Water Balances in the Eastern Mediterranean

edited by David B. Brooks and Ozay Mehmet

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EVALUATING WATER BALANCES IN ISRAEL

Harvey Lithwick

Introduction

Israel provides an interesting case study of how the understanding of a nation's water balances can change with advances in technology, growing economic sophistication, and evolution in internal and regional politics. In most circumstances, water balances have been viewed as exogenously determined — the difference between available sources and uses, both of which were deemed to be largely mechanistically predetermined. Over the past decade especially, research in Israel has revealed that the issues are much more malleable, particularly with regard to the role of market forces. As a result, what was once viewed as an impending crisis has now been more realistically addressed as essentially an allocation problem, one that is not simple, but much less apocalyptic. It has been learned that the potential for dealing with a variety of regional conflicts over water can be significantly enhanced with the wise application of management and pricing regimes. Indeed, there has been a radical revision in domestic policy with respect to water within Israel over this period, and it is to be hoped that this same change in thinking will help contribute to alleviating long-standing disagreements at the regional and international levels.

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Traditional factors shaping water balances

The traditional approach to water resources was to focus on the quantitative "stock" of water, with particular attention paid to additions to, and removals from, that stock. Removals from stock were shaped by allocation mechanisms, which in most countries reflect the interplay of powerful interests. I begin with a summary of this sort of water accounting in Israel. Then I provide a brief overview of the historical background and conclude with a discussion of several currently salient issues.

The entry point: supply of water

Israel has three major storage basins for its stock of water. One is rainwater and melting snow, primarily from Mt Hermon, which enter the upper Jordan River and then flow into the Sea of Galilee. The other two are the coastal and mountain (Yarkon) aquifers (Figure 1). These three sources account for almost two-thirds of Israel's current annual water supply of just less than 2 000 Mm^3/year. The rest is made up equally from smaller aquifers, especially in the Western Galilee and the Arava–Negev region, and from recycled and brackish water (Table 1).

These sources are primarily dependent on annual replenishment through rainfall. This entry point is problematic because of various factors, the most important being short-term climatic variability and the possibility of longer term periods of significant declines resulting from prolonged drought. The Sea of Galilee has had annual inflows ranging from a low of 100 Mm^3 in drought years (most recently in 1991) to a high of 1 500 Mm^3 (Kliot 1994). These phenomena impose

of Oriental and African Studies, University of London; Shaul Arlosoroff and Hillel Shuval, Hebrew University, Jerusalem; Raphael Bar-El, Faculty of Management, Ben-Gurion University; Zvi Eckstein, Tel Aviv University; Franklin M. Fisher, Massachusetts Institute of Technology; Nava Haruvy, Agricultural Research Association, The Volcani Center, Bet Dagan, Israel; The Israel Information Center; Moshe Israeli, Israel Water Commissioner; Mrs Esti Landau, The Armand Hammer Fund for Economic Cooperation in the Middle East, Tel Aviv University; Malaika Martin and Barry Rubin, *Middle East Review of International Affairs*, Begin-Sadat Center; Thomas Naff, University of Pennsylvania, Middle East Water Information Network; Uri Regev and Moshe Justman, Department of Economics, Ben-Gurion University of the Negev, Beer Sheva; Uri Shamir, Josef Hagin, and Ms Ella Offenberger, Water Research Institute, University of Haifa; Boaz Wachtel, Consultant, Tel Aviv; Amos Zemel, A. Issar, Gideon Oron, and Hendrik Bruins, The Desert Research Institute, Sde Boqer.

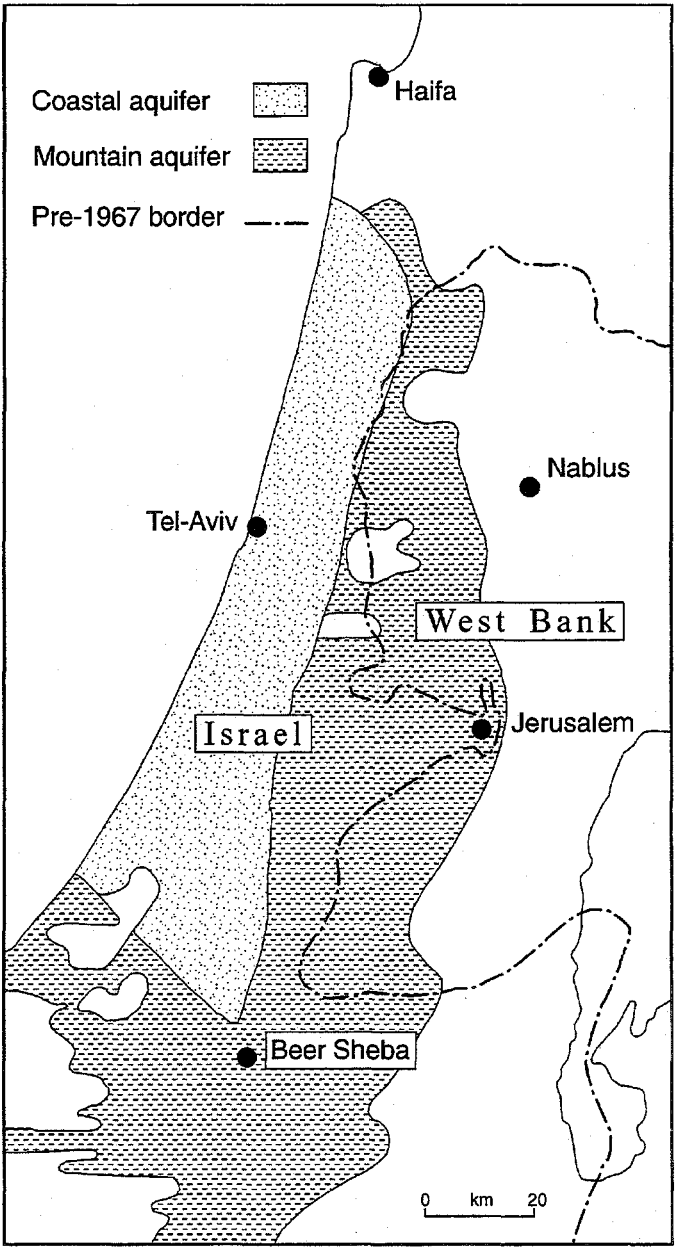

Figure 1. Israel's principal water-supply sources. Source: GOI (1998).

Table 1. Sources of water supply in Israel, 1996.

	Mm^3/year	% of total
Major sites		
Sea of Galilee	512.4	27
Coastal aquifer	418.0	22
Yarkon aquifer	326.1	17
Subtotal	1 256.5	65
Other sites		
Negev–Arava	89.0	5
Western Galilee	85.6	4
Other	162.2	8
Subtotal	336.8	17
Low quality		
Dan sewage water	140.9	7
Brackish water	130.7	7
Other	61.3	3
Subtotal	332.9	17

Source: GOI (1998).

on planners the need to make appropriate risk allowances when estimating future requirements. On the other hand, only part of the inflow manages to find its way into the water supply. Evaporation from the Sea of Galilee amounts to more than one-third of its annual inflow (Table 2). Also, losses resulting from leaky pipes, especially in urban areas, have been estimated at about 5% of the total annual production. In some cities, it has been estimated that up to 50% of the supply may be lost because of such leakage (Kliot 1994).

In Israel, there are long-standing stocks of water in the Fossil Desert aquifers (under the Negev and Sinai), which, at present, provide some 30 Mm^3/year but are estimated to be able to provide several hundreds of cubic metres of water

Table 2. Key storage basins for groundwater, 1995.

Major source	Mm^3/year	Comments
Sea of Galilee		
Effective stock	600	
Inflows:		
Jordan River	494	For years 1980–85
Runoff	216	
Precipitation	65	
Other	37	
Subtotal	812	
Outflows		
Evaporation	294	
Downstream	42	
Into water supply	500	
Subtotal	–24	Resulting in pollution and salinity
Coastal plain aquifer		
Effective stock	320	
Net flow	–96	Resulting in pollution and salinity
Mountain aquifer		
Inflow		
Precipitation	350	
Negev aquifer		
Outflow	30	

Source: GOI (1998).

a year (Issar 1998[1]). However, these stocks are not rechargeable, and this means that the draws on them are essentially nonreversible, which may partly explain why this source has not really been exploited.

[1] Issar, A.S. 1998. Global change and water resources in the Middle East: past, present and future. Unpublished manuscript.

The National Water Carrier, one of Israel's most important infrastructure projects, moves a very large proportion of Israel's water supply from the north of the country to users in the northern Negev (Figure 2).

Finally, there have been increased efforts to reuse water, that is, to put used water back into stock. This entails a lower level of water quality, which affects the allocation process, a subject that I shall return to below, as treated, recycled sewage water has been the major "new" source of water in Israel. Total sewage water produced in Israel amounted to 453 Mm^3/year in 1990. At that time, just more than one-third was treated for use in irrigation, but plans are to increase the volume of treated water for irrigation to 292 Mm^3 by 2000 (Kliot 1994).

Eckstein et al. (1994) provided more comprehensive estimates of Israel's potential water supply by source:

- Underground reservoirs, 1 250 Mm^3/year;
- Jordan and Sea of Galilee, 640 Mm^3/year;
- Lower Jordan–Yarmuk, 85 Mm^3/year;
- Streams and springs, 130 Mm^3/year;
- Treated wastewater, 460 Mm^3/year;
- Total, 2 570 Mm^3/year.

Most of these water sources are under dispute with Jordan, the Palestinian Authority, and Syria (Fisher 1995). The rough estimates of the annual water flow under dispute are as follows: Jordan, 600 Mm^3/year; Yarmuk, 500 Mm^3/year (250 of which flows south of Syria); the mountain aquifer, 600 Mm^3/year; and total, 1 700 Mm^3/year.

Traditional practice has been to search for new water sources to deal with a perceived shortage, and a number of schemes have been advanced over the years. There remains very active debate about capital costs, operating costs, and,

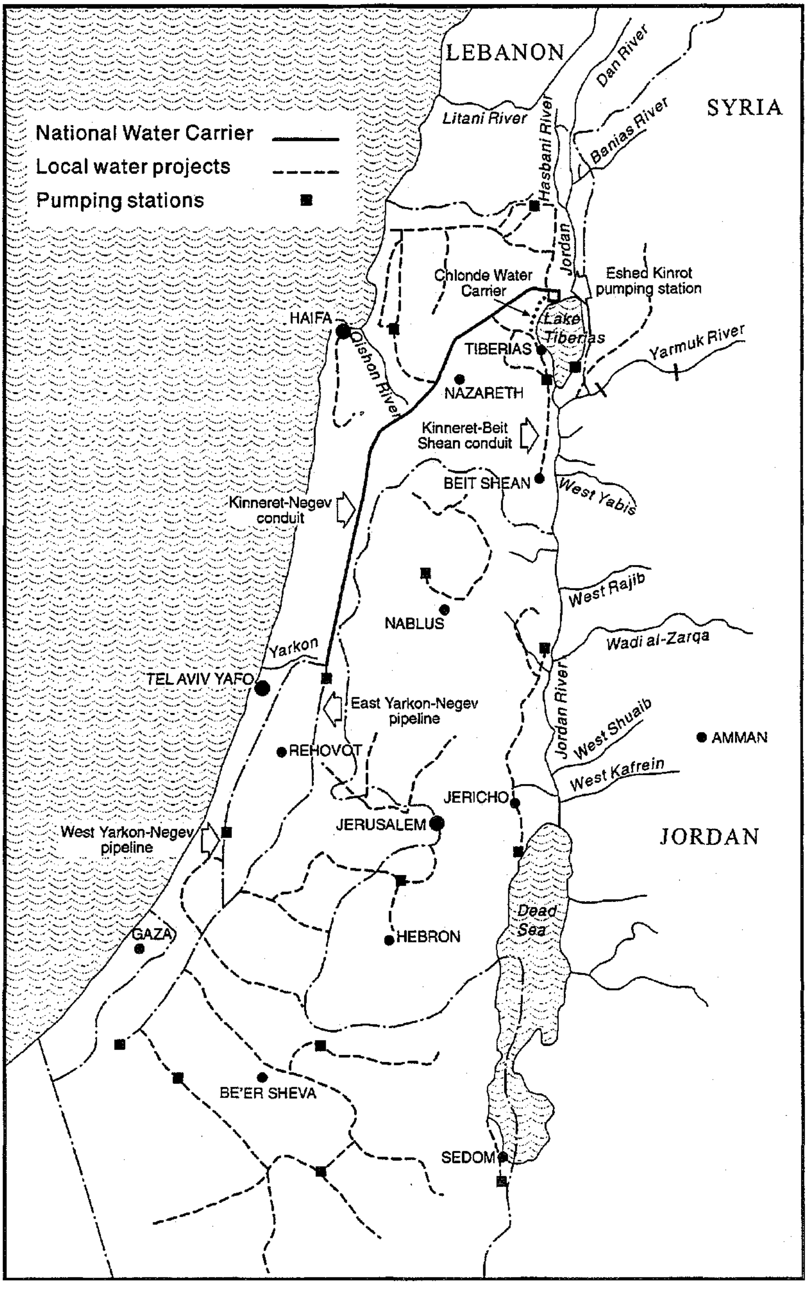

Figure 2. The National Water Carrier and related water products. Source: Kliot (1994)

of course, security of supply, when considering possible projects. Only a brief review of these schemes is possible here. The following is a summary of their key characteristics and, where appropriate, estimated costs per cubic metre.

- More intensive use of brackish waters (already being implemented);
- More intensive capturing of rainwater (a potential 160 Mm^3/year), including use of microdams (Laronne 1996);
- Desalination of seawater (with cost estimated at 0.75–1.00 United States dollars (USD)/m^3 in 1992 prices);
- Importation of water from the Litani River in Lebanon (geopolitical constraints);
- Importation of water by sea from the new Manavgat depot in southern Turkey (estimated costs have exceeded the minimum 0.75 USD/m^3 for desalination; James Cran (Cran 1994), a proponent of the Medusa-bag technique [using a ship to tow chains of huge plastic bags filled with water] estimated the cost of this solution at 0.18 USD/m^3, but this is far below the price that the Turkish authorities wish to charge [see Nachmani 1995]);
- Overland importation of water from Turkey (see Wachtel n.d.[2]) via Syria and the Peace Canal (this scheme is not costed, and it has major geopolitical constraints);
- Importation, by canal, of Nile water to Gaza and the Negev (a cost of 0.40 USD/m^3, but with geopolitical constraints); and
- Canals to link the Mediterranean or the Red Sea to the Dead Sea (Figure 3); the estimated costs, excluding delivery, range from 1.00 to 2.00 USD/m^3 (Bar-El 1995).

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[2] Wachtel, B. n.d. The Peace Canal Plan. Mimeo.

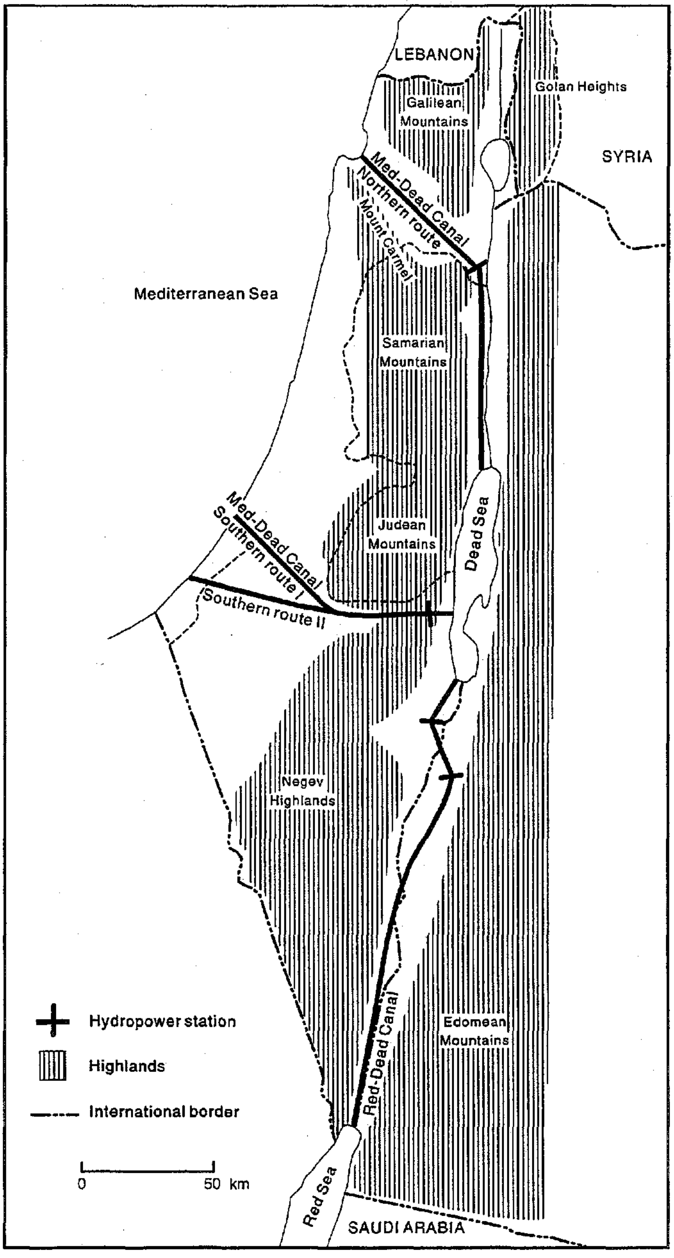

Figure 3. Proposed canal projects. Source: Hillel (1994).

Although widely used as the basis for choosing among alternatives, such cost comparisons do not even constitute cost-effectiveness evaluations. At best, they estimate direct costs, with little attention to accounting explicitly for external benefits or costs, and they would appear to use widely varying discount rates, etc. To the best of my knowledge, no systematic social cost–benefit analysis (SCBA), the most appropriate project analysis tool for such comparisons, has been undertaken.

It should be stressed that the availability of alternative water supplies at different costs makes the aggregate supply curve of water a rising-step function, rather than a vertical one, as is commonly claimed. The highest relevant cost is generally believed to be that of desalination — it will likely dominate all other major proposed sources in the next few decades. There is some dispute as to when it will become a cost-effective option. The Harvard team, headed by Fisher, concluded that desalination, compared with currently available options, would not likely become economically feasible until 2020. Shadow prices of other fresh water on the Mediterranean coast, where such plants would be located, are not expected to rise to more than 0.70 USD/m^3, in 1990 prices, until 2020. The cost per cubic metre resulting from the canal projects is higher, and, because of this, the canal option is dominated by the coastal desalination alternative (Fisher 1995).

The use stage: demand for water

The dominant user of water in Israel is the agricultural sector. Despite the decline of this sector in relation to the national economy, down from 11% to 5% of gross national product since the founding of the state, and despite the virtual elimination of Israeli agricultural products for export, down from 60% to 4%, agriculture has grown significantly in absolute terms, with important implications for overall water use. The area under cultivation has almost tripled from 162 000 ha to 445 500 ha, and the amount of farmland under irrigation has increased nine times, from 28 350 ha to 255 000 ha. As a counterbalance, new irrigation techniques have lowered water use per hectare by one-third. Nevertheless, agriculture still accounts for about 64% of all water consumed (MEWIN 1998). Of this, kibbutzim consume 44%, and moshavim (an organizational form involving cooperative management but private ownership) use 33% (Lindholm 1995). The strong political organization of these entities plays an obvious and important role in influencing the mode and levels of water allocation. By contrast, the share of domestic and urban use stands at about 30%, and industrial use is at 6% (GOI 1998).

The different prices charged to users have reflected a bias toward subsidizing water-intensive agriculture. At present, the price continues to differ by up to a factor of two. This influences not only the allocation of water among users but the overall rate of the use of water as well. The most recent average prices we have found are as follows (for October 1996, since raised):

	ILS	1996 (USD)	1992 (Eckstein et al. 1994) (Actual USD)
Agriculture	0.62	0.19	0.17
Industry	0.83	0.26	0.11
Domestic	1.12	0.35	0.50 to 1.22
Wastewater	0.50	0.16	

Note: ILS, Israeli new shekel. The exchange rate in 1996 was 3.2 ILS = 1 USD (in 1999, 4.0903 Israeli new shekels [ILS] = 1 United States dollar [USD]).

For efficient, realistic pricing, users should pay the marginal social cost of water delivered to their particular location; this marginal direct cost averages about 0.35 USD/m^3. As it is now, there is a major subsidization of agricultural and industrial water use by taxpayers, but the greatest burden is on domestic-sector users, who in 1990 provided an overall subsidy of some 200–250 million USD for water use (Kliot 1994). A major reason for these cross and overall subsidies is that in Israel a politically responsive state monopoly controls the allocation of water and investment in water projects, which ensures inefficient allocation of water supplies. I will elaborate on this issue in the following section.

Recent estimates project the annual growth in demand for water in Israel at about 30 Mm^3/year, mostly because of urban and industrial expansion. However, official projections, particularly those of Water Planning for Israel Ltd (TAHAL), have had to be subjected to some upward revisions because of changes that had to be made to their underlying assumptions. The most systematic of the revised estimates, until recently, were those of Eckstein et al. (1994).

For the household sector, the figures take into account the accelerated growth in population resulting from the wave of immigration from the former Soviet Union, which added some 700 000 to previous population growth estimates.

It also meant a higher than expected growth rate for the Palestinian population. The end result was an increase in household consumption by 39 Mm^3 in 1990, which will be 52 Mm^3 by 2010.

For manufacturing, most demand is concentrated on food processing, quarrying, and the chemical industry, much of which is located in the south of the country. However, not much growth in demand is expected for the industrial use of water, although the West Bank and Gaza are showing modest industrial growth, especially in the food production sector.

For agriculture, the estimates of use should be based on price assumptions. TAHAL stuck to volume estimates, albeit while implicitly reflecting an acceptance of higher prices, and projected a decline in quotas for agriculture that amounted to between 17 and 25% in total for all water and 55% for fresh water. This projection would be offset to some extent by an increase in agricultural consumption of water in the West Bank.

Naturally, there is serious concern over the net balance between inflows and outflows, discussed above, because over time the continued net withdrawals (or deficits) will deplete the water stock or render it less usable, as a result of qualitative deterioration. Kliot (1994) estimated these accumulated net deficits for up to 1990 (Table 3). These net flows should be seen in the larger context of the existing stock to provide some perspective on the nature and extent of the problem. One such attempt to estimate the relationship between stocks and flows at a key site — the Sea of Galilee — is summarized in Appendix 1 of this chapter, which shows that net annual flows constitute between 12% and 14% of the total stock of water in the lake. This is not meant to imply that all of this stock is available for extraction at times of severe shortage, because depletion below some red line will cause severe environmental damage to the lake and lakeshore. In recent years, the level has receded very close to that red line, and there is, therefore, legitimate concern over any annual deficit.

The politics of the water allocation process

With the whole stock of water in mind, decisions must be made regarding the allocation of these supplies among various sectors (agricultural, industrial, and residential); and the location of these various users is another factor. Allocations always reflect political considerations, together with economic realities. Allocation of water based on economic considerations tends to promote efficiency in both the

Table 3. Stacks and flows of water from major sources, 1990 (Mm^3).

Source	Net outflow	Overuse	Accumulated deficit
Underground			
Coastal aquifer	240–455	34–80 (1980–90)	100–1 400
Local aquifers	23–280		Small
Mountain aquifer	300–330	50 (1980–90)	300–350
Surface			
Sea of Galilee	575–950	25 (1980–85)	140
Floods and treated sewage	200–230		
Total	1 890–2 311		1 570
Water losses	60–100		
Balance	1 790		

Source: Kliot (1994).

production and consumption of water, as well as increasing the efficacy of major new water project investments, but other modes of allocation do not. In Israel, economic considerations long played a secondary role, thereby exacerbating the scarcity problem. However, over the past decade, Israel has made some substantial progress toward taking water allocation away from agriculture and putting it toward other uses that yield higher returns.

There is an interesting semantic phenomenon in referring to the use of water by various sectors as "demand." Economists define demand as the amount that consumers would like to purchase at alternative prices, but most of the forecasts for water demand appear to be based on quantitative extrapolations of water volume, ignoring or at best underestimating the importance of pricing and income effects on that demand. The consequence is that if prices charged are substantially below their true competitive equilibrium, the estimated volume demanded, and hence used, will be much higher than it would be economically efficient and socially optimal to supply.

Water is, for most purposes, what economists call an "intermediate input." As such, the value of water other than for household use is based, not on the utility derived from direct consumption of the water itself, but on the value of the goods and services it helps to produce. If the outputs are valued in competitive markets, the value of the water can be readily estimated. Where they are not, such as in highly protected agricultural markets, the value of water is more difficult to measure and must be derived through shadow pricing. It has been estimated that the value of the marginal product of 1 m^3 of water in agriculture is between 0.15 and 0.30 USD (Arlosoroff 1997). Economic rationale would therefore allocate water to such a use if its delivered costs were less than its value. As the delivered cost is a function of location, the net effect would be to reduce water use for agriculture in remote regions. Similarly, it would tend to reduce the production of those crops whose value, per unit of water used, is relatively low. Clearly, this would affect a wide variety of agricultural interests.

Although reduced consumption is therefore an appropriate goal, all too often it is promoted by the public sector in advocating specific technologies. Appropriate pricing is the preferred alternative, because it would encourage the most cost-effective technologies to be introduced at the appropriate time within the various sectors. However, the dominant users of water in the agricultural sector, represented by the Association of Farmers, have resisted such a policy orientation for perhaps obvious reasons.

To the extent that the allocation process is based on noneconomic considerations, it is very likely that use will bear a limited relationship to overall community valuations and real resource costs. That is not to argue that political considerations are not important — security of food and energy supplies for a security-conscious state like Israel is indeed of great importance. However, it may well be that misallocation of water actually contributes to less security by wasting a relatively scarce resource and making peaceful solutions to interregional water disputes more difficult. Recent attempts to impose a more rigorous cost and price discipline should go a long way to encouraging more efficient use of water (Arlosoroff 1997). Over the long run, efficient pricing also ensures that investments in the supply and use water are also efficient.

Calculations of water's scarcity value in Israel

In Israel, reallocation of water use is achieved in the face of the long-standing interests described above, mostly as a result of the accumulation of evidence on the costs and benefits linked to water use. It is useful to begin with extraction costs. Quantities extracted and costs of extraction (in 1992 prices) from other sources (common pool) are as follows (Eckstein et al. 1994):

	Volume (Mm^3)	Price (USD/m^3)	Conflict
Southern coastal aquifer	49	0.42	Gaza
Yarkon aquifer, north	90	0.14	
Yarkon aquifer, south	110	0.20	
Gilboa	131	0.31	
S'dom, Dead Sea	84	0.12	
Ramallah	25	0.57	West Bank

As for the aggregate supply prices of water, the marginal costs of extracting water have been estimated by Bental (1996), as presented in Table 4.

Based on Eckstein's estimate of the cost of water from the mountain aquifer (0.50 USD/m^3), some important orders of magnitude of the benefits to be derived have been clarified. If this represents the efficient price of water, then the value of the estimated 2 000 Mm^3/year used is about 1 billion USD, or 1.7% of the gross domestic product (GDP) of the entire region. For a highly efficient water-use regime to emerge, the allocation would have to change dramatically. Water in the northern Negev (and Gaza) costs about twice as much as in Galilee.

Table 4. Marginal water-extraction costs.

Volume (Mm^3)	Marginal cost (USD/m^3)	
	1991 ILS	USD
0	0.34	0.15
700	0.46	0.20
1 100	0.68	0.30
1 400	0.91	0.40
1 700	1.25	0.54
1 900	1.60	0.70
2 000	1.82	0.79

Source: Bental (1996).
Note: ILS, Israeli new shekel. The 1991 exchange rate was 2.3 ILS = 1 USD (in 1999, 4.0903 ILS = 1 United States dollar [USD]).

The efficient use of water would require a 10% cut in allocation in the north and a 40% cut in that in the south, mostly to agriculture and primarily for marginal crops that have a very low value added per unit of water input. The study estimates that if water had been priced based on efficient allocation, total water consumption would have fallen by 296 Mm^3 in 1992, to 1 779 Mm^3, that is, by 16%. The price of water would have risen by 0.30 USD/m^3, and the quantity used in agriculture would have fallen by 10–15%. The price of water in the south would have risen 170%, and the quantity used in agriculture would have fallen by 25–30%. Based on this evidence, current efforts to move major amounts of agriculture to the Negev appear to be extremely ill considered.

An important study by Gideon Fishelson (Fishelson 1993), at Tel-Aviv University in 1993, provided the first set of elasticity estimates for household water demand. He estimated the long-term income elasticity at between 0.2 and 0.4. The price elasticity was estimated at between –0.05 and –0.15. Based on these fairly low elasticities, the author argued that even at very high prices, household consumption would be very unlikely to decline below the benchmark current consumption of 110 m^3/year.

Historical trends and recent estimates

Long-term trends in water balances since the late 1950s reveal that the agricultural demands grew steadily until 1983 but then declined dramatically — by almost one-third — between 1983 and 1990. But this trend was sharply reversed during the first half of the current decade. It is the domestic sector that has undergone steady long-term growth, offsetting whatever savings were realized in agriculture over the previous 10 years (Figure 4). We should note, however, that on a per capita basis, overall water consumption has declined substantially in Israel (Figure 5), no doubt in large part because of the slowdown in agriculture's consumption of water since the mid-1980s.

Table 5 presents the most recent estimates of water balances in Israel, projected to 2040. They make a major improvement in water allocation planning possible because they are based on more realistic projections of demand, supply, and the use of efficiency-based allocation procedures. Overall, these procedures have granted Israel a period of perhaps a decade in which to find more fundamental solutions to its long-term water requirements. Knowing that these solutions will take

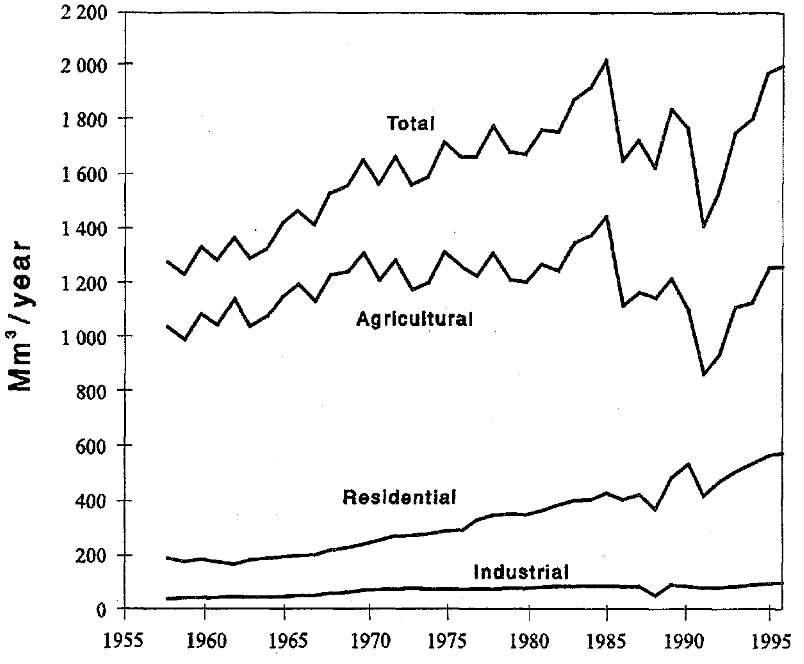

Figure 4. Historical trends in water use (Mm^3/year). Source: GOI (1998).

a number of years, it is a matter of some urgency to begin the planning in the very near future. Ideally, a combination of approaches should be considered in order to avoid undue reliance on any one technology. For example, a 10-year contract to purchase water from Turkey, coupled with the development of pilot desalination plants on the Mediterranean, could be considered, but only after appropriate SCBAs had been conducted.

Water: a heterogeneous product

I have, to this point, assumed that water is a homogeneous product, but what complicates the story of water use is that it can and does exist at different levels of quality. Some of its uses do not require the highest level. Clearly, a system that optimizes water use will attempt to allocate such quality-differentiated supplies in

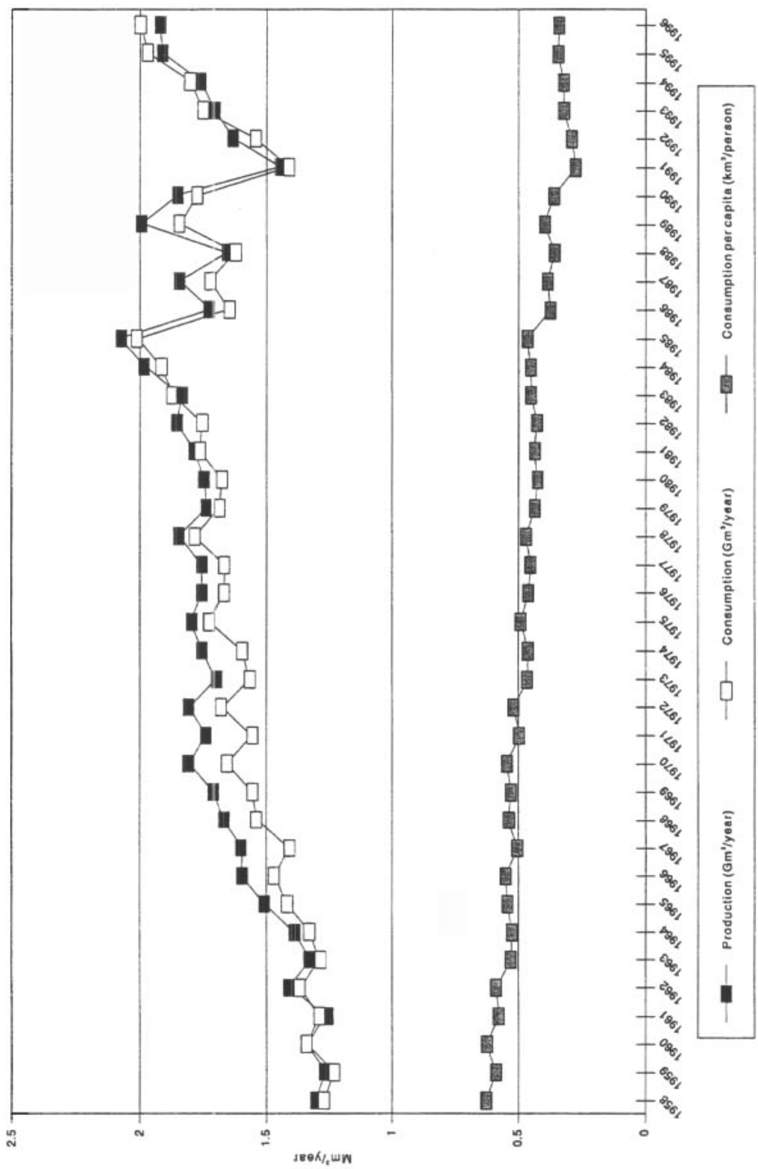

Figure 5. Historical trends in production and consumption of water in Israel. Source: GOI (1998).

Table 5. Israel's current and projected water balances (Mm^3).

		1990	2000	2010	2020	2040
Annual inflows						
Israel and West Bank	Groundwater	1 060	1 090	1 100	1 100	1 100
	Jordan Basin	660	670	670	670	670
	Floodwater	40	50	70	80	70
	Losses	–40	–40	–30	–25	–25
	Subtotal	720	1 770	1 810	1 825	1 815
	Reused water	198	296	418	651	1 071
	Total	1 918	2 066	2 228	2 476	2 886
Annual outflows						
Israel	Municipal	481	654	774	915	1 151
	Industrial	106	130	155	183	255
	Irrigation	1 200	1 200	1 200	1 370	1 920
	Subtotal	1 787	1 984	2 129	2 468	3 326
West Bank	Municipal	36	71	133	204	379
	Irrigation	100	155	190	280	300
	Subtotal	136	226	323	484	679
Gaza (net use)		43	43	69	94	147
	Total	1 966	2 253	2 521	3 046	4 152
Net flows						
Israel and the West Bank		–48	–187	–293	–570	–1 266

Source: Israel Water Study for the World Bank (cited in GOI 1997).

the least-cost manner, a process that is already under way in Israel, but, for perhaps understandable reasons, it encounters significant resistance. For example, because of the need and desire to supply an extremely high standard of drinking water to people, all water delivered to households must meet this standard, even though the bulk of it is not used for drinking or cooking, but for bathing, cleaning, laundering, and even watering the geraniums. Water for direct human consumption constitutes a minuscule portion of total household water use. Methods to encourage alternative modes of delivering drinking water could conceivably reduce significantly the need for high-quality water for other household uses and hence lower its costs. Also, a practice of encouraging direct household recycling of "gray" water for garden use would promote important efficiencies.

The allocation system implicit in the Telem study for TAHAL in 1988 (TAHAL 1988) was based on similar considerations. The plan was to reduce freshwater consumption from 1 800 Mm^3/year to 1 600 Mm^3/year. Household demand for fresh water would rise by 480 Mm^3, and water going to agriculture would fall by 660 Mm^3. Recycled water would be allocated in much larger amounts to the agricultural sector, both as a substitute for the lost high-quality water and to enable further expansion. The current distribution of water by level of quality is provided in Table 6, which indicates that the targets have been achieved.

The roles of technology and economics

A key question is what is the value of water to the Israeli economy. Using the price of desalination as the maximum willingness to pay and the shadow (efficient allocation) price of 0.50 USD/m^3, the net value of the common pool available is estimated at 200 million USD/year, or less than half of 1% of Israel's GDP (Eckstein et al. 1994). The net rents from the common pool are slightly less than 100 million USD, which could serve as the basis for financing water projects.

The scale of desalination to date is modest. Most of the plants are in the remote Eilat area, and they meet more than half of that city's needs. As we have seen, in other parts of the country, the process is not cost-effective, nor does it appear likely to be in the near future. A major factor contributing to the high cost of desalination is its heavy energy requirements, the costs of which tends to be understated and the security implications of which tend to be ignored.

Efforts to enhance rainfall through seeding clouds with silver-oxide crystals have been made over the Sea of Galilee for the past two decades. The result has been an increase in annual rainfall in that area by almost 20%.

Existing water supplies can be augmented through the use of new technologies, as Israel has demonstrated in numerous fields. On the one hand, improvements in drilling techniques have made once inaccessible stocks an important component of annual supply. On the other hand, microsprinklers and, more recently, drip irrigation with computerized control systems have made much more

Table 6. Water use by user and water-quality level, (1995) (Mm^3).

Use	Fresh water	Effluents	Brackish	Total	Mekorot share	Mekorot (%)
Agriculture	898	227	86	211	747	62
Domestic	578		2	580	444	77
Industrial	111		25	136	94	69

Source: Arlosoroff (1997).

efficient use of existing water supplies in agriculture. About 20% of consumption for irrigation has been reduced by these methods. New technologies for using brackish water in the agricultural sector, without diminishing yields, have had beneficial impacts as well.

A major new source of water is treated household and industrial effluents. More than 100 m^3/year from this source is now being used in agriculture (cotton and fruit growing), but another 200 m^3 is still discharged into groundwater or into the sea, owing to the absence of storage facilities.

A decade-old program involves building artificial lakes (120 to date) to collect surplus winter runoff. The water in these lakes can be used, not only for irrigation, but also for recharging aquifers; and the lakes can be used for storing water in transit between uses and locations. How these innovations came about — the result of responses to scarcity, signaled partly at least through rising prices — remains to be fully analyzed. Certainly, the subsidization of many uses of water has retarded such innovative processes, but it is expected that recent reforms will give much freer rein to imaginative solutions.

An alternative means of augmenting water supplies is through importation, rather than production, of especially water-intensive, low value-added food supplies. With the opening of global food markets and intense competition among suppliers, countries in the region, such as Egypt, have been able to forestall a potential water crisis by importing food. For decades, Israel followed the opposite path, subsidizing via the price of water agricultural production and exports, effectively encouraging the export of the water that it took to grow the food (Allan 1998a). By shifting to food imports, by more carefully allocating water supplies (especially to high-cost locations), and by avoiding crops with low value-added water input, the overall social impact of an increase in the price of water toward its true scarcity value can be substantially mitigated.

The other side of this coin is less comforting. The use of fertilizers and insecticides, which in part permits agriculture to make do with less water, also contributes to the reduction of water quality. Kliot reported that according to the Water Commissioner, most of the water for household use is below the official quality standard, especially with regard to its high nitrate content, which does not conform to internationally accepted standards (Kliot 1994). The most severe effects of overpumping, as a response to shortages, are seen in Gaza, where the level of contamination of the groundwater is extremely high (Kliot 1994).

Furthermore, Mekorot Water Company's distribution system is very energy intensive. Energy represents more than one-quarter of the company's operating costs, and the company uses 8% of the power generated by the Israel Electric Corporation. One suspects that the associated environmental costs (air pollution) directly attributable to water provision are not yet being factored into its price. Offsetting this is the fact that with the increased use of treated effluent water for agriculture, fewer pollutants enter urban streams and the sea, reducing the already alarming levels of environmental damage (with its high social costs) in densely populated areas. Groundwater is affected in the rural areas, where such water supplies are used, but lower densities of population in rural areas will tend to reduce the net social cost of this pollution transfer.

The role of geopolitics

The core problem facing Israel is that its major source of surface water (the Jordan River) and its underground water sources (the two aquifer systems) are also claimed by other jurisdictions. The Jordan River has a complex system of sources and distribution, as can be seen in the schematic presented in Appendix 2 of this chapter. The two major actors are Israel and Jordan. The Palestinians are involved primarily through their claims on the aquifers adjacent to their territory, adding a second dimension to the debate.

These intercountry conflicts can be broken down into two distinct issues: (1) the issue of who owns the water, or what is legally known as property rights; and (2) the issue of spillovers or externalities, situations in which one party's actions have implications (positive or negative) for another. An efficient allocation of water does not depend on property rights, so long as the water is properly priced and the rights to it are freely traded. There is no such simple solution for externalities, because parties acting in their own self-interest tend to avoid taking these effects into account. If the external effects are costs to others, the result is that too much is produced (the classic example being road congestion). If the effects are benefits, too little is supplied. A third-party or common management system is required in such circumstances to ensure that efficient amounts are produced and exchanged.

For a common management system to be completely effective, it must involve all actors with an interest in the system and the ability to affect it. Cooperation must take place in the form of joint action plans, commissions, and treaties, based on a regional approach to watershed planning that involves all riparian states and regional actors with an interest in the water source. In the case of Israel and its neighbours, this requires basin-wide cooperation, involving Jordan, Lebanon, the Palestinian Authority, and Syria, together with Israel. The peace treaty of 1994 between Israel and Jordan provided for a division of water resources without the involvement of the other riparian states. The supply of water affected by this agreement could be diminished and joint cooperative plans under way could be derailed by other parties with access to, and an interest in, this water source.

Is Israel able and willing to approach the management, distribution, and allocation of these shared water resources as a shared task? Any sharing of water will be seen as reducing Israel's ability to meet its own water needs, even if doing otherwise would entail infringing on others' right to meet their needs. Israel is in a unique position of having a great deal of control over the distribution of both underground and surface sources, and this affects its neighbours. However, Israel remains highly vulnerable to potential actions by the other riparian states as well. Israel is heavily dependent on two contested supplies: the 430 Mm^3/year that it receives from the mountain aquifer and an additional 305 Mm^3/year of fresh renewable water from the Golan, totaling 735 Mm^3/year of Israel's 1 587 Mm^3/year total freshwater consumption (see Table 6). The mountain aquifer poses a big challenge. The Palestinians are unable to expand their own water resources in this region. Extensive groundwater development in the West Bank would threaten coastal wells because of increased saltwater intrusion from the sea (Wolf 1995). Moreover, any pollution of this underground source of water will result in a net loss of water available for Israel's population. Therefore, to protect its scarce sources of water, Israel believes it needs to control groundwater exploitation and prevent contamination.

Despite the many innovations noted above, it is far from certain that the long-term water needs of the region will be met as demand continues to expand. To date, in the absence of frameworks for cooperative action, innovations have been made based on narrow, inward-looking criteria. For example, Jordan constructed its East Ghor Main Canal system, which runs along the east coast of the Jordan River, to serve agricultural needs in its country while Israel developed its National Water Carrier system, starting at the Sea of Galilee and carrying water throughout the country. These and other initiatives began to interact, resulting in growing tension. The war of 1967 is a key example of escalated tension leading to conflict. The inclusion of water issues in the multilateral Israeli–Palestinian peace negotiations highlights the importance of this issue to the future development of this region and the resolution of conflict.

The potential for cooperation is certainly there. In addition to nonconventional water resources that can be developed unilaterally, there is scope for joint research and innovation programs. Moreover, short-term water needs can be alleviated through interbasin transfers of water. Options include diverting water from the Litani River to the Sea of Galilee (providing 100 Mm^3/year to Israel, Jordan, and the West Bank), channeling water from the Nile to the Jordan watershed (resulting in 500 Mm^3/year), sending water from Turkey to the Jordan watershed by pipeline (1 100 Mm^3/year), and using Medusa bags to ship water from Turkey (500 Mm^3/year) (See Appendix 3 of this chapter). Longer term cooperation could focus on regional initiatives, such as desalination projects.

The degree to which these projects are possible will depend on the willingness of these states to cooperate for the sake of enhancing water resources to meet the water needs of the region as a whole. The combination of a need to expand water sources and a dependence on shared water sources should provide a powerful incentive to cooperate. A peaceful resolution to conflict in the region would increase the chances of successful implementation of any and all proposed projects. At the same time, pursuing these initiatives may encourage further dialogue and cooperation among riparian actors. As such, cooperation over water may contribute to, and benefit from, an environment of peace.

Water as a symbol

Perhaps the greatest barrier to finding reasonable solutions to the so-called Middle East water crisis, at both the national and regional levels, is the symbolism attached to the resource. In Israel, it is intimately bound up with the early Zionist views about land and the importance of agriculture in settling and claiming it:

> Water for us is life itself. It is food for the people, and not food alone. Without large-scale irrigation — we shall not be a people rooted in theland, secure in its existence and stable in its character.
>
> — Prime Minister Moshe Sharret, in 1952 (quoted in Feitelson and Haddad 1994, p. 73)

These views persist to this day in the subsidization of water for agriculture, which transfers costs to other users, as well as to the economy as a whole, in terms of wasted resources. The approach of focusing on water volume alone has led many to conclude that current rates of overuse are plunging the region into a crisis. Such a view has been justifiably ridiculed by no less an authority than a former Israeli water commissioner, Dan Zaslavsky, who pointed out that "there are local and temporary shortages because it's not the highest priority of the countries involved; that's all!" (quoted by Nachmani 1995; see also Zaslavsky 1997). The traditional view is changing, and more rational allocations, using more appropriate prices and more realistic water-quality mixes, are emerging on the part of the water authorities themselves.

One adjustment mechanism has been stressed by Allan (1998a), namely, importing "virtual water" at low cost in the form of food products from region's that have a comparative water advantage. Another is the major reduction in water use in Israel, from 2 000 Mm^3/year in the mid-1980s to less than 1 600 in less than a decade, primarily through an increase in productivity in agriculture, occasioned by higher prices, which reflect growing scarcity. Unfortunately, the update on that story is a bit less optimistic, as the last few years have seen a sharper increase than was anticipated, with total consumption in 1996 once again approaching 2 000 Mm^3/year (see Figure 4).

On a regional basis, issues of sovereignty enter in, and water has been at the centre of long-standing, major disputes. Once again, too much focus has been on water volumes alone and allocating them among the various states with conflicting claims. But these huge claims are based on existing patterns of allocation that fail to allocate water in terms of its scarcity value (shadow price), as strongly expressed by Nachmani (1995). In other words, few dare to question the demands or needs being claimed, but they are certainly exaggerated because use is priced below true scarcity value. Allan goes so far as to claim that in the Middle East, "water almost everywhere is treated as a free good" (Allan 1995, p. 344). Moreover, as Fisher (1995) and others have shown, the implicit value of the water in conflict is surprisingly small and appropriate solutions are feasible. The value of this water is estimated by Fisher at no more than 110 million USD, which will rise to some 500 million USD (in 1990 prices) by 2010 (Fisher 1995).

Of course, this argument ignores the possibility that water may not be the cause but the symptom of more basic conflicts, so that managerial–economic solutions are beside the point. Nevertheless, a less symbolic approach to water has helped Israel achieve substantial efficiency gains in its national water use, and a similar approach applied regionally may offer some hope for collective action at that level.

Prospects

Israel has obtained a modest window of opportunity to deal with its own and the region's water needs. By moving toward a policy of efficient allocation, it has been able to restrain the growth in demand, even with a very rapid surge in population resulting from immigration from the former Soviet Union in the early 1990s. The immediate challenge for Israel is to further reduce the share of fresh water going to the agricultural sector. The old mode of administrative allocations will not do the job, as it is subject to historical interests incapable of readily accepting the burden of such a change. One alternative would be to extend the current initiative to divert fresh water from irrigation and replace it with treated effluent, but this option is limited by quantitative and qualitative constraints and could only serve as a partial solution. Fortunately, market mechanisms have been proposed, including tradable rights and the use of appropriate scarcity pricing. If adopted, these changes would have a profound and beneficial impact on the whole water economy. Adoption of similar policies by neighbouring countries could provide temporary relief for the region as a whole.

Two critical steps are required if the region is to avoid serious impending difficulties. One of these would be to find the means to operate regionally (that is, multinationally), whatever the political circumstances may be, to deal effectively with the externalities intrinsic to this scarce resource. The other would be to make more effective use of the price mechanism, a move required to ensure efficiency in managing the stock of water. The advantage of this would be that it tends to be less political and less bureaucratic and can therefore help avoid the problems that are bound to occur in any multinational effort at regional cooperation (Eckstein et al. 1994; Fisher 1995).

Even with efficient pricing and regional cooperation in management, the growth in demand, early in the next century, will once again bring serious water shortages to the fore. A number schemes to add to Israel's and the region's water supply are being vigorously promoted by their respective proponents: desalination, a variety of canal schemes, importation of water from Turkey, and capture of runoff, to name a few. Despite substantial analysis of each proposal in isolation, I have been unable to discover a serious attempt to rigorously compare the full set of social costs and benefits from these alternatives, a question amenable to the tools of SCBA. Water projects have been the first, and still the most important, field for the successful application of this methodology (El-Bihbety and Lithwick 1998). Water authorities would be well advised to underwrite some baseline studies in this area to enable Israel to identify and implement realistic solutions.

Whatever schemes are adopted, progress toward regional cooperation in meeting short-term requirements can provide important institutional mechanisms for positive-sum long-term solutions as well. Acting collectively as water buyers, we can keep import prices down. Acting collectively as project developers, we can capture economies of scale and positive externalities.

Paradoxically, Israel's recent successes in dealing with its short-term challenges may lead it to resist those region-wide collaborative efforts that could do much to alleviate the longer term problems. Viewed constructively, a move toward regional cooperation may, in the short run, not only provide opportunities for low-cost, long-term solutions but also play a useful role in creating a less hostile geopolitical environment for everyone.

Appendix 1. Recent water balance of the Sea of Galilee (Mm^3/year).

Source of flow	Inflow	Plus	Minus	Outflow
Flow into Sea of Galilee	544			
Rainfall over sea		65	–270	–474
Flow from local runoff		70		
Springs in and around sea		65		
Evaporation from sea surface				
Outflow to lower Jordan River				
Total volume of sea	4 000			

Source: Murakami (1995).

Appendix 2. Stocks and flows of water from major sources (Mm^3).

Source	Net outflow	Overuse	Accumulated deficit
Underground			
Coastal aquifer	240–455	34–80 (1980–90)	100–1 400
Local aquifers	23–280	Small	
Mountain aquifer	300–330	50 (1980–90)	300–350
Surface			
Sea of Galilee	575–950	25 (1980–85)	140
Floods and treated sewage	200–230		
Total	1 890–2 311		1 570
Water losses	60–100		
Balance	1 790		

Source: Kliot (1994).

Appendix 3. Comparison of alternative water import schemes.

Mode	Volume (Mm^3/year)	Price (USD/m^3)
Litani to Israel	100	0.14
Nile to Israel	500	0.20
Turkey, overland	1 100	NA
Turkey, Medusa bag	500	0.21

Source: Wolf (1995).
Note: NA, not available.

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