4) irrigation with wastewater which is more saline than fresh water.

A major issue is the "time chloride bomb" above the (unconfined) coastal aquifer. The salts accumulated in the soil profile above the groundwater will ultimately reach the aquifer and gradually cause its deterioration. According to Mercado (1992), this is an irreversible process. It may be slowed down, and probably is, by more efficient systems of irrigation which reduce the deep percolation but no irrigation system prevents deep percolation totally, and there is still deep percolation due to rain.

The overall trend of salinization of the water sources was recently estimated by TAHAL (1988) as follows:

PERCENT OF TOTAL POTENTIAL

%

PPM/CL	1985	2010
250 >	79	63
250-400	12	15
400-800	5	10
800 <	4	12
	100	100

There are two levels of issues concerned with the management of brackish water use - the farm level and the national (or the regional level.

At the farm level the focus is on the optimal use of brackish water in the short and long run (Yaron, 1984; Feinerman and Dinar, 1991).

At the national/regional level the major problems are (i) how to deal with the externalities of irrigation with brackish water, and (ii) how to incorporate brackish water into the farmers' quotas (as long as this system prevails) and what should be the rate of substitution between the brackish and the high quality water. A Water Commission Committee has recently issued policy recommendations in this regard, which are being put into effect. Details fall beyond the scope of this paper.

TREATED WASTEWATER AND ITS USE

As shown above, treated wastewater will continously comprise an increasing share of the total supply potential to agriculture and perhaps to industry as well. It is assumed that between 50-60% of household water can be recycled and re-used, if there is sufficient demand for its use.

The alternatives regarding wastewater are: (a) disposal to the sea; (b) treatment and re-use in agriculture, and, perhaps (c) re-use in industry. Note that re-use in households and offices is not currenlty considered as a viable alternative even though it may become such in the future (with dual supply systems in households and offices, as, for example, in large office buildings in Japan). According to the international agreements, disposal of wastewater to the sea implies a certain level of treatment (hereafter "base level") and long pipes for discharging away from the shoreline for its discharge.

The use of treated wastewater in agriculture involves strict environmental rules, with a double aim: preservation of groundwater when irrigation takes place above unconfined aquifers, and public health considerations aimed at preventing the spread of bacteria and viruses, carcinogenic materials, etc.. Strict restrictions on the use of treated wastewater in irrigation have been passed; the issue of gradual contamination of groundwater by chemicals is being studied (e.g. Falkovitz and Feinerman(1994), Feinerman and Voet (1995)); however, problems of enforcement of the regulations are far from being solved. (See Schwartz (1990), Avnimelech (1992)).

A major issue is agriculture vs disposal. According to a recent report by the Water Commission (1993): "If the environment preserving regulations are followed, allocation to agriculture seems economically viable in most cases." A major difficulty involved in the allocation of treated wastewater to agriculture is the problem of interseasonal storage. Underground storage capacity is limited and even if locations can be found, there is an alternative cost of storing treated wastewater rather than fresh water; storage in open ponds bears too an alternative cost in terms of land. Furthermore, there is a loss in quantity due to evaporation, and even more important is the effect of evaporation on increasing salinity. Available observations suggest that the salt content of reclaimed sewage is higher by about 100 ppm Cl than the incoming fresh water supplied to urban consumers. If the current salt content of the water supply by the National Water Carrier is about 220 ppm Cl, the salt content of reclaimed sewage without underground mixing will be 320 ppm and after open pond storage may reach the level of 450 ppm Cl or even more. Such a level is considered as damaging to the sensitive crops e.g. citrus, avocado, mango, etc.

In Table 3, we present a compilation of estimates of costs of treated wastewater for small plants (10 MCM/year and of the Tel Aviv Metropolitan Plant ("Shafdan"). It presents the costs involved in the different levels of treatment and its use in irrigation. It is unclear (regarding Table 3a) under which conditions tertiary high treatment, which involves sand filtration, is actually needed; if it is not, the total cost of treatment for small plants should be reduced accordingly. A second comment regarding Table 3 refers to the cost of infiltration and groundwater storage of the Shafdan plant. It is being debated whether infiltration is necessary for disposal to the sea, or if the treatment alone, perhaps with some upgrading, may be sufficient.

It seems sensible and rational to assume that the cost of treatment up to the level required by the rules aimed at the preservation of the environment will be borne by the producers of the waste, i.e. the urban population. Thus, the share to be borne by agriculture includes storage and conveyance. Under conditions of high profits from the agricultural use of treated wastewater, there might be a case for sharing the profits between the farmers and the municipalaties (see e.g. Dinar et al (1986)). However, such a situation seems unrealistic today. With all this taken into account, the range of costs of using treated wastewater in irrigation might be considered as falling between 10 to 25 cents per CM.

Table 4 presents a distribution of water supply sources according to the costs per cubic meter. The cost of supply from natural sources is based on the Mekorot Work Plan and Budget (1993, Hebrew). The cheapest category of water from natural sources includes water supplied by private non- Mekorot projects (Mekorot supplies about 65% of the total). Scrutiny of Table 4 suggests that the cost of treated wastewater is lower than about one half of the water from natural sources and it is considerably cheaper than the desalinization of brackish water by reverse osmosis, and certainly than deslinization of seawater. Thus, treated wastewater can absorb the additional costs involved in upgrading quality and still be competitive.

Table 3: ESTIMATED COST OF TREATED WASTEWATER

a) SMALL PLANTS (10 MCM/YEAR)

US cent/cm

TREATMENT COST	OM	CAPITAL COST	TOTAL
Secondary level	5	7	12
Tertiary level I	5	4	9
Tertiary level II 1)	4	4	8
	14	15	29
IRRIGATION COST			
Storage (open ponds) 2)	3	3	6
Conveyance (10km)	3	2	5
Total	6	5	11

Footnotes: 1) Sand filtration if needed

2) Infiltration to underground water is cheaper

b) TEL AVIV METROP. PLANT

TREATMENT COST	OM	CAPITAL COST	TOTAL
Treatment	8	14	22
Infilitration 3)	7	12	19
Total	15	26	33
IRRIGATION COST			
Conveyance (Negev)	10	8	18

FOOTNOTES:

3) It is unclear whether infiltration is necessary for disposal to sea.

Table 4. COST OF WATER FROM VARIOUS SOURCES

Cents/CM

	COST cents\cm	%
Natural sources	< 22	43
	22-40	32
	40 >	25
Treated Wastewater	10-25	
Desalinated brackish water	40-50	
Desolinated seawater	80-120	

THE USE OF WASTEWATER IN AGRICULTURE

There are two major interrelated problems involved in the stragegy of using wastewater for irrigation: the inter-regional geographical allocation and the treatment level.

In general, there are limited regions and a limited agricultural potential for low level (secondary) treated wastewater. This situation will only be exacerbated due to the process of urbanization and increasing density of population.

A major concentration of wastewater sources prevails in the coastal plain where the urbanization process has been the greatest. However, this region is located above the coastal aquifer and there are considerable hazards with irrigation in this region even with very highly treated wastewater. Note that while the wastewater can be treated up to a level objectively equal to potable standards, uncertainty and lack of knowledge regarding carcinogenic materials and perhaps other currently unknown damaging elements are a source of worry and objection on behalf of those in charge of public health. On the other hand, there is relatively plentiful land in the South and the Negev which are not located above an unconfined aquifer and secondary treatment level of effluent can be used there from the point of view of conserving groundwater.

There are two strategic alternatives widely discussed nowadays: (a) conveying most of the coastal plain wastewater south and shifting agriculture from the coastal plain to the Negev, and (b) using high quality effluent above the coastal aquifer. The latter alternative evades the currently prevailing restrictions. However, a recent document prepared by the researchers of the Volcani Institute (Fein et al (1995)) suggests that irrigation with treated wastewater in the coastal plain is envoironmentally feasible and at least not inferior to irrigation with quality of water from the National Water Carrier.

The advantages and disadvantages of the two alternatives are obvious. Conveying the wastewater to the Negev and expanding the agriculture there avoids the rigidities and restrictions derived from the currently prevailing system of land allocation and other institutional realities. The problem in the Negev is whether, under the current socio-political climate and the diminishing support of agriculture on behalf of Israeli society such a development can indeed take place. On the other hand, in the coastal plain, the land is perhaps the most fertile in Israel, with favorable climatic conditions, and there is still a viable core of good farmers with a strong infrastructure for farming. Furthermore, some parts of Israeli society, place a high value on green and verdant open areas, despite the fact that they are giving way, gradually, to the forces of urban pressure.

TREATED WASTEWATER FOR ALL PURPOSES ?

Under the current technology, highly treated wastewater meets all the objective standards of drinking water, yet dual supply systems are developed in order to avoid any unforseeable hazards. My own observations suggest that even triple systems are being introduced and expanded, such as the use bottled mineral water, home treatment of water, etc.

Research by Schechter and Rebhune (1986) presents an economic rational approach to the determination of the optimal treatment level of wastewater for drinking purposes under Israeli conditions. They include in their analysis estimates of value of life and the fear of disaster which has a very low probability of occurrence. However, due to this fear of disaster, many policymakers tend to exaggerate in the required level of treatment. This is a case of the policy of "do vs not to do" decision making. Many decision makers in the field of public health prefer to err on the side of overdoing to avoid accountability for public health disasters even if their probablility could be considered as negligible. On the other hand, public expenditure for the prevention of car accidents (improved highways etc.) seems to be below its social optimum level, because the accountability is not there.

It is proper to end this section with a question. Could highly treated wastewater serve as an emergency source for households under condtions of severe drought and severe water scarcity? Some water experts suggest constructing desalinization plants, and use as an argument severe water scarcity situations with low probability of occurrence.

Could highly treated wastewater , supported by bottled drinking water, serve as an alternative solution?

WATER ALLOCATION AND PRICING

The fresh high quality water is allocated to users according to an institutional quota system. These quotas were established in the early sixties and have not been thoroughly revised since then. According to the Water Law of Israel and its underlying philosophy, the water is considered as the property of the nation and is allocated for self-use purposes. Accordingly, quota transfers among users are illegal. Due to the developments since the early sixties and the prevailing realities, transfers are practiced despite their illegality.

Various arrangements prevail regarding the allocation of brackish water and the right to use reclaimed wastewater. A major problem faced by the Water Commission is, how to incorporate the low quality water into the quota system and what should be the rate of substitution between high quality and poor quality water.

The water supplied by Mekorot to the farmers is priced according to a block differential (tier pricing) system: The first 50% of the quota has a low price (price A - 14.5 cents per cubic meter in the Fall, 1994), next 30% of the quota bears a higher price (price B - 17.5 cents); and the remaining 20% of the quota bears price C - 23.5 cents (Fall, 1994). Users exceeding the quota have to pay a considerably higher price with an element of penalty.

The pricing system enables inter-user water mobility without changing the quota system and facing the struggle with farmers' rights to the quotas. It is also a venue for subsidizing farmers (via prices (A) and (B)), with potentially efficient prices at the margin of the quotas. Furthermore, no extra transaction costs are involved because all water supplied by Mekorot is metered and the charging system for water is automated.

This system is a mix of political - institutional allocations with the market mechanism being effective at the margin of allocations. In other words, this is a mix of egalitarian and efficiency measures (see also Yaron 1992, Hebrew). In the view of this author, market mechanism alone may lead to results incompatible with the non-economic goals (national, social). Another advantage of the block differential pricing is that it takes away some of the rent, potentially accumulated by water suppliers, and transfers it to the farmers. Note that the marginal costs of water supply is increasing in shifting from one water plant to another within the same region. With the introduction of desalination, the shift in marginal costs of water supply may be substantial. For efficiency, the marginal water should be priced according to the marginal costs. But if all the water supplied is priced at the marginal cost, as free market mechanism suggests, a huge rent that will be left in the hands of water supply companies. Block prices (A) and (B) leave some of this rent in the hands of the farmers without additional transaction costs.

While the current system has evident advantages, it is time for revision. First of all, the current quota system does not take into account the changes which have occurred since their establishment either in terms of the growth of urban population or in terms of changes in the agricultural production, introduction of greenhouse technology, etc. and in general, the differential development of production systems of the farms, even in the same region.

In reality, the quotas are not observed. While the towns systematically exceed the quotas, the agricultural settlements use less water than is allocated to them by the quotas.

Deviations from the quotas in recent years were in percents:

	TOWNS	KIBBUTZIM	MOSHAVIM
1988	+17	-13	-11
1989	+18	-24	-17
1990	+28	-18	-11

Thus the quotas should be revised. At the same time, complete cancellation of quotas to farmers is not feasible because farmers need some reassurance.

Another weakness of the current pricing system is that water is priced at the same level in all regions and the marginal price (C) does not necessarily reflect the real marginal cost of supply on a regional basis.

URBAN USES

Water supplied by Mekorot to municipalities is charged 31 cents per CM (Fall 1994 prices) for domestic use and 23.5 cents per CM cubic meter for industrial use. However, the ultimate consumers pay considerably higher prices for water because the municipalities use the supply of water as a venue for taxation, thus making water supply as a source of profit. According to the research by Eckstein and Rosovitz, (1993), the profit as a percentage of outlays in 1989/1990 was as follows:

Tel Aviv	44%	Ashdod	23%
Bat Yam	169%	Raanana	80%
Herzliyah	135%	Ramlah	6%
All municipalities (simple average)			26%

It was observed by Eckstein and Rosovitz that the richer the inhabitants of a community, the higher the percentage of profit from water supply.

SPECIAL PROBLEMS

Linkage in supply between domestic and agricultural users

A considerable share of water supplied by Mekorot is delivered thorugh plants which serve both the domestic and agricultural users. However, the parameters of demand by these two groups of users are different as shown in Table 5. The parameters of demand for industry seem to be similar to those of domestic users exept for water quality.

Table 5: **DIFFERENT PARAMETERS OF DEMAND FOR WATER FOR DOMESTIC AND AGRICULTURAL USES**

PARAMETER	DOMESTIC	AGRICULTURAL
Short term reliability	High	Low
Long term reliability	High	Medium
Water qulaity	High	Low
Peak/average ratio	Low	High

As the water plants jointly supply domestic and agricultural users, the supply has to meet the most demanding parameter. Thus, in most cases, agriculture is served by plants which meet demand parameters not required by agriculture. The issue of cost allocation between domestic and agricultural users is therefore raised. Qualitatively, the cost allocation policy and, accordingly, the pricing policy are clear. In order to arrive at the quantitative measure, research should be carried out. As the shortage of fresh water to both domestic and agricultural users becomes more severe in the years to come, the importance of this problem will become more acute.

Taxing groundwater

In some regions of Israel, there are shallow aquifers with low pumping costs and therefore low water supply costs (e.g. the Coastal Plain). There is a considerable difference between the private and the social costs of water in this region. The alternative for using this water in the region by private well-owners is conveying it to the Negev by the N.W.C. and substituting for water from the Kinneret.

Until recently, the shallow aquifers low cost water was levied using a mechanism of "equalization fund". The fund thus collected was used to subsidize the national water system operated by Mekorot. Recently, the Water Commission has been looking for a more rational system. Taxing of groundwater is being discussed with economic parameters being used for setting up the tax level. The parameters under consideration include the distance from the Negev, water salinity and the level of groundwater (the high level, possibly involving overflow to the sea, would be exempted from levy, whereas a low level of groundwater which may lead to shortages in the following years will be heavily levied).

Privatization

As previously mentioned, Mekorot Water Company controls 65% of the total water supply in Israel. The issue of privatization or partial privatization is being discussed.

This issue is only mentioned here, due to its importance; due to its complexibility it falls beyond the scope of this paper.

Shortage of economic research

As in many other countries, the water system in Israel is dominated by engineers, hydrologists and agricultural experts. The economic research is relatively limited, while the demand for economic analysis is quite high as evidenced by the previous examples.

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