Promoting water resource management in the Middle East

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Introduction

The Middle East and North Africa face an environmental crisis, much of it a result of water scarcity and the existing and potential pollution of its resources. It is estimated that the needed investment to deal with and solve the problem could reach 800 million and up to 1000 million USD in the period 1995-2005.

The hydrological conditions are in constant deterioration. As pumpage from ground and surface water resources increases, so do the problems associated with water levels and decreased quality. Inadequate human and industrial waste treatment, as well as inappropriate wastewater reuse programs lead to higher concentrations of chemicals and organic contaminants. The level of heavy metals and other compounds has already reached alarming levels at various sites and the projected future cleaning cost could reach prohibitive levels unless urgent and rigid measures are followed.

A major contributor to the problem is the expected population growth in the region. The World Bank forecasts indicate a growth of 40% (from 250 million to 350 million) by the end of the century. Governments are unable to generate the financial and human resources needed to provide adequate water and sanitation facilities to meet future demand, resulting from expected population growth.

Presently, almost 20% of the total regional population lack adequate potable water supply and almost 35% lack appropriate sanitation. Less than 20% of the urban water supplied in 1990 has been properly treated while in the industrial world this figure is above 70%. Water pollution problems are endangering most countries of the region.

During the last generation the average water availability per capita has dropped from 3500 cu.m. to 1500 C.M.P.C. It is expected to drop to below 100 CMPC of fresh water supply in a number of countries by the year 2020 (CMPC = cubic meters per capita).

A few countries already exploit more than 100% of their natural water replenishment levels. They include the Hashemite Kingdom of Jordan, Israel, the proposed Palestinian Autonomy, Oman, Qatar, Saudi-Arabia, Yemen, Bahrain, Kuwait and the Emirates.

It is estimated that by the year 2005 only five of these countries will have sufficient water to satisfy their growing demands.

The World Bank in its recent report on the environmental problems of the Middle East and North Africa strongly recommends that governments take the following actions soon to implement comprehensive water demand management policies: raise water prices (complete cost recovery and even impose marginal costs of next resources), in order to enhance conservation in all sectors and install water conservation technology, eliminate subsidies on fertilizers and pesticides in order to slow down the potential pollution of resources, recycle and re-use solid and liquid wastes, and promote the introduction of the private sector into the water industry and utilities.

Background

The present population of Israel is approximately 5.5. million, increasing at an approximate rate of 2.5% per year (excluding immigration and its effect on the growth rate). The population is estimated to reach 6.3 - 7.0 million by the end of the decade. Best estimates for the year 2020 indicate a population of between 9 and 11 million Israeli citizens. (Variations are mainly due to unclear immigration levels).

Present average urban water consumption (domestic, commercial and industrial) is approximately 110 m^3 per capita per year, taking into account past efforts which have resulted in 30 % savings. Present industrial forecasts

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Balance of Sources and Uses (including West Bank and Gaza)

	Conventional Sources (MCM = million cubic meters)			
Year	2000	2010	2020	2040
Groundwater	1,090	1,100	1,100	1,100
Jordan Basin	670	670	670	670
Floods	50	70	80	670
Effluents*	198	198	198	198
Gaza	87	87	87	124
Losses	(40)	(30)	(25)	(25)
Total		2,095	2,110	2,137

*** This quantity relates to unrestricted use of tertiary treated effluent. The rest of the effluent quantity is not included in this table.**

Forecast water demand for years 2000 - 2040 (cumulative MCM)

Year	Population (x 1000)	Urban sector water demand	Agri. sector water demand	Total demand	Existing sources	Cumulative deficit	New sources	
							Wastewater	Other
2000	8,900	903	1,210	2,113	2,055	58	98	-
2010	10,900	1,151	1,424	2,575	2,095	480	288	192
2020	13,400	1,440	1,644	3,084	2,100	974	453	521
2040	19,100	2,041	2,072	4,113	2,137	1,876	873	1,103

Source : World Bank (1994) : Water Economy in Israel

coupled with projections for urban consumption per capita converge at an estimate of 100 - 120 m^3 per capita per year by 2020. These figures assume a much higher standard of living coupled with rigid and wide-scale impementation of demand management policies. When multiplied by the projected population, water demand level will amount to approximately 1000 - 1300 million m^3 of fresh water.

Minimum inelastic agricultural demand for water to supply basic fresh food (dairy products, eggs, vegetables, etc.) is estimated at 25 - 30 m^3 per capita; this adds an additional 220 - 330 million m^3. Total inelastic consumption of fresh water resources will amount therefore to approximately 1200-1650 million m^3 per year in 2020, in addition to areas where fresh water cannot be replaced by sewage effluent Therefore the forecasted total inelastic demand will reach 1400-1850 million m^3.

Irrigation for agriculture will be supplied by treated urban human waste.Re-use of treated effluent in Israel will reach 70-75% of the total DCI supply (domestic, commercial, industrial) which amounts to almost 100% of the total sewered flows (the entire population will be sewered). Therefore the forecasted treated flows by 2020 will be approximately 700 - 1000 million m^3.

In order to sustain the country's demand for water (fresh plus effluent), major investments, aggressive public education, government incentives and penalties, implementation of a water market, as well as appropriate changes in water rates and institutional arrangements will be necessary. It calls for an elaborate social and political campaign and may lead to lengthy litigation in order to achieve a high level of wastewater exchange and re-use in agriculture. At present it may look like a very "tall tree to climb". Costs per m^3 to treat, transfer and exchange fresh water sources with secondary or tertiary treated effluent could rise to close to desalination costs. Environmental benefits will have to be charged to general taxation. In the Southern Negev Desert, desalination of brackish water has already been integrated into the system as it is cheaper than piping water from the North; irrigation systems there use mainly brackish water and effluents. In the Central Negev, desalination of the existing brackish aquifer there may be a major source of water, possibly as soon as 2000 - 2010. All these policies cannot be implemented unless large-scale investments are made, including the use of international funding and private-sector involvement.

Israel's sustainable fresh water potential is approximately 1600 - 1700 million m^3/year. Thus Israel will devote all its fresh water resources to meet inelastic demand, while the treated effluents will be used in agriculture and industry. Its main sources are the Sea of Galilee, the coastal and mountain aquifer - Israel could not, therefore, hope to satisfy the total needs of the PPA (Proposed Palestinian Autonomy). Although the Palestinians are presently consuming water at relatively low rates, however, with 4 - 6 million people projected

Israel's Water Supply : Major Resources

Source	Available volume	Overpumping or Overutilization	Accumulated Deficit
Underground Sources	*Million Cubic Meters per annum*		
(1) Coastal Aquifer	240 - 300 (455)	34 - 80 (1980-90)	1,100 - 1,400
(2) Local Aquifers (Galilee, Carmel, (Gilboa)	23 - 280		small
(3) Mountain Aquifer	300 - 330	49 - 50	300 - 350
TOTAL	**850 - 1,200**		
Surface Sources	*Million Cubic Meters per annum*		
(1) Lake Kinneret Basin	575 - 610 (950)*	25 (1980 - 85)	140 (1987)
(2) Flood & Reclaimed Water	200 - 230		
Total water sources	1,890 - 2,311		1,570
Total water losses	60 - 100		
Balance	1,790		

* Including surface flow, underground springs, direct rain flows from the Yarmuk and saline springs.
Reference : for a detailed list of references see Kliot, 1994, p. 235
Source : R. Just, Horowitz, Netanyahu, University of Maryland, 1994.

within the PPA by the year 2020, and inflexible demand at 60 - 80 m^3 per capita/year, additional resources will have to be developed and distributed. Beyond a comprehensive demand management program, regional water transfers as well as sea water desalination are the only feasible solutions and must be integrated into the water systems of the region in the coming decades. The timing of the integration of the expensive water resources will be decided by the effective implementation of the demand management strategy.

Supply and demand

General background - Israel and its neighbours

There are a number of major policy options which could significantly change supply and demand pressures in the region. Reduction of government water subsidies changes public funding of water prices and demand. Changes in water re-allocation policy could lead to a new equilibrium. As quantity of sewage effluent increases with urban industrial growth, and as urban and industrial growth will consume all incremental water supplies, government policies supporting re-use projects and exchanging fresh resources for effluent are essential for large-scale implementation of supply and demand policies. In addition, demand management and water conservation strategy are indispensible. Changes in the global and regional commodity markets may bring about substantial changes in water demand. Governments may continue some support for agricultural use of water for internal, social and political reasons despite damaging economic implications. As demand for water by party "A" has a direct link to the supply of water to "B" or "C", similar policies should be followed. Assessments of supply and demand must integrate data from all consumer groups and suppliers, to be available for all parties as part of effective joint-management regime.

The figures from Israel, Jordan and the PPA illustrate substantial differences in the efficiency of water use in the two production subsectors (agriculture and industry), as well as the urban unaccounted for water and the application of techniques to reduce domestic water use. In the irrigation sector of Israel, for example, cotton grown with automated drip irrigation systems can increase product value per unit of water by more than 50%, in comparison with controlled sprinkler irrigation. Citrus and other horticulture crops could reach similar levels, as could vegetables and field crops. Israel's large-scale demand management policy in the 1970's led to a significant increase in the product value per unit of water or land. Industrial production per unit of water also has increased in Israel; during the 1970s by over 80%.

Israel has used a host of tools - including water rate adjustments, government incentives and penalties, investment credits to increase water use efficiency, enhanced R & D, applied soil and extension services and local manufacture of high-quality technological systems. These all promoted decreased demand for water and enabled the authorities to reduce water allocations without decreasing the net income of the production sectors. Replication of this strategy within the PPA or in other Middle Eastern countries could alleviate

WATER USE - ACTUAL AND PROJECTED

Water Use - Actual (1989/91)

	Population (millions)	Total domestic use (Mm^3/year)	Per capita domestic use (m^3/year)	Total industrial use (Mm^3/year)	Irrig. area (ha)	Total Irrig. Use (Mm^3/year)	Irrig. Water applic. rate (m^3/ha/year)	Grand total Water Use (Mm^3/year)
Israel	5.0	495	100	115	200,000	1,100	5,500	1,710
West Bank	1.0	35	35	5	10,000	100	10,000	140
Gaza	0.7	20	25	-	5,000	60	11,000	80
Jordan	3.6	170	50	40	70,000	760	10,850	970
Total	**10.3**	720		160		2,020		2,900

Water Use - Projected (2040)

	Population (millions)	Total domestic use (Mm^3/year	Per capita domestic use (m^3/year)	Total industrial use (Mm^3/year)	Irrig. area (ha)	Total Irrig. Use (Mm^3/year)	Irrig. Water applic. rate m^3/ha/year	Grand total water use (Mm^3/year)
Israel	12.8	1,280	100	260	N.D[1]	1,900	N.D	3,440
West Bank	3.8	380	100	40	N.D	350	N.D	770
Gaza	2.6	260	100	-	N.D	100	N.D	360
Jordan	16.9	1,700	100	180	N.D	550	N.D	2,430
Total	**36.1**	**3,620**		480		2,900		7,000

[1] N.D - No data available

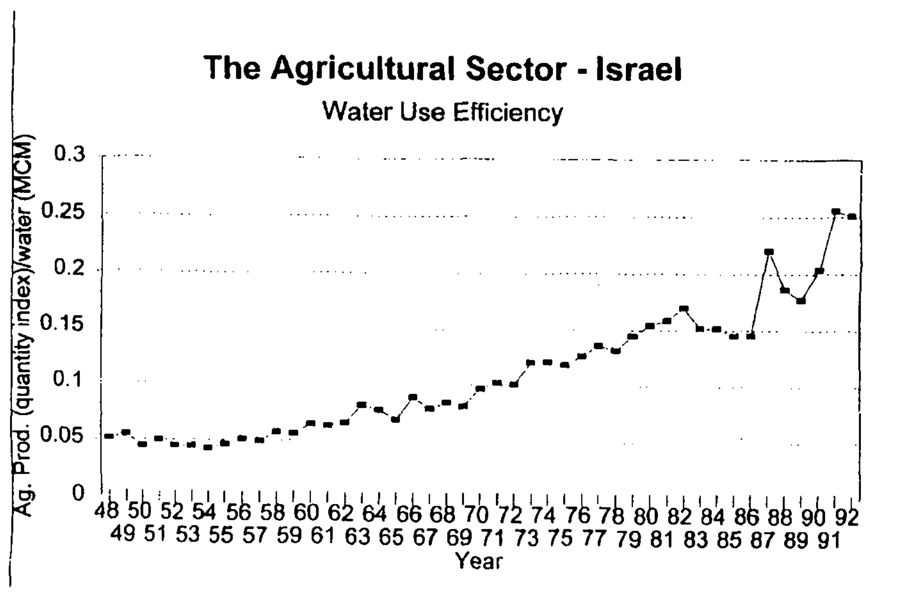
Source: The World Bank reviews or estimates

many existing problems and promote more effective policies. The World Bank for example could act as a catalyst for the implementation of institutional changes, research and policy-making, in order to gain similar results, in its member countries in the region.
One way to deal with the complicated question of supply and demand levels is to assess inelastic water demand and then to project additional agricultural demand based on improved irrigation efficiency and socio- economic conditions of the rural populations. In evaluating inelastic water demand, issues of standards of living, level of industrialization, economic utilization, wide-scale implementation of water conservation technologies and the impact of water rates should all be taken into account. These factors clearly demonstrate the complexity of applying economic instruments to reduce water demand in each sector and in each country of the Middle East. However, the "water market" option could undoubtedly facilitate feasible solutions. Demand projections in this case may avoid entanglement with complex political considerations.
It is assumed that authorities will tend to defend their demand projections based on "equitable sharings" or "appreciable harm" as forcefully as they can. Turkey versus Syria, Syria versus Jordan and Israel, Lebanon vis a vis the Litani diversion plans, Israel vis a vis its present use of the Jordan and the mountain aquifers, and the PPA's use of the mountain aquifer are all areas of protracted controversy. Another source of conflict likely to arise as the peace process advances is the as-yet undefined scope of "return" migration of Palestinians and Jews and its implications for population growth and demand for water.
These and other issues will likely be addressed within bilateral and multi-lateral discussions: they are all relevant to projections of future water demand and supply. The hosts and participants in the peace process could play a major role in various studies following agreements among the concerned governments. Their potential role and leverage when funding additional resources, especially regional transfers, may become indispensible.

Demand management

Issues and policies

This endeavour includes continuous efforts (technological as well as economic measures, credits and incentives) for further reducing water use in the urban centers, in industry and to improve the efficiency of water use in agriculture. Incremental costs of water saved range from US$0.05 - $0.40/$m^3$. The best judgement for now would lead to a skewed distribution curve with an average cost of approximately 25-30 cents/m^3.
The figures in irrigation and industrial sectors as quoted assume increased



Source: R. Just, Horowitz, Netanyahu, University of Maryland, 1994.
Source: Israel Statistical Abstract, Central Bureau of Statistics, Israel, 1993

production per unit of water in real terms; they do reflect some changes in the basic production cycle, i.e. adapting to more economical cropping patterns and changing industrial processes. The levels of direct and indirect water production through savings and improved efficiency of water use are very important as they represent permanent reduction of demand. Israel has gone a long way in its efforts while the PPA, Jordan, Syria and Lebanon could still benefit significantly from such efforts to shrink demand and decrease the need for developing new sources.

Means include large-scale application of adequate technology (drip, sprinkler, automation), changes of industrial water use and water processes such as "cascading"*, changes in cooling methods, etc. and the application of demand- management policies and technologies in the utilities networks. Training, public education and effective extension services, must accompany the promotion and implementation instruments. The "trickle down" system will not work by itself. Finally, the efficiency of pricing mechnisms and the market system can play a dominant role in the whole operation. A comparison of prevailing prices for irrigation water between Jordan and Israel illustrates and partially explains the gap in the two countries' agricultural yield/m^3, and the potential for decreasing agricultural water demand.

Israel is ready to play an important role in the application of demand-management policies throughout the Middle East and thus assist delaying the need for expensive future projects in the area. Water conservation should be the first priority short-term strategy within the proposed plans for regional cooperation. If only one partner invests and applies rigid demand-management policies, the impact will be limited. Otherwise overall demand for water will rise beyond the supply capacity and overpumping may lead to regional conflicts.

Unaccounted-for water (UFW) causes significant water and financial losses to urban utilities and municipalities. Unaccounted-for water has been substantially decreased in Israel but remains a serious problem in Jordan, the PPA and other Middle Eastern countries. In Jordan, for example, UFW rates in many cities are above 50% and represent critical water and financial losses. Leakage is estimated to account for almost 50% of the total UFW (approximately 30 m^3 per/capita/year) which means that three million m^3/year could be recovered per 100,000 urban users. If multiplied by 50 cents (the minimum marginal costs of future water supply), the utility's financial annual losses equal approximately US $15 per million urban residents. There is no doubt, given experiences in Israel and many other countries, that these losses can be reduced to more resonable levels.Large sums of money can be saved and reinvested in further conservation and maintenance efforts. Water saved will increase urban water coverage.

Research done in Israel and California show that the costs of water saved through leakage control vary between US $0.15 - 0.35/m^3. These activities are usually an integrated part of improving utility management as utilities cannot reach finanical viability without it. Urban demand management addresses demand reduction at both the household and utility levels, and if applied on a large scale, it should reduce the cost of water in the Middle East as a whole.

Demand management efforts in Israel, Singapore, California and the Boston area and in other sites which included water conservation kits, have produced significant results. The kits include toilet flush reduction, two-volume flushing, regulated shower heads, flow regulators in kitchen and bathroom sink taps, leakage control as well as improved garden and parks irrigation) achieve demand reductions of 10 - 20% (sometimes 20 - 40%) - at an approximate cost US$0.10 - 0.15/m^3. Retrofitting should be done in all households and commercial buildings.Singapore can be seen as a very successful model, especialy in the commercial subsector.

These efforts could "produce" millions of cubic meters in each city and country at one of the lowest marginal costs available in the region. If the total urban population in Israel used demand management appliances, the water

* *The expression "cascading" means the internal re-use of water within separate production cycles of an industry quality as it is and/or improved.*

savings could have reached 100 - 150 million m^3 in 1994. However, it must be stressed that if the sewage effluent is totally and efficiently re-used, the end result of retrofitting may lose part of its economic value.
To conclude: one cannot underestimate the importance of urban and domestic water demand management strategy, as the growth of water consumption in the region will be concentrated in cities and towns. This water conservation strategy will generate permanent savings at low marginal costs.

Water demand management/ effluent reuse in the production sectors

Israel has completed most of its efforts at establishing and adopting water demand management for its existing industries while new industries are currently installing cooling systems and pre-designed "cascading" facilities. The price mechanism as well as effluent charges are gradually being enforced and are contributing their share to industrial water management. Many of the industries are located in the urban sector and are subject to the additional utility prices. Industrial water prices start at $0.30/$m^3$ and increases for use beyond basic allocation.
An additional revision of the data based on the value of incremental water savings in the industrial sector indicates that the value of saved water ranges between US$ 0.10 - 0.50/m^3. In most of the cases the lower figure is attributed to basic water management practices and the upper limits indicate the savings involved with air cooling and re-use of in-house or external effluent after complete secondary or tertiary treatment of the wastes.
The average cost of water saved in previous modest efforts in Israel was in the US$0.15 - 0.25/$m^3$ range. The fresh water allocation for the Israeli industry is approximately 7-8% of the total use and therefore the additional potential savings is relatively small. However, the environmental aspect of industrial wastes management could by itself justify higher levels of investment in treatment facilities, as in-house treatment and re-use reduces potential pollution of streams and water resources.
Re-use of wastewater effluent should be analysed in the industrial and urban conservation context. When effluent charges are enforced and subsidies are removed, market forces typically produce optimum results. Israel will probably demand that the Palestinian Authority assures adequate effluent treatment and disposal policies in order to ensure the safety of the sensitive western mountain aquifer underlying the West Bank. As relatively high levels of treatment will have to be adopted, it is reasonable to assume that local reuse for irrigation purposes will be the cost-effective solution, mainly in areas where aquifer pollution is not expected. Automatic drip irrigation of horticulture tree crops is preferred in these conditions when the fields surround most, if not all, the town and cities. It is essential that the design and implementation of adequate sewerage systems are given top priority when the external funding instruments become available. Vegetable irrigation should be avoided and therefore high-level monitoring must be established. Under these unique conditions, there is no alternative to the rigid involvement of the public sector.
Effluent re-use is a valuable method of decreasing demand for water and therefore it is used in conjunction with water conservation. The legislative/financial/ economic arrangements for conservation and reuse should be closely linked, for example:
* Industrial effluent charges and demand management should be integrated in a common program. When effluent charges are correctly imposed and enforced, in many cases the public sector will not need to monitor industrial (and perhaps urban) water conservation. Minimizing effluent flows will decrease industry costs and reduce its water bills, thus internalizing the decision-making process. However, supervision must be enforced as concentrated effluents could be hazardous.
* Urban water re-use: the economics of this strategy is strongly linked to whether the effective and efficient use of effluent for irrigation is a viable option. Treatment and transfer costs could determine whether a river or a marine outfall is the most economical, and under what conditions farmers will be ready to trade fresh water for treated effluent (i.e. at what price and ratio of exchange, under what investment sharing plan between the city and farmers and whether "bridging" funds are provided by the authorities). So there is a clear connection between urban demand management activities (except reducing unaccounted-for water, which is a separate issue), and effluent quality, effluent re-use, trade-off policy and legislation. Salinisation of the effluents will make them unsuitable for irrigation, so the city has a direct interest in avoiding "contaminating" the waste flows. Israel for example is considering economic sanctions linked to the salinity level of water supply and effluent.
These policy changes could have immediate impact on the design of conservation and effluent reuse programs in Gaza, Ramallah, Nablus, Tul-Karem, Kalkilya, Jerusalem, Amman and many other cities. The level of effluent re-use may decide the economic feasibility of other demand management efforts.

Increased efficiency of irrigation systems

Israel has been involved in improving irrigation efficiency since the 1960s and offered farmers accelerated financial support and credits for implementation during the 1970s. (These efforts were partially supported by the World Bank Agricultural Credit projects).
To date gravity irrigation has been eliminated, most farms have been redesigned and modern sprinkling, drip and automation systems have been installed. Old pipes have been replaced and the concept of measuring the value

*** For example, farmers pay today for 50% of their frozen 1989 allocation 15 cents/m^3, for an additional 30% 19 cents/m^3 and for the balance, 25 cents. Additionally, there is a formula for automatic updating of the rates.*

of water by its incremental contribution to yields has been developed.These changes led many farmers to alter and greatly improve their cropping patterns. There is still a great deal that can be done with the assistance of improved soil and extension systems and further applied research. The trend is toward higher-value crops, especially as a result of the fluctuations in world prices for cotton (a major irrigated crop), citrus, oil seeds, export vegetables and others. Water rates, equipment, pricing and credit mechanisms would play a dominant role in this subsector, as well as the availability of incentives and proper technology. (See graph to illustrate the achievement of the total efforts).

Reuse of sewage effluents

Here again, Israel has already come a long way. Nearly the entire population (both urban and rural) enjoys sewer services and almost all effluent undergoes extensive secondary treatment (activated sludge or lagoons). An additional 20-30% of the present annual effluent can be incorporated into the total national reuse system. Additional and significant investment in the inter-regional wastewater re-use system may capture 60-70% of the incremental quatity for urban and industrial use in the future. Therefore this resource will become the major avenue for exchange with fresh water resource, to be reallocated to the urban sector hopefully through a market mechanism.

The additional costs of further collection, treatment, storage and distribution (up to the farmers' field) as well as in the changes of the primary and secondary irrigation systems will be approximately 40 to 60 cents/ m^3 with an estimated average of approximately 50 cents/m^3. Responsibility for the cost will be split between the urban sector, the public sector and the agricultural sector. The concept of "the polluter pays" may be legally adopted and its scope will change the real economic costs of the water sector in the future. The extent of the formula of what is included in the polluter responsibility will decide the balance of costs to be funded as environmental incentives and farmer's rates.

These figures apply to the present situation within Israel. However, in order to better understand the dimension of the problem, one can estimate that by the year 2000, a population of over ten million will use approximately 1.0 - 1.2 billion m^3 of water per year (domestic and industrial use) between the Mediterranean Sea and the Jordan River (this region includes Israel and the Palestinian Autonomy). Thus, it is necessary to plan for the adequate treatment and reuse of approximately 700-900 million m^3 of effluent per year. Planning must be done in order to safeguard the aquifers, which are vulnerable and indispensible sources of potable water and to assure the proper conveyance of the effluent to the new sites. International funding must play an important role in providing budgets for sewage collection and treatment, as well as for effluent irrigation. Especially with regard to the PPA-area over the mountain aquifer, safeguarding its long range quality as the main source for high quality potable water for Israel and the PPA.

Water market - a temporary or permanent solution?

Water in Israel is used within a system of allocations (annual or multiannual) while in most countries it is user rights that determine use. In many regions, a person who owns land (or cultivates it) has the right to the water flowing beside and under his plot. In other regions, various quota systems allocate the amounts of water on an annual, monthly, weekly, daily (or even hourly) basis. Veteran users usually have the right to continue to use the resources. Riparian rights and other rights were obtained like titles on land, despite changes in population, prices (shadow costs of water), and changes in quality.

Throughout the world including the Middle East, the absence of adequate price mechanisms has led to substantial inefficiencies in water utilization, even in Israel, despite the tight allocation system and relatively high prices** However, efficiency of water resource allcoation and use can be substantially improved through increased use of price mechanisms. The parties will voluntarily trade water under the oversight of an agency like the Water Commission, with the expectation of profiting from the trade. Although the urban sector in Israel enjoys greater benefits within the present policies, it could profit tremendously from the new system in the long run through savings in water desalting costs. Most parties in the region will benefit by obtaining water at costs lower than other alternatives or by exporting or selling water at a cost higher than its marginal value to them. One option would involve the exchange of water based on the shadow price at the transaction site. The assessment of the adequate shadow-price could be done using an economic simulation model like the one developed by Harvard/Kennedy School/ISEPM with local experts. (The simulation model is needed because shadow-prices are not available and are subject to constant changes). Other options are available.

For setting trading costs, like the National Water Carrier Accounting System. Following the basic agreement on water allocation between Israel and Jordan (as well as for Jericho and Gaza) water will be traded under economic rules. The supervisory agency will monitor the market mechanism and could act as mediator to transfer the revenues from the sales to the contributors, minus transaction costs. Prices will be updated as they fluctuate according to supply and demand.

Extra revenues from transactions could be used for investments to improve and expand the water transfer system or to decrease transaction costs. The economic model should assist in the appraisal of alternatives.

Different trading mechanisms can be implemented. One option is joint management by the parties - Israel and the Palestinian Authority, Israel and a Jordanian agency, or the three together with or without an international agency

like the World Bank, acting as a facilitator and as a funding source for transactions and investments.
The National Water System of Israel run by Mekorot (the national water company, supplying about 65% of the water in Israel) is highly developed and will help minimize transaction costs.

Desalination of brackish water

I am ranking this option third, following conservation and sewage re-use because existing data supports the idea that reverse osmosis (RO) of brackish water may cost less than the development of other marginal or regional water resources. It includes also the possibility of using reverse-osmosis (RO) to improve ground water contaminated by salinity and/or other pollutants which accumulate in aquifers used for urban populations.
Brackish water is available from the vicinity of the mountain aquifers, the coastal aquifer and the fossil aquifer in the Negev (as well as from other sources along the valley of Jordan, the Dead Sea, the Negev Desert and the Arava Desert).
On the basis of available data, RO of brackish water of a quality of 2000 - 4000 TDS (or less) with a reduction ratio of 1:2 or 1:3 removing pollutants, sodium, nitrates, etc. to a potable level should cost (excluding the costs of pumping and piping to the site) approximately 40 - 60 cents/m^3, with an approximate average of 45 cents/m^3. Israel's brackish water supply system to be integrated could reach 150 - 250 million m^3/year in the next 10 years. It may involve still larger quantities to be treated (desalted) if ground water quality will continue to deteriorate (especially in the coastal aquifer (between Hadera and Ashkelon). The same would apply if demand for water will rise in the Negev Desert, in Gaza or the Dead Sea area. In Jordan large quantities exist and their desalination and integration will play a very important role. Local desalination reducing aquifer pollutants would cost between 25 - 40 cents/m^3, which means that in the future potable water quality within the coastal urban centers will likely be maintained by local RO of the well water inside the cities or in the vicinity. Pilot projects to analyse and demonstrate its application will be designed and installed during the next five years.

Development of other local water sources (non-desalinated)

Other local water sources include the fossil aquifer in the south(to be used for saline-resistant crops), deeper ground water resources, rainwater collection projects, additional multi-yearly storage arrangements (such as increased winter pumping from the Sea of Galilee and Yarmuk during rainy years for aquifer recharge), the use of additional storage in Adasiya/Mukheiba, the Jordan and/or the Netofah Valleys. Total feasible quantities will not exceed and additional 100-150 million/m^3 year (which will be shared with Jordan and/or Syria when stored in the Yarmuk or Jordan Dams). Cost estimates vary between 55-75 cents/m^3, with a possible average cost of approximately 60 - 65 cents/m^3 if dams will be built or additional NWC enlargement will be needed. In this analysis I do not assume increased rainfall through cloudseeding. The potential benefits of such an operation are inconclusive and far too indeterminate to estimate the results of present or future efforts or its costs per m^3. (In the Jordan-Yarmuk watershed, this issue is directly linked to additional operative storage. In most rainy years (when rain-storms of the cumulus-nimbus clouds prevail, part or most of the effects of the seeding may be wasted). The issue of additional storage will be dealt with in a separate article).

Sea water desalination (local and regional solution)

With newly developed technology in many other countries as well as Israel, sea water can now be desalinated on a large scale commercial basis.This option, the most expensive solution, is ranked before regional projects only due to the political complexity associated with regional transfers. Sea water desalination involves regional considerations as well. The basic questions are the economic implications, timing, and whether incentives or subsidies can be justified in order to increase water supply in the region by desalting sea water. A desalination program will boost water quantities and mitigate environmental problems, and will improve water supply quality, through mixing operations. Mekorot Corporation in Israel has published an international tender for such a plant in Eilat recently. Other RO plants exist in the Gulf, Malta, etc.
There are some benefits from economy of scale associated with large-scale desalination. The three main options are single RO plant, multi-stage distillation (MSD) plants, or various multi-purpose power and desalination. Only detailed designs and a complete bidding process (an international process including BOT or BOM alternatives)2 will enable the planning and financial process to be concluded. Dual purpose nuclear, hydro or gas powered plants (for example Gulf or Egypt to Israel-gas pipelines) Saudi Arabia to Jordan and desalination could be environmentally and economically preferable, given enhanced efficiency, effectiveness and marginal costs per kilowatt hour (kwh). However, the costs will be prohibitive if each party in the Middle East will demand its own plant, usin their own piping and pumping systems.
Recent data from the most efficient large-scale RO-sea water desalination plants as well as Multi Stage Distillation (MSD) led us to assume the following:
* Real present costs (in Malta, in the Gulf) are approximately $1.00-$1.10m^3.
* At current energy costs of about 5 - 6 cents/KWH and total capital return of 8 - 9% /year, the costs of desalted water in smaller plants (of approximately 15,000-25,000 m^3/day) would be approximately 90 cents/m^3 by the turn of the century. Plants of 150,000 - 250,000 m^3 /day might produce water at approximate costs of 70 - 80 cents/m^3 (1994 costs). These forecasts are based on improved processes presently under accelerated research and development such as

improved conventional RO plants and/ or:
a. hydrostatic pressure (interconnections between the Mediterranean and the Dead Sea or Jordan River or "Red-Dead" project;
b. hybrid systems (multi-stage distillation/RO and power grid;
c. possible solar ponds connected to RO and/or MSD;
d. other combinations of co-generation and hybrid MSD/RO units. All costs are ex-plant and significant additional costs will be attributed to the piping and pumping linkages, up to the final destination.[3]

One could assume that large-scale desalination has economic feasibility only if:

* Israel, the PPA and Jordan increase significantly the efficiency of water use in all sectors. Entities must invest in comprehensive efforts to increase water product value in agriculture and in industry and maximize urban water conservation and demand management (up to the economic intersection between desalination plus distribution costs and incremental costs of conservation).
* Desalination plants take advantage of economies of scale and serve two or three separate entities.
* plant operation is optimized ex-ante and ex-post. The planning and bidding process should look at two options:

a) a constant operation (excluding maintenance stoppages); and
b) operation of the plant during peak periods only. Costs may vary substantially. Flexible options should be incorporated in the design.

The use of joint multi-annual storage facilities (for example, the Sea of Galilee, aquifers, artificial recharge, Adasiya/Mukheiba and/or "Unity Dam"), combined with the two planning options, higher investment and lower O & M costs versus lower investment and higher O & M costs, both should be carefully evaluated to forecast the impact of changes in the future related to demand, conservation, pricing mechanisms and storage alternatives. Possible impacts of partial or total privatization/alternatives in order to further promote efficiency should be considered.

2 BOT = Build, Operate and Transfer (to owner at end of contract) BOMS = Build, Operate, Manage, Sell water (plant belongs to operator)

3 One should mention that Israel Desalination Engineering Corp. (IDE) has informed clients that they "could go down to 65-70 cents/m³ "(ex-plant)" - if adequate R & D funds will be available to them.

Regional projects

The above will be discussed in a separate paper(article to be published in a forthcoming issue).

The author ranking is as follows:
1. Litani East
2. Litani West
3. Marine transfer from Turkey or Greece
4. Pipelines from Turkey
5. Nile transfer options

Geopolitical problems plus costs could hamper the execution of these projects.

Conclusions

Out of approximately 600 MCM/year being supplied to the urban and industrial sectors in Israel, it is possible and feasible to reduce the water demand by 15-20%. It is assumed that if the proper program is implemented, 80 - 120 MCM of water per year can be saved. It may delay future sea water desalination plant (at an estimated investment cost of approx.$400 million) and will save present running costs (energy, chemicals, etc.) of approx. 15-20 cents per m³. Large savings can be expected if conservation strategies are applied in Jordan or the Palestinian Autonomy.

As most of the incremental demand growth will be concentrated in the urban/ industrial sector - a comprehensive demand management policy should become a major component of the regional water policy. By the year 2020, when the population west of the River Jordan will rise to over 12 million, the potential savings would amount to approximately 200 - 250 MCM/year, and if multiplied by present sea water desalination costs, it may reach a saving of approximately $200 million/year. This huge annual sum of money could be used for indefinite coverage of water conservation and effluent re-use projects throughout the region.

Increasing efficiency of water use in agriculture could by itself produce substantial results of increased production per unit of water (or effluent) and/or absolute savings. The 25 years effort of Israel has lead to the 350-400% increase in production per m³.

It is estimated that the cost of a cubic meter of water saved (or its compatible value in production) will be (based on Israeli experience) approximately 10-15 U.S. cents, much lower than the forecasted marginal cost of water in Israel.

Regional projects (Litani East, Litani West, transfer of water by marine routes, pipelines from Turkey or Egypt) are to be dealt with in aseparate paper. The geo-political problems hamper conducting proper feasibility studies in order to evaluate the economic costs of the various options (to be discussed in a separate article in a forthcoming issue).

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