Chapter VI

Israel's Water Policy: A National Commitment

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SUMMARY

Israel's concerted national response to its severe water problems involved the use of several measures that may have relevance for some of the arid/semiarid U.S. agricultural regions. These include:

- development of a vigorous water-data collection and evaluation project, including the mapping of ground water resources to determine their sources and ages;
- close monitoring of withdrawals and recharge to predict ground water level changes and allowable withdrawals;
- management of water demand through the use of such tools as water-use metering, pricing, and allocation; and
- extensive and ongoing research, training, and technical assistance programs that involve the farmer in the design, manufacture, and application of new water management devices and techniques.

INTRODUCTION

Israel's approach to water management has been defined largely by limited freshwater resources, poor natural distribution of those resources, and an expanding and dispersed population.[1] The latter aspect has been nearly as important a factor in determining water policy as the physical characteristics of the land and water resources (see table 9). The population of Israel has more than quintupled since the country's founding in 1948, increasing from about 800,000 to nearly 4 million largely because of a liberal immigration policy. To accommodate this growth, Israel directed its new citizens away from established population centers to new settlements throughout the country. This created not only a demand for more water but also a need to distribute the water to dispersed and remote users at an equitable cost.

The major obstacles to meeting these demands have been:[2]

[1] S. Arlosoroff, "Israel-A Model of Efficient Utilization of a Country's Water Resources," paper prepared for United Nations Conference on Water. Much of this section is derived from this article and an interview in April 1982 with the author.

[2] M. Ben Meir, "Development and Management of Water Resources in Israel, " *Water and Irrigation Review*, Journal of the Water Workers Association of Israel (Tel Aviv), July 1981, p. 15.

Table 9.—Facts About Israel, 1979-80

Total population	3,921,700	
Number employed in agriculture	83,200	
Total area	5,021,000 acres	(2,032,000 hectares)
Cultivated area	1,055,117 acres	(427,000 hectares)
Irrigated area[a]	469,490 acres	(190,000 hectares)
Total freshwater available	1,378,400 acre-feet	1.7 billion cubic meters/year
Agricultural water available	973,000 acre-feet	1.2 billion cubic meters/year

[a] From Central Bureau of Statistics, Ministry of Agriculture, Jerusalem.

SOURCE: Statistical Abstract of Israel, 1981.

1. There is no rainfall during the 6 months of summer, and total rainfall varies greatly from year to year.
2. The principal sources of water, the Jordan River and Sea of Galilee, are located mainly in the northern half of Israel, while more than half of the arable land is in the south.
3. Capacity in the Sea of Galilee and the two major aquifers is insufficient to meet both perennial and seasonal storage needs.
4. Most of the water is needed at elevations much higher than these main sources of supply; the Galilee, actually a lake, is more than 200 meters below sea level. Water must be pumped, and its distribution is energy intensive.
5. The coastal areas next to the Mediterranean contain ground water, but withdrawals must be controlled to prevent seawater intrusion.
6. Freshwater in deeper limestone reservoirs is adjacent to highly saline water bodies. To prevent intrusion of brackish water into the reservoirs, withdrawals must be kept below the annual recharge rate.

Israel's available freshwater resources amount to about 1,378,400 acre-feet (1.7 billion cubic meters) annually. By 1985, an estimated 1,621,700 acre-feet (2 billion cubic meters) per year will be needed or about 15 percent more water.[3] Israel has limited options for increasing water supply. Virtually no untapped sources of freshwater exist, and present ground water levels are not likely to increase. Other water sources are questionable, particularly in terms of quality, and not yet fully developed. They include reclaimed sewage, brackish water, and storm waters. The Israeli Government's plan for agricultural development during the first half of the 1980's estimates that the total volume of water available to agriculture in 1985 will grow only slightly—from a 1980 level of about 973,000 acre-feet (1.2 billion cubic meters) to 1,135,200 acre-feet (1.4 billion cubic meters).[4]

By the end of this century, it is expected that 30 to 40 percent of the water used for irrigation will be reused effluents, and 10 percent of the total amount of water used for agricultural purposes will be brackish water of high salinity.[5] This projection reflects a shift in focus in water resources during the last decade from the development of additional supplies to management of demand.[6] Demand management aims to make a given physical volume of water provide the maximum possible benefit to the community. Since the early 1970's, Israel has followed a policy by which development of new water resources has been considered and weighed against the investments and benefits of demand strategies. This policy has been informally called "drip and automation versus dams, deep boreholes and pipes."*

[3]Arlosoroff, U. N., op. cit.

[4]*Six Year Plan for Agricultural Development, 19801985* (Jerusalem: Ministry of Agriculture, 1981), p. 84.

[5]Ibid., p. 141,

[6]Meir, op. cit. p. 2.

*Comments made by S. Arlosoroff, former Deputy Water Commissioner for Israel in correspondence, Oct. 28, 1982.

WATER USE PROGRAMS

Israel has pursued a concerted, integrated response in dealing with its severe water problems. Managing demand for water is a major element. Other elements include national control of water resources, development of a national water supply system, and technical assistance to farmers and to all sectors of water use.

These programs have been possible for a number of reasons. Israel is a small country; its size has facilitated the widespread installation of water-related technologies. Consequently, distribution of water has not required prohibitive investments in pipelines and canals. The country as a whole has had a serious commitment to the development of a strong national water policy and program effort. The lack of a traditional farming community or a strong private water property rights system at the birth of the nation also has reduced opposition to an extensive national water legislation with strict enforcement provisions.[7]

State Control of Water Resources

Under Israeli law, the water resources in the country are public property. They are subject to the control of the state and are intended for the use of its inhabitants and for the development of the country. The country's first water law regulations were drafted and enacted in 1949. The legislation was gradually amended and perfected until the current comprehensive water law went into effect in 1959.[8]

Supply and Distribution[9]

Israel embarked on an ambitious scheme in the late 1950's to create a national water supply system to meet the demands of a growing population and to distribute water equitably. The backbone of the system, known as the national water grid, is the National Water Carrier, which began operation in 1964.

The Carrier, Israel's largest single development project, consists of a 155-mile (250-kilometer) system of pipelines, canals, and tunnels extending from the Sea of Galilee in the north to the Southern and Western Negev Desert with an extension up to Eilat on the Gulf of the Red Sea. From 1964 to 1975 it transferred an average 283,800 acre-feet (350 million cubic meters) of water annually, operating to maximize use of the land's storage capacity. Regional exchanges of water between sources with high and low salt concentrations have helped to mitigate problems of salinity, During the wet period, when demand is not so great, water from the carrier is used to artificially recharge wells and aquifers. Thus, heavier withdrawals

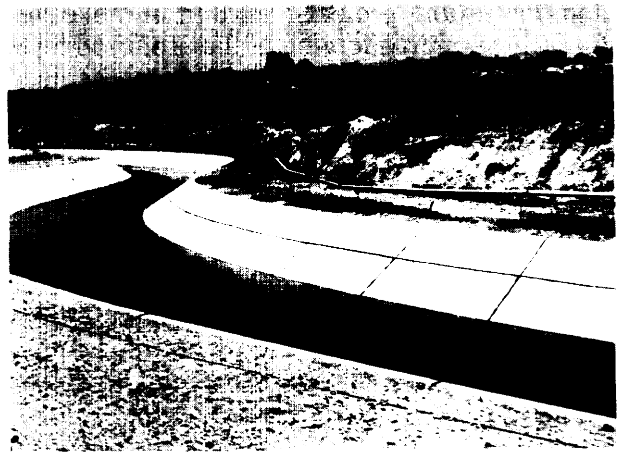


Photo credit" Embassy of Israel

Israeli's National Water Carrier, known as the national water grid

are possible during the dry season. Recharging has the additional effect of mixing high-quality water with lower quality ground water. Wastewater, after tertiary treatment, also is used for recharging. The flexibility of this system of recharge and water transfer enables Israel to achieve a very high degree of efficient water use.

As part of this program, the Government conducts a vigorous water exploration and research project, including mapping of ground waters to determine their source and age, prospecting for new resources, and increasing the flow and use from sources already known. The national grid and close monitoring of withdrawals and recharges allow Israel to predict ground water levels to within a few centimeters. Wastewater reuse, desalinization research and application, and operational cloud seeding for enhancement of precipitation also area part of this effort.

Demand Management[10]

In view of its limited water supplies, Israel has chosen to focus heavily on demand management. This policy has required a complete package of elements, including legislation, administration, sanctions, funds for research and

[7]Arlosoroff interview.

[8]S. Arlosoroff, ''Water Resources Development and Management in Israel, " KIDMA, published by the Israel Chapter of the Society for International Development (Jerusalem), vol. 3, No. 2 (No. 10/1977), p. 5.

[9]Arlosoroff, U. N., op. cit.; and Meir, op. cit.

[10]Arlosoroff interview.

demonstration projects, and in some cases funds to support adoption of the preferred technology. It has been justified in light of the need to maintain or increase irrigated agricultural production under arid/semiarid conditions, when government resources for development of new water resources are limited.

Under this policy, water use is strictly regulated within a licensing and allocation system. The water law prohibits inefficient water use. The primary tools used to discourage inefficient water use are metering, pricing, and allocation.

Metering

All water users, whether in agriculture, industry, or the domestic sector, are metered. Water users are licensed by the Government and the license must be renewed annually. Failure to use water in a manner consistent with the license can lead to its forfeiture. Each license prescribes the quantity of water that can be withdrawn from any source, including underground, runoff, * and sewage effluent sources. Underground sources supply 60 percent of the water consumed by Israel. The water commission has the right of unlimited access to water meters and inspects them regularly. Most water meters must be installed outside buildings. If a meter is inside under lock, the state inspector must be given the key. Farm units are included within the metering requirements, and all farm wells are metered and inspected.

Pricing

The price of water is state controlled. Those people living in areas where water costs less to produce, such as the coastal Mediterranean sector which has access to a shallow aquifer, must pay a levy (based on cubic meter of use) to a national Water Charges Adjustment Fund. In the more remote or high-elevation regions where water costs are high, the Fund pays a subsidy to users. In addition, water rates are set on a progressive block basis—that is, as more water is used, the marginal unit cost becomes higher.

Allocation

As much as 70 percent of Israel's water withdrawal is designated for agricultural water use (table 9). So it is important that allocation of water for farming be strictly managed. Each farmer, cooperative rural settlement (moshau), or collective farm settlement (kibbutz) receives a yearly allocation, based on the type of crop and the average water use for the particular area over time. A citrus grower, for instance, will be told that the allocation for the coming year will be "x" amount. Moreover, the grower may also be told that, in the following year, it will be "x" minus an amount which should be saved because of increased water use efficiency. * This policy of further restricting allocation for the next year is not implemented every year.

The farmer may appeal an allocation judgment to the water commissioner, then to a special Water Tribunal which serves as a court dealing with water disputes. In the event of an adverse decision of the Water Tribunal, the farmer may appeal to the Supreme Court of Justice. Once the allocation is set, however, the farmer must either: 1) implement new techniques to use water more efficiently, or 2) let yields drop as water supplies are reduced and plants are overly stressed using the existing practices. The incentive in this system is that any surplus water a farmer can gain by efficiency may be used to irrigate more land, and thus farmers have a strong motivation to adopt innovative techniques because most of them have more land than available water can irrigate.

As might be expected, the Government's strict regulation of water use has caused a number of problems in administration and enforcement. For instance, it has been suggested that farmers who want to use water without pay-

*Runoff is that portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, ground water runoff, or seepage.

"Water-use efficiency refers to crop production per unit of water used, irrespective of water source, expressed in units of crop weight per unit of water depth applied to unit area.

ing the per-cubic-meter equalization charge or a higher rate block charge could simply reverse the flow of water through the water meter so that increased water use is subtracted from the reading.[11] This is a criminal offense. However, it forces the water commission to police water users regularly.

On the other hand, the Israeli system encourages farmers to develop and use water-efficient technologies and farming practices. Even when water is restricted, the farmers generally cooperate when they are assured that by adopting new technology and practices they can manage with less water, still boost crop yields, and in most cases increase their net income over time even with the additional capital investments.

Technical Assistance[12]

Finally, the Israeli Government assists farmers in implementing more water-efficient technologies by providing technical assistance. This assistance includes:

- promoting the research and development of efficient cropping and irrigation methods and systems,
- offering technical assistance in their introduction,
- granting loans at attractive interest rates,
- reducing temporarily market prices of water-efficient appliances,
- providing applied research and demonstration projects, and
- wide-scale immediate dissemination of the positive and negative results throughout the country.

The key to Israel's technical assistance and adoption success is the link between the research effort and the farmer. The Israeli Government conducts ongoing agroeconomic studies to convince farmers to adopt new techniques and methods. These studies cover crops, irrigation techniques, and methods that improve water efficiency and profits. Then, by working with progressive farmers, the Government field-tests new technologies such as plastic sprinklers, drip irrigation techniques, automatic metering, and computerized irrigation controls. New irrigation devices and techniques commonly are manufactured by farming communities themselves, an important feature of Israel's technology adoption success. The manufacturers, being also the users, are unlikely to market something that does not work.

Similarly, researchers and kibbutz farmers often are the same individuals. They may work in research in the morning and on the farm in the afternoon, or take leave from the kibbutz to work full time in research. Almost every kibbutz sends a significant proportion of its members for advanced studies (master- and doctorate-level programs) each year. Consequently, there is an ample supply of agricultural engineers and scientists.

[11] Arlosoroff interview.
[12] Ibid.

SELECTED IRRIGATION TECHNOLOGY APPLICATIONS

Israel is recognized as one of the most advanced nations-in applying certain irrigation technologies. These include: 1) irrigation with treated effluent water, 2) drip and sprinkler irrigation, * 3) computer-controlled irrigation, and 4) saline water irrigation. The technologies have been introduced along with new cropping systems, fertilization regimes, plant varieties, and other management aspects to improve agricultural yields. 'Application of fertilizers, pesticides, and other agricultural chemicals with the water through the drip or sprinkler systems has forced farmers to be very careful about each unit of water applied in order to achieve optimal water, nutrient, and chemical application and distribution.

"Drip or trickle irrigation is a system for supplying filtered water directly onto or below the soil surface, Water is carried to each plant through an extensive pipe network which is generally stationary once installed. Sprinkler irrigation is a system of applying water to a field with the use of one or more rotating sprinklers, spray nozzles, or perforated pipes. With each method, water is sprayed into the air under pressure and falls to the ground in various sized drops.

It is difficult to obtain data on increased crop yields resulting from the application of these irrigation technologies because they are an integral part of the larger management packages. Overall, Israel has reported a net agricultural production increase over the decade 1968-78 of an average of 6.8 percent annually. For the same period, purchased inputs rose at an average annual rate of only 4.7 percent (table 10). This was achieved with an approximate 21 percent reduction over the same period in the amount of water allocation per unit of irrigated land (fig. 6). Among the kinds of new technologies Israel has used to increase water efficiency and crop yields are those discussed below.

Wastewater for Reuse

Agricultural and other reuse of domestic sewage and industrial waste is a high priority in Israel. Under the water law, wastewater is publicly owned and is treated legally as if it were freshwater. Although a separate ministry is responsible for wastewater, a legal mechanism exists to coordinate freshwater and wastewater management. According to one report, by the end of the century more than 30 percent of Israel's total wastewater flow will have been recycled for irrigation or industrial use.[13]

[13] J. Shalhevet, "Deciding on Agricultural Research Priorities in Israel, " KIDMA, vol. 7, No. 1 (Jerusalem: spring 1982), p. 24.

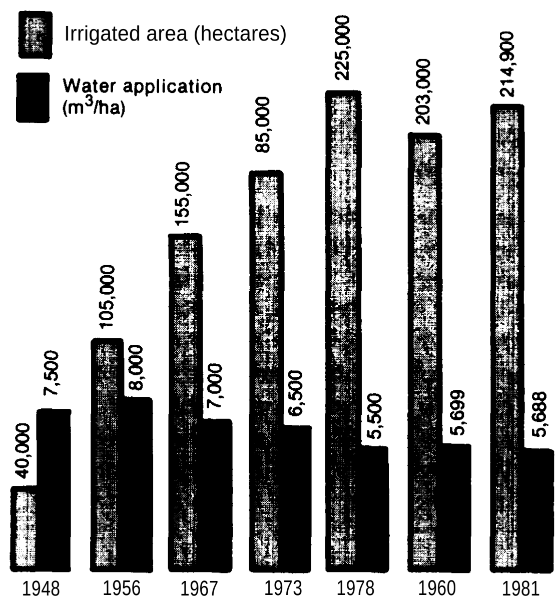
Table 10.—Average Yearly Rates of Change in Percentages in the Major Components of the Agriculture Sector[a] Account, 1968-78 (percent)

	1968-73	1973-78	1968-78
Real rate of change in:			
Agricultural production	5.6	5.5	5.5
Agricultural output[b]	5.9	5.8	5.8
Purchased input in agriculture	6.3	3.2	4.7
Agricultural net domestic product[c d]	5.2	8.4	6.8

[a] Agricultural sector means all agricultural activity (including livestock production, etc.).
[b] Agricultural output is defined as agricultural production *less* intermediate produce *plus* production for investment.
[c] Net domestic product is defined as income originating in agriculture *less* compensation for damage by nature.
[d] Reflects total income including nonwater-related production.

SOURCE: Centrat Bureau of Statistics and Computations of the Survey and Advice Department, Planning Authority, Ministry of Agriculture, published in *S/x-Year Plan for Agricultural Development,* 1980-85 (Jerusalem: Ministry of Agriculture, 19S1), p. 34.

Figure 6.— Efficient Use of Water



SOURCE: Adapted from Israel Water Commission, from J. Shavalet, KIDMA (Jerusalem), vol. 7, No. 1, spring 1982, fig. 1, p. 24.

A major effort to use wastewater in Israel is the Dan Region Sewage Reclamation Project.[14] The first stage (1975-80) of this project involved treatment of 12,200 acre-feet (15 million cubic meters) of wastewater for reuse. Preliminary findings indicate that the treated water could be fully integrated with the National Grid System if the supply network in the south were converted to a dual system separating water for potable and nonpotable uses. With tertiary treatment and the addition of water from other sources, reclaimed water may be suitable for widespread agricultural use.

The Dan Region Project plans to use 113,500 acre-feet (140 million cubic meters) of wastewater annually from the metropolitan Tel Aviv area for irrigation in the south of Israel. The effluent from Tel Aviv is treated in oxidation lagoons or algae ponds, which eliminate much of the contamination. Additional biological, chemical, and physical (sand filtration) treatments are also employed. Besides agriculture, the project also plans to produce treated water

[14] E. Idelovitch, "Wastewater Reclamation by Advanced Treatment," KIDMA, vol. 3, No. 2 (No. 10/1977), pp. 30-35.

for recharging ground water sources and supplying water for industrial and domestic nonpotable purposes.

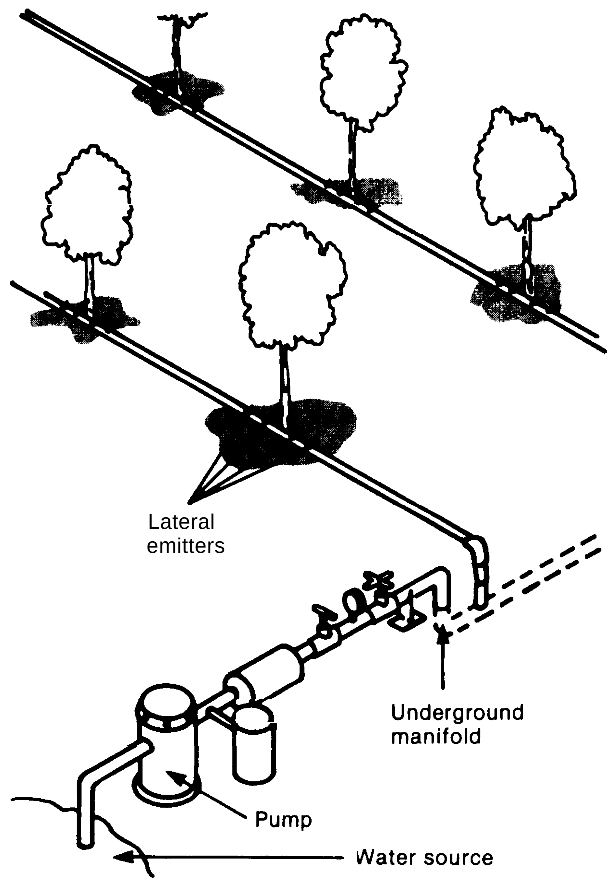
Irrigation with treated effluent has not been without problems. In 1970, a cholera outbreak was traced to the illegal irrigation of salad crops with raw sewage effluent from East Jerusalem in the West Bank. The water had been collected from the discharge stream. Regulations for effluent quality were tightened, and efforts to broaden the scope of wastewater treatment and use were intensified.[15] A 1971 amendment to the water law now limits the use of treated effluent in irrigation to industrial crops, such as cotton, or to food crops where either the water does not contact the produce directly or the produce is normally cooked before being eaten.[16]

Drip (or Trickle) and Sprinkler Irrigation

Israel has focused heavily on improving low-pressure sprinkler and drip irrigation technologies. In normal gravity fed field or furrow irrigation, plants do not use much of the applied water because of evaporation, percolation past the root zone, and runoff from the surface. With standard sprinkler systems, evaporation and runoff losses also can be heavy. The problem is compounded with heavy runoff because the runoff water takes with it natural or added nutrients critical for the plant growth. In contrast, low-pressure sprinklers and drip irrigation systems deliver virtually all of the water and any added nutrients directly into the plant root zone. The national water grid supplies water under pressure which accommodates these systems, so the use of drip irrigation is expanding. Drip irrigation today accounts for about 10 percent of Israel's total irrigated area.[17] Figures 7 and 8 show the trickle and sprinkler systems of irrigation, respectively.

[15] Ibid., p. 30.
[16] Arlosoroff, KIDMA, p. 10.
[17] "Irrigation in Israel," in special issue of *Irrinews (No. 25, 1982),* Newsletter of the International Irrigation Information Center, Bet Degan, Israel.

Figure 7.—Trickle Irrigation System



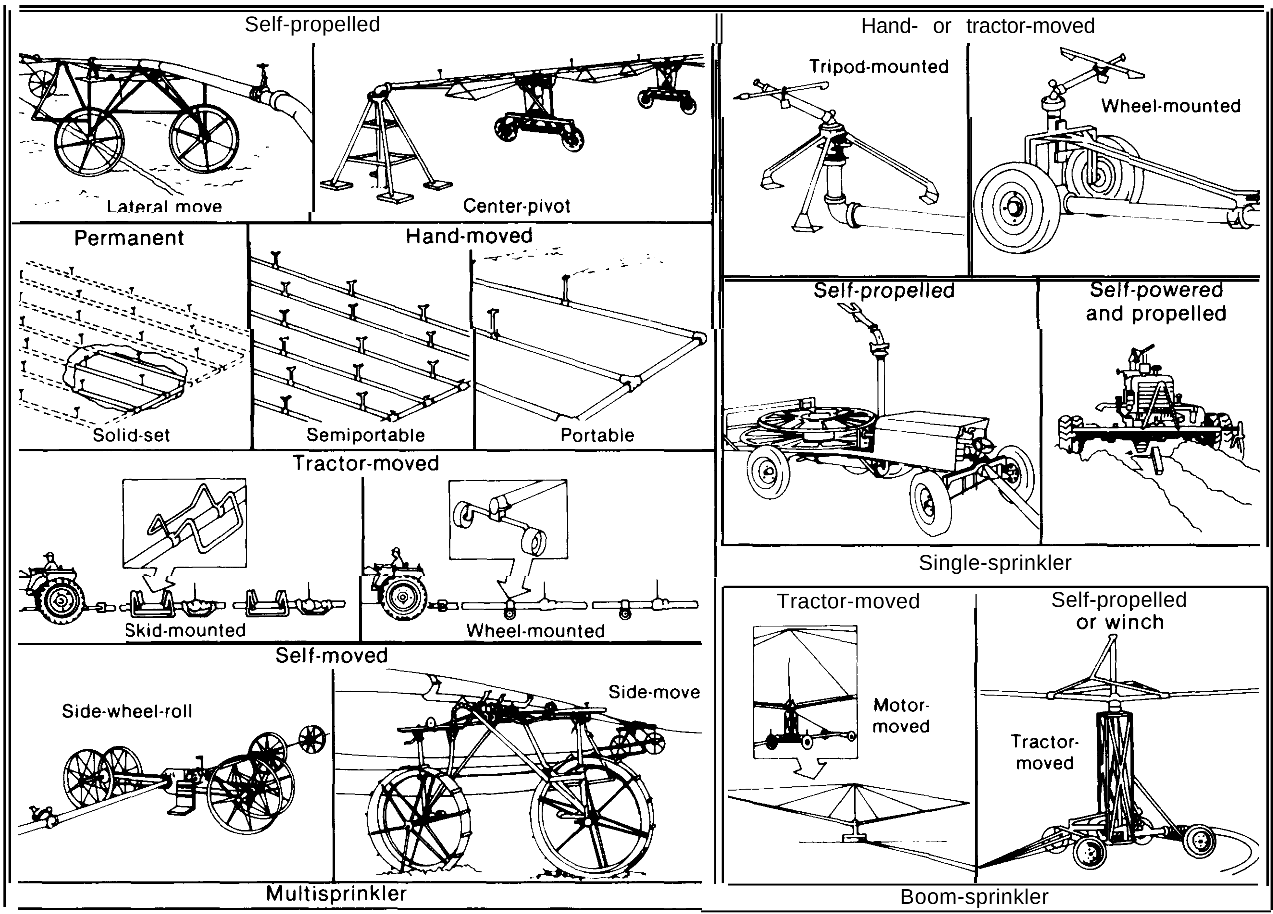
Trickle irrigation is a system for supplying filtered water directly onto or below the soil surface. Water is carried through an extensive pipe network to each plant. The outlet device that emits water onto or into the soil is called an "emitter." After leaving the emitter, water is distributed to a "wetted zone" by its normal movement through the soil.

Surface application by the trickle method. Water is applied very slowly onto the surface of the soil through special outlet emitters in plastic pipe.

SOURCE: J. Howard Turner and Carl L. Anderson, *Planning for an Irrigation System* (Athens, Ga.: American Association for Vocational Instructional Materials, 1980).

Traditional irrigation technologies used portable metal pipe systems that were towed along the fields and stationary irrigation grids with permanent pipes laid in the soil. The increasing cost effectiveness of using plastic tubing is causing a shift toward stationary irrigation systems because portable systems are labor intensive and unwieldy.

Figure 8.—Typical Types of Sprinkler Irrigation Systems



SOURCE: J. Howard Turner and Carl L. Anderson, *Planning for an Irrigation System* (Athens, Ga.: American Association for Vocational Instructional Materials, 1980).

However, for large rectangular plots of field crops, such as grains, cotton, maize, and sorghum, Israel is experimenting with dragline sprinkler systems. * These systems use pipes or sprinkler booms positioned across each field and supported on tall towers mounted on tractor-like vehicles on each side of the field. These vehicles move back and forth picking up water from a channel that parallels the field, pumping the water through the pipes for distribution on the soil by means of dragline hoses. The system uses lower water pressure and causes less runoff damage than most other sprinkler systems. It can apply water more uniformly and can cover a considerably larger area.

In contrast, the drip or trickle irrigation systems involve the placement of plastic tubes with low rate emitters along rows of plants. There is one emitter per plant or a pattern of emitters in the case of orchard trees. Using this method, water flow is continuous and slow, evaporation loss minimal, and plants can be fertilized at the same time they are watered. This technique is particularly well suited to perennials such as fruit trees. It also is being applied successfully to cotton and other row crops. The continuous flow method saves labor by eliminating the necessity of turning the irrigation system on and off.

*The United States is experimenting with a similar system called in some publications the linear-move lateral system.

To overcome some of the problems with drip irrigation lines, Israeli technicians have developed a variety of filters that solve most of the clogging problems resulting from water that contains organic and colloidal suspensions. The problem of chemical clogging when fertilizer is fed through the lines is being solved by using acids mixed with water.[18]

Results with drip irrigation, according to an Israeli Ministry of Agriculture report, have been favorable for such vegetable crops as table tomatoes, peppers, eggplants, squash, strawberries, artichokes, and grapes. For fruit trees such as apple, apricot, peach, and almond, drip irrigation also is the preferred method for saving water and maintaining water quality. Percolation of water to the ground water table and extra runoff to surface water is eliminated or reduced, avoiding agricultural, chemical, and natural salt contamination of those water bodies. This method appears to be the least expensive of the irrigation systems for these crops.[19]

Tables 11 and 12 are the results of experiments in the Negev conducted under extreme arid zone conditions with brackish water, showing comparative yields using drip, sprinkler, and furrow irrigation.

Computer-Controlled Irrigation

Irrigation can be almost totally automated by using pressurized irrigation systems. This requires linking the irrigation water lines to a remote control mechanism that uses small computers. Israel introduced these computerized controls into its farm management systems in the early 1970's, At that time, the principal reason for the program was protection for farmers who were in danger from land mines and snipers when they went to the fields to maintain irrigation controls. Later, automated irrigation was developed into a water-efficient technology and a means of increasing crop yields.

Over the past decade, Motorola Israel Ltd. (a subsidiary of Motorola, Inc., U. S. A.) has been the principal company marketing computerized irrigation control systems in Israel. The company manufactures one system for small farms of up to 320 acres (130 hectares) and another for farms of 1,000 to 5,000 acres (400 to 2,000 hectares) or more. In the larger units, a central computer can send instructions via wireless radio or cable to field units equipped with sensors to relay information back to the main system. For large farms, many control mechanisms are run from a central computer. Since the 1970's, more than 50 large units and 1,000 smaller ones have been installed in Israel. They have been exported and are now gradually coming into use in the United States (primar-

Table 11 .—Production Comparisons for Various Crops Under Different Irrigation Systems

	Muskmelon yields	
	Yield (tons per hectare, t/ha)	
Irrigation methods	Total	Export grade
Sprinkler	23.8	13.0
Furrows	24.2	16.7
Drip	43.0	35.0

SOURCE: D. Goldberg, B. Gornat, and D. Rimon, *Drip Irrigation* (Kfar Shmaryahu, Israel: Drip Irrigation Scientific Publication, 1976). Published in Ilan Amir and Benjamin Zur, "Irrigation in Arid Zones: The Israeli Case, " in *Arid Zone Settlement Planning (New* York: Pergamon Press, 1979)

Table 12.—Effect of Irrigation Methods on the Yield of Tomatoes and Cucumbers

	Arava Valley growing season yield (t/ha)			El Arish (Coastal Sand Dunes) growing season yield (t/ha)		
Crop		Drip	Sprinkler		Drip	Sprinkler
Tomatoes	Sept.-March	65.3	39.0	Sept.-March	79.0	30.0
Cucumbers	Nov. -Feb.	39.0	0.0	Apr. -June[a]	1.5	3.6

[a]Summer growth–out of season in this region.

SOURCE: D Goldberg, B. Gornat, and D. Rimon, *Drip Irrigation* (Kfar Shmaryahu, Israel: Drip Irrigation Scientific Publication, 1976). Published in Ilan Amir and Benjamin Zur, "Irrigation in Arid Zones: The Israeli Case, " in *Arid Zone Settlement Planning (New* York: Pergamon Press, 1979).

[18]Moshe Boaz and Irzhak Halevy, Extension Service, Ministry of Agriculture, Israel, "Trickle Irrigation" (unpublished paper, undated).

Ye Ibid.

ily in California, Arizona, and Hawaii) and other countries.[20]

In either the small or large systems, the computer can control water flow; detect leaks; shut off faulty lines; adjust water application for wind speed, air temperature, and soil moisture content; and apply fertilizer on schedule. An added advantage of the computerized systems is their ability to locate malfunctions and alert the operators to make necessary repairs before the faulty element causes too much damage or water loss.

On the basis of systems implemented in Israel, Motorola Israel reports the following benefits:

- increased efficiency in water and energy use in the range of 10 to 30 percent;
- increased yields in the range of 2 to 10 percent;
- accurate and precise application rates, resulting in minimized return flow, aquifer and stream pollution, and related drainage problems;
- labor savings in such areas as the operation of valves, gates, and checking of laterals.[21]

The kibbutz Kfar Aza in the Negev provides an example of a successful computerized irrigation control program. An evaluation of the computerized system installed at that kibbutz reported an overall water savings of 15 percent of the kibbutz allocation.[22] Crop height remained uniform, indicating even plant development. Other advantages cited by a kibbutz official included reduced labor, energy, fertilizer, and maintenance costs. Exact yield increases caused by the computerized controls are difficult to estimate because other management factors also played a large part in crop production. But one estimate put the general yield increase at about 3 percent for vegetables. In addition, the system saved an estimated 25 workdays per season. Furthermore, 25 breakdowns were located in one season, saving an estimated 20 acre-feet (25,000 cubic meters) of water as the system automatically shut the faulty lines down. As a whole, the Israel experience has been that automated systems pay for themselves within 3 to 5 years, even when installed at market interest rates.

Irrigation With Saline Water

Israel has sizable supplies of brackish water, much of it underground in the Negev Desert. At 2,500 parts per million total dissolved salts, the concentration of salt is too high for use in traditional irrigation or for most industrial uses. However, it has been estimated that if uses were found for the water, approximately 81,100 acre-feet (100 million cubic meters) could be drawn from this source annually without serious effect.[23]

Israel has an intensive program of research and development in the use of brackish water for agriculture. In particular, irrigation techniques are being fine-tuned and adapted to local conditions to minimize buildup of salts in the soil while making use of brackish water. At the same time, the genetic improvement of salt-resistant crops is being studied. Brackish water management packages are being used successfully with vegetables, wheat, and cotton. Expectations are that with more research and intensive management experience, additional production advances will be made. *

[20] Telephone interview with Motorola official.

[21] Elisha Yanay, "Computerized Irrigation Control Systems and Their Application in Drip Irrigation," *Drip/Trickle Irrigation* (Fresno, Calif.: Agribusiness Publications, spring 1981), p. 23.

[22] Ami Kahana, "A Computer Controlled Irrigation System in Kibbutz Kfar Aza" (unpublished paper, undated).

[23] Arlosoroff, U. N., op. cit., p. 49.

*In the United States, a salinity level that has been considered high and has led to the construction of desalinization plants is considered a low level in Israel as the result of their brackish water management (S. Arlosoroff, correspondence, Oct. 28, 1982).

TECHNOLOGY TRANSFER CONSIDERATIONS

Israel's success in implementing its agricultural and water-use policy has been the result of a unique combination of factors, including country size, a national program commitment, the public status of water, and special characteristics of its agricultural technology program. The agricultural element has involved educated farmers who have become manufacturers of water appliances and technologies, and leading agricultural researchers who verify and test these technologies,

Water has always been a limiting and critical factor in the national development of Israel's agriculture. Israel's generally arid land leaves little alternative for agriculture other than a strong national effort at total management of the scarce water resource. In addition, the status of Israel's water as a public resource subject to total public control avoids some of the legal complexities related to management and control likely to be encountered in the United States. The United States can still learn, however, from the Israel experience in application of technologies.

The United States and other countries have adapted, to varying degrees, many of the irrigation technologies used by Israel. For example, Motorola Israel Ltd., which first introduced its line of automated irrigation control systems in Israel, subsequently began manufacturing them for the United States and other markets. About 100 small units and four large systems had been sold in the United States as of 1982.[24] Drip irrigation is another technique that has become more popular in the United States following Israeli commercialization proving the technique to be highly efficient, The experience of Israel with the use of drip, trickle, and sprinkler irrigation systems is also being shared with other countries. Israel's methods of allocating and pricing water and reusing effluents are attracting more interest in such areas as the Western United States as demands increase for limited water supplies.[25]

In light of the mutual benefits to be derived in arid and semiarid agriculture, the United States and Israel have been cooperating to promote agricultural research for many years. The United States-Israel Binational Science Foundation (BSF) was established in 1972 by an endowment to promote continued cooperation in science and technology research between the two countries. Through this program, proposals are submitted by collaborating U.S. and Israeli investigators. Of the proposals submitted between 1974 and 1981, 223 were for agricultural research; 69 of these (8 percent of the total number of grants) were approved. [26]

In 1977, the United States-Israel Binational Agricultural Research and Development Fund (BARD) was established to provide a more formal mechanism for the United States and Israel to share and collaborate on agricultural research of mutual benefit. Since this program is devoted entirely to agricultural research and development, the number of BSF grants in agriculture has been reduced. In 1978 BARD began funding proposals out of the income from its $80-million endowment.[27] A Technical Advisory Committee comprised of five U.S. and five Israeli scientists makes recommendations on the research proposals submitted. Most of the projects have been for 3 years, and many of them are with the University of California at Riverside and Davis. Administration of the program in the United States is handled by the U.S. Department of Agriculture. Appendix E

[24] C. G. Karasov, "Irrigation Efficiency in Water Delivery," *Technology,* March/April 1982, p. 71.

[25] Arlosoroff interview.

[26] United States-Israel Binational Science Foundation, *Annual Report 1981,* Jerusalem, Israel, 28 pp.

[27] BARD Abstracts of Supported Projects 1979-1980, U.S. Department of Agriculture, Federal Building, Hyattsville, Md., 259 pp.

contains abstracts of some of the proposals related to water management in Israel. Although it is too soon to determine specific technological benefits from this research, the cooperation between the two scientific communities and the exposure of different approaches should contribute to new developments and discoveries of mutual benefit.