Contributing Paper

Irrigation and Agriculture Experience and Options in Israel

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ABSTRACT

Advancement in water resources development, agricultural production and irrigation technology are matched by the magnitude of the still facing problems of quantity, quality and cost of water for irrigation. Major constraints include among others: water scarcity and fluctuation, depleting resources, frequent droughts, degradation of water quality; prohibitive costs of dams and water reservoirs and technological uncertainty and high cost of non-conventional sources, rapid urbanization, abandonment and desertification of agricultural land.

To maintain water supply and agricultural growth, under a dynamic and changing world, new policies related to future needs for water, food security and agricultural production have to be crystallized, aiming to make the agricultural industry freely competing with industrial and domestic users. Emphasis should be on integrated water management encompassing: conventional and non-conventional sources, conservation of rivers, water courses and aquifers, increased water use efficiency and efficient allocation across sub-sectors and users, while preventing local and regional conflicts and considering social, cultural and environmental goals.

Expansion of irrigation systems should be on the basis of reallocation of water gained through improved efficiency, modified cropping patterns favouring less water-demanding crops and improvement of field efficiency

Furthermore, international and regional commitment to avert water crisis and cooperation in agricultural production, water resources development, water transfer and interconnection of water systems has to be promoted.

At the country level, the prevailing arid and semi arid conditions of Israel make irrigation imperative for the development of intensive agriculture and food production. Available renewable potential is already fully utilized, while the widening gap between supply and demand is made up with marginal resources, especially, reclaimed municipal wastewater which is becoming an increasingly important source of water for agricultural and industrial purposes.

The average annual renewable potential amount to some 1,600 MCM, of which about 95% are already exploited and used for domestic consumption and irrigation. About 80% of the water potential lies in the northern parts, hence, large quantities of water have to be conveyed over 200 km to supply the water needs in the south. Surface water contributes about 33% and groundwater supply the difference, mainly from

two major aquifers. Artificial recharge is practiced through spreading basins and single and dual purpose deep wells connected to the National Water Carrier.

Currently, about 275 MCM of effluents, treated to varying degrees, are already utilized for irrigation, about 65% of the generated wastewater. Cloud seeding has been practiced for last 30 years, yielding a significant increase of 10 - 15% in rainfall. Several small and medium desalination plants have been installed, for desalination of brackish and sea water for domestic water supply, including a 10,000 cum/day sea water desalination plant in Eilat.

The quality of supplied water in Israel varies from very low salinity water of the Upper Jordan River (10 mg/l of chlorides), to medium salinity in the Kineret and major aquifers (100 - 200 mg/l of chlorides) and excessive salinity in the non renewable aquifers in the south (more than 1500 mg/l of chlorides). Due to irrigation, a gradual increase in salinity and other pollutants is observed, resulting in the increase in mineral and other pollutants contents in groundwater. Based on past trends, more than 25% of available groundwater will have a chlorides content of more than 250 mg/l by the year 2025.

Israel is already in the process of crystallizing development policy to support decision making with regards to future development and management of water and agricultural production. The technologies which have brought about, the dramatic increases in water use efficiency and agricultural production will be harnessed to develop a highly productive agriculture, less demanding in land and water and adequately competing with other industrial and economic users. The total cultivated area and water available for irrigation will not significantly change, but the water quality will be dramatically reduced, due to large substitution of fresh water with treated effluents and brackish water.

Further improvement of water use efficiency (improved distribution systems and ultra low volume irrigation) and techniques suitable for irrigation with marginal resources and soil amelioration will be applied, contributing to sustainable land use and conservation of open space and agricultural land. The use of new cultivation techniques and development of salinity tolerant crops adjusted to irrigation with brackish and secondary effluents will be expanded.

Various innovations are expected to influence the water balance including**:** induced rainfall, improved forecasting techniques of rainfall and water balance, elucidation of the global warming and its effects on water resources and, possibly, economic competitive water desalination systems.

Institutional reform is foreseen, with sector deregulation, leading to full cost recovery systems taking account of access to water, ability to pay and other relevant social aspects, water trading (voting rights will replace existing water rights), control of performance. Seeing water as an economic good dealt with financial and economic terms will also induce the reallocation of water resources, leading to efficient production and allocation systems, adapted to open markets and free competitive trade.

On a regional scale, Israeli agriculture is very small and bears no competition to the regional agriculture. Most of the Israeli innovations and accumulated experience in agriculture, irrigation technology and water management are easily adaptable to various conditions and are widely used in developing and developed world alike.

The strategic issues of water industry and agricultural production in Israel and possible solutions to achieve sustainable water economy and best practices available are discussed in the following, covering constraints and anticipated initiatives and development to achieve long term sustainability.

Section 1: INTRODUCTION

1.1 State Background

Physiography. Israel covers an area of 20,770 km^2 and has a population of about 6.0 million (1997), of which 90% lives in urban areas and 10% in rural areas. Israel is located in the Mediterranean region. The land is divisible into three longitudinal strips running from north to south, comprising a coastal plain, a long inland escarpment and a large desert area in the south. The main river is the Jordan and the principle mountains are the Judean hills, Carmel mountain and Galilee mountains. The general topography is flat in the coastal plain and flat to hilly elsewhere. Seismicity is low, the most seismic area being the Jordan rift valley.

Soils. The major soil types in the Coastal Plain are sand dune, Pleistocene sand and sandstone. The soils in the north of the country are alluvial loamy and clayey, and in the Northern Negev, light rendzina, coastal dunes sand, sandstone and sandy loam, calcareous soils with loess deposits, loess and rocky "hamada".

Climate. Israel has a semi-arid, Mediterranean, temperate climate. The average annual rainfall in the Coastal Plain varies from 600 mm in the north to 150 mm in the south. In the lower elevations of the Hilly Zone (150 m to 600 m above mean sea-level) the average annual rainfall varies from 700 mm in the north near Safad to 500 mm near Hebron and declines sharply towards the Negev. The annual average rainfall in the Negev varies from 400 mm at Ashkelon (near the shore) to 200 mm at Beer-sheba, and 30 mm at Eilat. The average annual precipitation is 360 mm/year and the total mean annual precipitation volume is 7.2 km^3 The country has about four rainy months (November – March). The climatic conditions of Israel, especially the lack of rain during the long summer, make irrigation imperative for the development of intensive agriculture.

Population. Israel's population increased from 0.87 million in 1948 to about 4.0 million in 1980 and 6.0 million in 1998. About 90% lives in urban areas and about 10% in rural areas. The population is concentrated to a considerable degree in and around the three cities of Jerusalem, Tel Aviv-Yaffo and Haifa. In 1999 about 70 per cent of the urban population (60 per cent of the total population) lived in the conurbation of these three centers.

Urban and Rural Population. The rural population amounts to about 0.5 million of which the number of farming households is 25,000, or about 100,000. The rural population has decreased from about 28% in the fifties to the current 9%. The number of farming households was also reduced from about 75,000 in the sixties to the current 25,000. The farmers were replaced by hired labour, which contributes about 50,000 of the total employment in agriculture. 3.7 per cent, or approximately 75,000 persons, were engaged in agricultural activities in 1995. Farm employment contributes 3.1 per cent, of the total employment or approximately 67,000 persons.

Land Resources. Out of the total area of about 21 million ha, arable land amounts to 452,000 ha. The area actually irrigated is 230,000 ha or approximately 50 per cent of the arable land. The land holding allotted to a farming unit in the collective and cooperative settlements vary in size according to the soil and climatic conditions. The average holding is 7 ha.

Land Ownership. The major part of the land in Israel is owned by the State and the Jewish National Fund. The land is given on lease for 49 years to groups or individuals able and willing to cultivate it.

Farm Settlements. Most of the arable land is controlled by collective (Kibbutzim) and co-operative (Moshavei Ovdim) settlements, totalling about 25,000 farm units.. A small part of the agricultural land belongs to small private farmers who reside in rural villages. There are also a few larger commercial farms.

1.2 Agricultural Production

Israel's agricultural sector is characterized by an intensive system of production stemming from the need to overcome the scarcity in natural resources, particularly water and arable land. Lack of water, shortage of labor and the need for conservation of open space and the environment dictate the ongoing accelerated development towards intensive production incorporating advanced engineering techniques and biotechnology.

Agricultural production encompasses citrus, avocado and deciduous tree plantations, field crops of which cotton is the major crop, vegetables and flowers and fish ponds. Most of arable land estimated at about 430,000 ha is cultivated and about 50% is irrigated. The extent of the irrigated area varies and depends on the water resources capacity and agricultural commodities market, within a particular year. Major characteristics of the Israeli agriculture are shown in Table 1.

Table 1: Cultivated Area, Major Crops and Irrigation water Use, 1998

Major Crops	Cultivated Area (000 ha)		Irrigation Water MCM
	Dry Farming	Irrigated Land	
Tree Plantations	15	75	540
Field Crops	195	72	200
Industrial Crops - Cotton		35	170
Horticulture	5	35	190
Aqua Culture		3	100
Total	**215**	**220**	**1200**

Source: Compiled from Central Planning Authority, Ministry of Agriculture, 1998.

Israel's Agricultural Production and Yields per Unit, 1995

Crop	Yield ton /ha
Tomatoes -open field	60-80
Tomatoes - Greenhouse	200-300
Potatoes	45-55
Apples	42-45

Israel produces 95% of its own requirements, supplemented by imports of grains, oil seeds, meat, coffee and sugar, which are more than offset by a wide range of agricultural products for export as shown below:

Despite the continuous decrease in the number of farmers, agriculture still plays a significant role in the national economy, contributing, in 1996, about 1.9 % of the GDP, 7% of exports and 3.1 % of the total work force (66,500). Agriculture is particularly important for the outlying areas where agriculture provides the sole means of livelihood for the population. Agricultural export amount to US $ 1.42 billion (7% of the total export). In addition, the production of agricultural inputs stands at over $2 billion, of which 70% is exported.

1.3 Water Resources

a. Conventional Water Resources

The average annual precipitation is estimated at about 10,000 MCM of which 60 % evaporates, and 10 % flows down the dry river beds and the few perennial rivers to discharge into the Mediterranean in the west, or into the Jordan River and the Dead Sea in the east. The remaining 30 % seeps into the ground and is gathered in natural aquifers, or flows into Lake Kinneret. Part of the remaining quantity that percolates into the ground is also lost to deeper underground layers or drains into the sea.

Israel's main water resources are:

- Lake Kinneret – the Sea of Galilee.
- The Coastal Aquifer - along the coastal plain of the Mediterranean Sea.
- The Mountain Aquifer - under the central north-south (Carmel) mountain range.

Additional smaller regional resources are located in the Upper Galilee, Western Galilee, Beit Shean Valley, Jordan Valley, the Dead Sea Rift, the Negev and the Arava, see Table 2.

Table 2. Long Term Annual Average Quantities of Renewable water for Major Water Resources

Resource	**Replenishable Quantities (MCM)**
The Coastal Aquifer	320
The Mountain Aquifer	370
Lake Kinneret	700
Additional Regional Resources	410
Total Annual Average	**1,800**

The average annual renewable potential amount to some 1,800 MCM, of which about 95% are already exploited and used for domestic consumption and irrigation. Other sources include intermittent water runoff and reclaimed wastewater

About 80% of the water potential lies in the northern parts and only 20% in the south, while most of the population and arable land are found in the central and southern regions, hence, large quantities of water have to be conveyed over 200 km to supply the water needs.

Surface water - The Kinneret Basin. This basin which covers 2,730 km2 is situated in the north east of Israel and is drained by the Jordan River which forms a confluence of three tributaries providing about 520 MCM of a total average inflow of about 650 MCM/year. The Jordan river and its tributaries flow into the lake of Kineret, having a surface area of about 170 sq km and a total volume of 4,300 MCM.

The Water level at the lake is regulated by the Deganya Gates maintaining an operational volume of 590 MCM, between -209 and -213 m. Of the annual yield about 380 MCM (20 cum./sec.) on average are pumped out of the watershed, lifted over 400 m from an elevation of -212 m below sea level. while the remaining is used by consumers within the watershed. The Kineret watershed contributes about 33% of the total resources.

Groundwater. Groundwater are available from two major aquifers: the Coastal Aquifer - a relatively shallow sand aquifer, lying along a deep limestone - Dolomite Aquifer, named Yarkon-Taninim Aquifer or the Mountain quifer.

The Mountain Aquifer main water body is a 150 km long between Taninim in the north and Beer Sheva in the south, underlying the Judea and the Summaria highlands. Natural outlets are the Yarkon and the Taninim springs with a possible outlet to the Mediterranean Sea. More than 300 deep boreholes are used to abstract about 340 MCM/year, including 40 MCM of brackish water, maintaining a water table level at +16.5 m. Artificial recharge using excess supply from the Kineret is practiced through single and dual purpose deep wells connected to the National Water Carrier.

The Coastal Aquifer. The aquifer extends over some 120 km along the Mediterranean cost from the Carmel in the North to Gaza Strip in the south, having a total area of about 1,800 sq. km. Rainfall, storm water and return flow from irrigation. Also artificial recharge of storm water and excess supply from the NC is practiced through several spreading basins and boreholes. The safe yield which is fully utilized is estimated at about 300 MCM/year. A certain level of sea water intrusion is allowed for optimal exploitation of the aquifer. The interface was stabilized at about 1500 m from the coast.

Being a sand aquifer with a large holding capacity, the aquifer is used for short and long term storage, allowing a normal supply in drought years. However, due to frequent droughts, the trend was for excess pumpage and depletion of reserves, endangering the sustainability and the long term functioning and conservation of the aquifer. To counter balance these trends, artificial recharge has been intensified and pumpage is carefully monitored, while consumers reliance on local supply has been reduced.

Other Aquifers. In addition to the two major aquifers, there are several smaller and localized aquifers in various parts of the country. The most significant is the Western Galilee Aquifer, having a safe yield of about 60 MCM/year.

b. Non - Conventional Water Resources and Conservation

Reclaimed Wastewater Effluents. The use of reclaimed and treated municipal wastewater is becoming an increasingly important source of water for agricultural and industrial purposes. Currently, about 275 MCM of effluents, treated to varying degrees, are already utilized for irrigation, about 65% of the generated wastewater. Treated effluents are used for irrigation of industrial crops and fruit crops, before or after artificial recharge into a confined aquifer.

Intercepted runoff and artificial recharge. Surface runoff although sporadic and infrequent is being utilized and several regional and local schemes were established. The schemes divert storm flow into surface reservoirs or to spreading grounds where it percolate through sand layers into the underlying aquifer. An annual average of about 40 MCM are intercepted out of a potential of 135 MCM/year of storm water. In addition to large schemes, they are many local runoff interception schemes with a total capacity of about 130 MCM.

Cloud Seeding. Cloud seeding with silver iodide crystals has been practiced in Israel for last 30 years on a countrywide basis. Over the years ground incinerators were replaced by special air-crafts using brine as the seeding material. Controlled seeding experiments that were conducted between 1960 and 1975 provided the scientific justification for the routine seeding since. It is assumed that a significant increase of 10 - 15% in rainfall is achieved.

Desalination: Many small and medium desalination plants are in operation for the desalination of brackish and sea water, mostly for domestic water supply in the Arava Valley and the Gulf of Eilat. The largest facilities near Eilat produce 44,000 cum/day of water from brackish groundwater and sea water.

c. Water Quality

The quality of water varies from 10 mg/l of chlorides in water of the Upper Jordan River, 200 mg/l in water of the Kineret and up to 1500 mg/l and more in groundwater. Groundwater exploitation is controlled to prevent sea water intrusion to the Coastal Aquifer and movement of saline water bodies within the Karstic Limestone Aquifer. However, despite the limits on water withdrawal, due to man made activity, there is an increase in the mineral and other pollutants contents in groundwater.

Based on past trends, groundwater with chlorides contents of more than 250 mg/l that was 20% in 1990 and is expected to increase to 30% within 20 years. Regular monitoring of water resources, including: replenishment and recharge, water table levels, abstraction, salinity (chlorides) and pollution (nitrates) data are regularly monitored and maps restricting land use activities are produced to protect vulnerable aquifers.

d. Water Supply and Demand

Water Production and Supply. As of 1997, annual water production reached approximately 2,000 MCM, of which 75% were potable and the remainder was marginal (treated effluents, brackish water and runoff water), as shown in Table 2. Normally, water supply fluctuates from year to year in accordance with the annual rainfall. Groundwater constitutes between 55-70 per cent of the total and is adjusted to availability of other resources.

Water Demand. Annual water demand amount to about 2000 MCM/year, of which about one half is used for agriculture and the remaining is used by the urban and industrial sectors. The agriculture sector used 65% of water production, the domestic sector used 30% and the rest was consumed by industry (Table 3).

Domestic Consumption. All settlements are served by public waterworks supplying an average of about 250 liters/capita/day. Currently, the urban sector consumes about 700 MCM and will increase to about 1,300 MCM with the increase in population and living standards.

Agricultural Consumption. With a current consumption of 1250 MCM (60% of fresh resources, compared to 77% in the sixties), agriculture is still the largest consumer, but the consumption in this sector is strongly influenced by the annual rainfall, and during drought periods fresh water allocation is drastically reduced.

Available water resources and water balance for the years 1997 - 2020 are given in Table 3.

Table 3: Water Supply and Demand – Israel 1997-2020 (MCM/year)

Water Supply							
Year	Population (Million)	Water Sources					
		Surface Water	Ground water	Brackish Water	Treated Effluents	De-salinated	Total
1998	6.0	600	1020	125	275	10	2030
2010	7.4	645	1050	165	470	100	2430
2020	8.6	660	1075	180	565	200	2680

Water Demand						
Year	Urban Sector	Agricultural Irrigation				Total
		Fresh	Brackish	Effluents	Total	
1998	770	850	100	250	1200	1970
2010	1060	680	85	495	1260	2430

2020	1330	600	60	565	1350	2680

Source: Israel Water Commission, 1998

e. Water Storage

To overcome spatial and temporal gaps between supply and demand, most of the country's fresh water resources are inter-connected into the National Water Carrier. The carrier conveys a compounded amount of about 1,100 MCM over 180 km from north to south and is the backbone of the national system which connects between the seasonal storage of lake Kinneret with the long term storage of groundwater aquifers.. An integrated network of pumping stations, reservoirs, canals and pipelines allows the conjunctive use of surface and groundwater sources. Excess supply is recharged into the aquifers. and used in dry years when the yield of surface resources is minimal.

f. Financing and Pricing of water

Water Cost. The main water system is characterized by heavy investments in water elevation, large conveyance systems and treatment plants. The average water cost indicated by the National Water Co. - Mekorot, which supply about 60% of the total consumption, is US C 31/cum. The cost includes: capital costs (41%), fixed costs (26%) and variable costs (33%).

Water tariff. Water prices for the various consumers are fixed by a parliamentary committee adopting an Increasing Block Rate Prices system for payment for the first 50, 80 and 100% of the allocation. Different block rates are fixed by the Government and differ for the various sources and region, while a penalty is levied on consumers exceeding their allocation. Current tariffs have totally eliminated the subsidy for water supplied to the urban and industrial sectors, while charges for irrigation are still subsidized at about 18%.

Financial Support. The Government through the relevant ministries provides grants and low interest loans for the improvement and expansion of water supply systems. Funds are channeled through special development and rehabilitation funds.

Section 2: CONTRIBUTIONS OF IRRIGATED AGRICULTURE

Irrigation Water Use. Early irrigation development was based on surface irrigation but due to water shortage there was a gradual transition to pressurized irrigation and water saved on the process was used to increase the area under irrigation as shown in Table 4.

Table 4: Cultivated land and irrigation development 1950 - 1998

Year	Total cultivated area (000ha)		Irrigation Water (MCM)		Irrigation Systems
	Total	Irrigated	Total	cum/ha	
1950	335	47	410	8700	Gravity
1960	415	135	1020	7560	Sprinklers
1970	415	173	1240	7150	Sprinklers
1980	425	205	1200	5850	Micro-irrigation
1990	435	220	1230	5590	Micro-irrigation
1998	435	220	1200	5450	Micro-irrigation

Over the last 50 years, the irrigated land has increased from less than 50,000 ha to about 220,000 ha, while water used for irrigation has increased from about 400 MCM to about 1200 MCM/year. Currently, the agricultural sector consumes about 1200 MCM/year to irrigate about 220,000 ha. This quantity has not changed significantly over the last 30 years, despite the significant increase in irrigated land and agricultural production.

Irrigation water comprises of fresh and marginal water, of which:

- fresh water - 840 MCM
- Brackish water - 100
- Treated effluents: 260
- Total - 1200 Mcm

Due to scarce water resources, there has been continuous endeavor to improve irrigation efficiencies and reduce unit application of water by improving the efficiency of irrigation methods and using advanced techniques for system management. By mid-1970's sprinkler irrigation was the dominant technology while drip irrigation was making its first steps in irrigation of vegetables and flowers. The breakthrough was the expansion of drip irrigation to field crops and especially cotton which allowed cotton production on marginal soils, utilizing brackish water and municipal effluents and the introduction of fertigation, and advanced pest and weed control and other cultivation techniques.

Irrigation Technology. Efficient irrigation was possible due to the introduction of water saving measures coupled with a gradual change in cropping patterns and a shift toward crops that do not require high quality water. Technological breakthrough in low volume irrigation technologies such as drip irrigation and micro-sprinklers reduce water loss and increase water use efficiency. Computer-assisted irrigation management enhances these results. The wide scale adoption of low volume irrigation systems (e.g., drip, micro-sprinklers) and automation has increased the average efficiency to 90% as compared to 64% for furrow irrigation.

Irrigation Water control. Computers were introduced to allow real-time operation of the irrigation systems, providing precision, reliability and savings in manpower. Soil and plant moisture sensors are also used to provide information on moisture, allowing automatic operation of the system when needed. Further irrigation efficiency is being attempted by regulating water application to each individual plant, using individual moisture sensing emitters. The root volume can also be controlled, leading to a shortening of the crop growing cycle.

Irrigation Efficiency. The wide scale adoption of low volume irrigation systems (e.g., drip, micro-sprinklers) and automation has increased the average efficiency to 90% as compared to 64% for furrow irrigation. Other factors include:

- water metering
- water pricing policy,
- computerization and remote control of irrigation
- fertigation - fertilizer application via the irrigation systems

As a result, the average requirement of water per unit of land area has decreased form 8,700 m3/ha in 1975 to 5,450 m3/ha in 1998. At the same time agricultural output has increased twelve fold, while total water consumption by the sector has remained almost constant.

Drainage And Flood Protection. In the 1920's and 1930's much effort was invested to drain swamps and wet lands to redeem land for agricultural use. The early work was followed by large scale regional operations, enabling control of whole river courses or drainage basins. The emphasis in these drainage works has been on:

(a) Improvement of poorly drained soils
(b) Flood protection
(c) Diversion of runoff water from agricultural lands
(d) Swamp drainage
(e) Concentration of the runoff from local or regional drainage works and their integration into the water supply network.

However because of high peat content of some of the reclaimed soils and subsequent deterioration, due to frequent fire outbreaks, dust storms and subsidence, some of the soils become unsuitable for intensive production and abandoned. In the Hula Valley, the adopted solution, to the neglected soil peats of the upper Jordan river, involved the re-flooding of part of the area, creating a new shallow lake and maintaining a high water in the rest of the area. New drainage and irrigation techniques and installations were employed to create a new agro-ecology, in which land cultivation is adjusted to the sustainable needs of the terrestrial and aquatic ecology of the Kineret watershed.

Environmental aspects of Irrigation. Agricultural production is considered to be compatible with the environmental protection and issues of open space, soil conservation and protection of the natural vegetation and water resources can greatly benefit from appropriate agricultural production systems. In accordance, sustainable use of brackish and effluents without detrimental effects on the environment, water conservation and extremely efficient use of water in agriculture alleviating environmental pollution are attempted.

Short, medium and long term targets are being evolved, as related to the following:

- efficient production to avoid agricultural waste;
- reduced use of fertilizer and pesticides;
- use of brackish and wastewater for irrigation
- production of functional food.
- controlled plant nutrition and released/leaching of nutrients and pesticides, under
- development of alternative soil phyto-sanitation techniques
- maximum recycling of wastewater, sludge and compost, and,
- reduction of salinity constituents and potentially toxic trace elements in effluents
- understanding the long term effects of irrigation with effluents, and
- rational use of land and water resources

Pricing of water for irrigation. The average water cost indicated by the National Water Co. - Mekorot. is US C 31/cum (1996). Water charges for the various consumers are fixed by a parliamentary committee. An Increasing Block Rate Prices system is applied, leading to 10 - 15% savings in water used for irrigation, as shown in Table 5.

Table 5: Block Rate Tariffs for irrigation water supply Mekorot, 1996

Water Source	Part of Allocation (%)	Price (US C/cum)
Fresh Water	1 - 50	15
	50 - 80	18
	80 - 100	21
	Average	19
Tertiary Effluents	Low Season	14
	High Season	15
Secondary Effluents	Average Price	12

Source: Israel Water Commission, 1996

Government Subsidy. Currently Government support amounts to bout 20% of the cost. The current tariffs are however on an increasing scale, as shown in Table 6.

Table 6: Water Cost and Tariff for Irrigation, Mekorot Co. 1986- 1997

Year	Cost	Tariff	
	(US C/cum)	(US C/cum)	(% of Cost)
1986	14.3	10	70
1993	36.4	16.1	44
1994	34.4	17.1	50
1995	32.8	19.0	58
1996	30.5	21.1	69
1997	28.2	23.2	82

Source: Mekorot Water Co. Financial Statements, various years.

A substantial increase in water charges coupled with a restructuring of the national water company - Mekorot has resulted in a significant reduction in Government subsidy from 50% in 1992 to about 20% in 1996.

Financial, Institutional and Management Programs. The Government through the relevant ministries provides grants and low interest loans for the rehabilitation and expansion of water supply systems and construction of wastewater and other marginal water reuse schemes.

Investment capital is channeled through:

- Water Networks Rehabilitation Fund
- National Sewerage Programme
- Irrigation systems Improvement Fund
- Wastewater Renovation and reuse Programme

Future Prospects. Previous achievements in irrigation and irrigation technology are matched by the magnitude of the problems still facing irrigated agriculture, centered around the quantity, cost and quality of water available for irrigation. Future irrigated agriculture, as an important industry, would require improved systems, capital intensive and significantly less demanding in water, yet economically productive to compete freely with industrial and domestic users.

The total cultivated area and water available for irrigation will not significantly change over the planning period, but the water quality will be dramatically reduced, by large substitution of fresh water with treated effluents.
Other changes will include:

- transition and shifting of agriculture production to the arid south
- substitution of fresh water for brackish and wastewater effluents for irrigation
- development of salt tolerant crops and crop diversification
- environmental protection/recycling of agricultural waste
- adaptation to open markets and free competitive trade

Section 3 – CHALLENGES AND DIFFERING PERSPECTIVES

Global climatic change. Change in the weather pattern have to be considered as uncertainty in future scenarios and their consequences on food production are not understood. Increases in spatial and inter-annual climate variability, decreasing precipitation, higher frequency of extreme rainfalls and droughts are already apparent in the region and climatic change is considered a long term risk. Likely changes would jeopardize the sustainability of resources and threatens the existence of both rainfed and irrigated farming systems by raising average temperatures, lowering average rainfall and increasing its variability.

Rain simulation studies for the coastal areas of the Middle East region showed a decrease of rainfall around 10-15% and an increase in winter temperature of 1.5°C in the coastal areas and by 1.75°C to 2.5°C inland. The impact of climate change on precipitation and water resources in general and crop evapo-transpiration in particular should therefore be considered in water resources and irrigation development plans, through improved predictive capacity and monitoring.

Decline in water storage volume. Surface reservoirs are threatened by the inevitable decline of storage capacity due to heavy sedimentation. In North Africa, the loss of reservoir storage is at present 1 to 2.5 % per year in Tunisia; 2 % in Morocco and 2 to 3% in Algeria. It must be pointed out that this phenomenon may be even further amplified if global climate change leads to more extreme and violent events, provoking increased erosion in the watershed. The loss in storage volume has detrimental economic implications as well as loss of water resources

Land and environmental conservation. The conversion of land into areas of intensive agriculture is inevitable and in many ways compatible with the functioning of ecosystems. However, because of rapid increase in population and urbanization, the fragmenting landscapes and ecosystems for intensive agriculture, the pressure on natural resources is increasing. Land fragmentation, due to the rapid increase of the population, would affect the future viability of farming systems, while land ownership and uncontrolled urban expansion are other constraints in developing profitable agriculture. There are also serious concerns about possible degradation of the environment, as the genetic resources of native species are under a serious threat of extinction.

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Furthermore, irrigation is strongly related to degradation of water quality and irrigated land. The reasons are multiple:

- Increasing intensity of inputs in agriculture
- Increasing pollution from urban and industrial areas
- Saline intrusion in over-exploited coastal aquifers
- long term effects of using brackish water and sewage effluents for irrigation.
- Soil salinization and water logging
- Unsustainable development of marginal lands

Water and soil quality. Given current measurable negative effects of pollution generated in all sectors, soil and groundwater quality could be deteriorated, especially where recycling of water is practiced, leading to an increase of undesirable chemical loads in soil and water. To avoid irreversible processes, vigorous actions will have to be undertaken, including improvements in irrigation techniques, soil cultivation and cropping systems.

Structural adjustment**.** Agriculture which dominated the national economy in the early years has gradually decreased as reflected by the sector contribution to the national product**.** Irrigation has greatly contributed to the increase of agricultural production and to the economy. In cereal terms, an irrigated field yields 6 Tons/ha as compared to 1.5 Tons/ha for non–irrigated field. However, the role of irrigated agriculture is decreasing in relative terms, as other sectors develop more rapidly.

Nonetheless, irrigated agriculture still consumes more than 60% of available water resources, while contributing only 2 % of the GDP. Fierce competition with other markets and reduced government involvement in terms of protective quotas, direct support and subsidies were the major factors contributing to the fall. Moreover, because of the current difficulties facing agriculture, coupled with dwindling land and water resources and large dependence on cheap labor, the most able farmers are giving up farming activity, adversely affecting the social structure and the economy of the rural areas of Israel.

As the result, the Israeli agriculture is undergoing a transformation both in production and in marketing, as reflected in:

- change in cropping systems and crop diversification,
- diminishing use of fresh water for irrigation and its substitution with brackish water and wastewater
- increasing competition from external markets.

Production systems. Israeli agriculture has reached a turning point in which the existing R&D infrastructure and the highly capable industry are being diverted from conventional production into advanced production systems. The Israeli science has already acquired the basic capability in genetic engineering and biotechnology which is essential to support large scale production of innovative products and it is ripe to generate a range of new products for new markets. Therefor it is assumed that agriculture could further expand and flourish, provided that a technological and industrial approach is adopted in which agriculture is diversified into the production of original sophisticated products, making efficient use of scarce resources of land, water and labor to yield the highest economic return possible.

Far reaching economic and organizational adjustments to be made within the sector would encompass production, economic framework and organizational structure, including rapid industrialization of the farm settlement and reduced degree of cooperation within the farming communities, at the local and regional levels. Changes are also anticipated within the family production units, the supporting cooperative organizations and especially a change of focus from direct production to agro-industry and services.

New production systems are being envisaged, having the capability to:

- compete with other economic sectors on available water resources

- produce high value crops, innovative highly productive and less demanding in water
- favorably competing with import from external markets.

Other aspects being considered are:

- the transition of agricultural production from the temperate coastal plain to the arid south and the related effects on production and the desert ecology

International and Regional Aspects

Regional Water Resources. Population projections for the Middle East indicate a population growth, from 350 Millions in 1995 to an estimated 613 Millions in 2025 (medium UN projections for 18 Middle East and North Africa countries). On the other hand, due to the arid to semi-arid environment, leading to water scarcity and the increasing demand by the growing population, the availability of fresh water per capita is falling. Although the region is not homogeneous with respect to its dependence on energy, water resources per capita, economic development, contribution of agriculture to the national economy, and the capability of institutions to face the future challenges, water is equally critically important and will become more and more precious both in economic and social terms.

Therefore, to alleviate some of the inevitable conflicts, further development of potential conventional and non-conventional water resources should be pursued, while employing a water conservation, and improved water use efficiency policy.

Rural development and rural stability. Given the demographic pressure and the underlying concerns about social stability. Maintaining an equilibrium between rural and urban development is an important driving force behind the current agricultural and rural development with expansion of irrigated areas, undertaken by some countries in the region. In general. complete food self-sufficiency is neither feasible nor desirable, taking into consideration the social and environmental domain and potential and prevailing marketing system for agricultural products; farmers financial capabilities in investment in cash-crops and export-oriented products and adaptation to modern technology and above all, the future of non-economic subsistence farming systems, dependent on subsidized inputs.

It is however recognized that evolution towards a market economy must be controlled to avoid social instability and access to the free international market will be adjusted to the development of efficient farming enterprises and the potential of other sectors of the economy to generate jobs and absorb rural migration.

Food Supply. *A*verage nutritional intake per capita in the countries of the Middle East Region (MENA) (3070 Kcal) is reasonable by world standards. 56% supplied by cereals, 16% by animal products and 28 % by other products (oil, sugar, vegetables, fish, etc.). However, despite an important and steady increase in grain production during recent decades (2.7 % per year), MENA has not been able to fully meet the rising demand of increasing populations and has increasingly relied on food imports to balance the supply of staple foods. In 1995 the region relied on the international market to meet 33% of its cereal consumption**.**

Current food imports by the MENA region (55 MT) are equivalent to 50 % of the net surplus generated by the USA, the largest exporter of cereals. This reliance on food imports makes the region a significant user of "virtual" water. On the basis of 1 m3 per kg of grain, the average virtual water supply per capita is 110 m3/year. Thus, its is likely that the regional dependency on the international market will increase, assuming that grain import would increase to about 100 millions tons for 2025.

Free Trade and World Market. Preferential trade in the international food market, over-production in the world agricultural market and financing problems are a hindrance for fair trading and competition.

Regional Cooperation. Regional cooperation on water resource management should be promoted with emphasis on research and development and technology transfer and trans-boundary water development and transfer. Effort should be placed on drought and flood response, rainfall harvesting and surface and underground storage.

Since the late fifties, Israel has been sharing its agricultural expertise with countries in Asia, Africa and Latin America. Much of its accumulated experience in fields such as irrigation technology, water management, applied agricultural research and integrated rural development has proved adaptable to the needs of developing regions.

Collaboration in water resources and agriculture constitute about one third of all Israel's international cooperation programs and training courses in Israel and on-the-spot are delivered by Israeli experts sent abroad on long- and short-term assignments.

Section 4: AVAILABLE OPTIONS

4.1 National Policy and Institutional - Potential for Improvement

Water Law. In 1959, a comprehensive water law was passed making water resources a public property and regulating water resources exploitation, allocation and prevention of pollution and water conservation. Under the law all available water resources are under public domain and made available for use by the consumers as directed by the water Commissioner. The Water Commissioner is the sole statutory body responsible for executing the State's water policy, regarding exploitation, allocation and conservation of water. The Water Commission, headed by the Water Commissioner is the government organization that regulates the production and supply of the limited water resources to the increasing population and the expanding demand for water by all sectors of the society.

Water Management. Water is administratively allocated by the Water Commissioner, empowered by the water Law 1959. The Water Commission administration fulfills the following functions:

- Issues abstraction and allocations license to consumers, on a yearly basis, based on resources availability.
- Water allocations for the domestic, agricultural and industrial sectors is adjusted to quality, reliability and service, in accordance with national development plans.
- Planning, construction and operation of the water supply systems and delivery facilities necessary in order to meet national demand.
- Advising the Government about water tariffs based on water quality and sector of consumption.
- Monitoring and evaluation of water resources, and
- Creation of public awareness about water conservation needs.

Wastewater Administration. The Water Commission is also responsible for coordinating activities between the Government Ministries, local municipalities and operational bodies. These activities pertain to all aspects of construction of waste treatment facilities and their disposal and reuse in accordance to criteria determined by the Ministry of the Environment and the Ministry of Health. The within the Water Commission carries out Government's policy on wastewater treatment including allocation of grants and loans for the construction of wastewater treatment and reuse projects by the local authorities.

The National Water Supply Company - Mekorot. Mekorot Water Company Ltd, founded in 1937, is a Government-owned company which is responsible for the development and regular delivery of water to all localities and for all purposes. Mekorot is in charge of the wholesale supply of water to urban communities, industries and agricultural users. Mekorot operates about 1,300 wells, 700 pumping stations 600 reservoirs and 6,500 kilometers of pipes. It also operates water quality laboratory testing and constructs and operates desalination and fluoridation plants, and carries out cloud seeding operations.

Mekorot produces and supplies about two-thirds of the total amount of water used in Israel and the remainder through privately-owned facilities. In 1997, Mekorot supplied 1,380 MCM of water, of which 745 MCM were supplied for irrigation, 540 MCM for domestic use, 94 MCM for industry and 27 MCM were recharged to aquifers.

Water Charges. Charges and water allocation are based on a quantitative allocation to groups of consumers, namely: towns, local councils, and water users associations. water prices for the various consumers are fixed by a parliamentary committee based on recommendation made by the Ministry of Finance and the Water Commission. Recently, an Increasing Block Rate Prices system is applied for payment for the first 50, 80 and 100% of the allocation, leading to 10 - 15 % savings in water used for irrigation. Different block rates are fixed by the Government and differ for the various sources and region. A single tier level is imposed on all crops, although this could distort farm level cropping pattern decisions in favor of crops with relatively low water requirements, but sensible when the ultimate goal is water conservation. Current tariffs have totally eliminated the subsidy for water supplied to the urban and industrial sectors and a slight cross subsidy is apparent.

New National Water Policy

Sector Deregulation. The Israeli water economy is on the verge of a major reform in which seeing of water as a cheaply available public resource is to be abandoned and a new policy reflecting water limited supply and competitive economic value is to be fully considered. It is assumed that market forces and sector deregulation are the most suitable tool for the efficient use of water in the agricultural sector.

A restructuring of water management will be initiated, aiming to:

- seeing water as an economic good, considering the economic value of water and charging the full cost of water
- induce public participation and involvement in planning implementation and operation stages
- transfer functions performed by the government to the private sector, using free trade and economic principles,
- rationalize the use and conservation of natural resources in general and in agriculture in particular,
- safeguard environmental, social (ability to pay) and food security aspects

New water suppliers will be carved out of the National Water Company - Mekorot whose role will be limited to the operation of the National Carrier, while the regional water supply schemes will be privatized and defined as public service under the supervision of the Water Commissioner. For water sold by Mekorot to the regional authorities, a real price will be charged.

New Water Pricing. Water prices that were largely determined by the government, based on the existing block rate and the non-tradable allocation are to be changed into a market negotiating systems.. The general view is that market forces are the most suitable tool for the efficient use of in the agricultural sector, while price incentive is applicable to encourage the use of reclaimed effluents for irrigation.

To balance between supply and demand, a shadow price reflecting the water value at source will be added to water charge, thus rendering the historic allocations into a non - effective issue, but maintaining their regulation order in case of emergency or under a series of drought years. The price of water will include not only the direct costs but also its scarcity value, quality deterioration, over exploitation (mining) on one hand, and the social aspects, such as access to water and the ability to pay of low income groups, on the other. Subsidized prices if available will be fully indicated and calculated reflecting their portion of the full costs and budgeted for each specific system.

Water Trading. Shares allocation attracting dividends and voting rights will replace existing water rights. The shareholders will control the performance of the new regional corporations, while external efficiency will be achieved by the market forces and the value of the shares in the financial market.

Urban water sector reform. Urban water sector is expected to undergo a profound reform, stemming from the introduction of the new Law of corporation, under which the municipalities are to transfer the management of the municipal water supply to private hands. The aim is that the activities in the municipal water sector will be carried out through independent profit making enterprises.

4.2 International and Regional Policies For Water and Food Supply

Water resources development and irrigation. There is a common understanding that water is of high value in economic terms but also more importantly in social terms. Access to safe water is considered as fundamental to life. However, some countries have already reached the limits of their exploitable water resources, while others are still engaged in large scale development, including massive irrigation expansion. Nevertheless, decrease in water availability for agriculture is expected in most countries, especially in countries where water supply is mainly linked to non-renewable groundwater, in contradiction to continuous population growth and the increasing needs for food and food production.

Pressure on water resources can be reduced if countries can rely on an external market for food import, but this cannot be done at a regulated price and the free trade may adversely affect existing preferential trade relationships and may raise social unrest.

Integrated rural development. The focus would be on an integrated approach in which irrigation is part of rural development, and encourages people to stay in rural areas and contribute to rural development.

Institutional reform. A trend in transfer of responsibilities for operation and maintenance to local actors is already noticeable. A clear shift is apparent towards demand driven community management while strengthening the role of the state as a regulator of resources (quantity and quality), as a watchdog and as crisis manager, including:.

- eliminating direct government support and input subsidies to farmers
- developing private enterprises in irrigated areas
- recovery of operation and maintenance cost
- increasing the responsiveness of local actors to the development.

Sustainable agriculture. Modern and advanced agricultural production is geared towards the protection of the environment, and efforts are being directed to minimize the detrimental effects of agricultural activity on the environment. Suitable measures are being introduced including:

- ♦ improved farm management to avoid agricultural waste,
- ♦ reduced use of fertilizer and pesticides,
- ♦ recycling of wastewater, sludge and compost, and

In addition to environmental clear advantages, sustainable agriculture reflects on market demand which increasingly shows preference to agricultural products produced by farmers who are sensitive to the environment, yielding additional economic benefits to the producers.

Research & Development. *A*griculture, as a primary sector, is a conditional element in the accelerated economic development which takes place in many countries. Furthermore, agricultural production has to commensurate with the environment, and issues of open space, soil conservation and protection of the natural vegetation and water resources have to be considered.

Continuous growth in agricultural production is dependent on close cooperation between researchers, extension workers, farmers and agro-industries and application of newly developed technologies. Based on experience, a two-way flow of information between research personnel and farmers has to be established for new science-based technologies to be incorporated in normal production, leading to increase in the quantity and quality of the country's agricultural produce.

Funds have to be raised to develop new technologies to convert conventional and low income agricultural production systems into agro-industrial systems, producing high value crops and other sophisticated products of high commercial value.

International and regional cooperation. Regional cooperation should serve the immediate and present relative advantages of varying production systems, bridging between fragmented and small mixed farming units and intensive production systems, leading to a complementary market.

Issues for cooperation:

- ♦ water resources development
- ♦ Agricultural planning, farm management and market research
- ♦ sustainable farming
- ♦ desertification,

- poverty alleviation,

Effective tools for cooperation:
- human resources, technology transfer and capacity building
- establishment of out-stations and demonstration plots
- creation of data bases, uniform analytical procedures and standards
- joint congresses, workshops and publications

Technical and organization considerations. To ensure farmers participation, user associations should be formed to ensure access to new technologies and extension services to demonstrate improve irrigated agriculture and appropriate operation and maintenance. Effective arrangements should be made to train and support farmers in correct operation and maintenance procedures with a strong support from the private sector.

4.3 Technological - Potential for Improvement

Water Conservation. Water conservation is the most reliable and least expensive way to stretch the country's water resources. This challenge has to be met by all sectors. Public water conservation campaigns coupled with technical and economic measures should be applied to reduce consumption and to increase awareness to the water scarcity conditions.

Water saving measures applies in Israel:
- Water metering is compulsory for all type of consumption and consumers
- Abstraction licensing have to be obtained, adjusting annual and peak month abstraction rights to water availability
- A three block rate pricing system and a penalty for exceeding allocation rights are applied
- Use of on-farm advanced micro-irrigation systems
- Household pressure reducer devices, pull handle taps and cisterns with double quantity dispensers
- Public awareness and media campaigns

In industry, special re-use facilities are being phased in and cooling facilities and other water-intensive devices have been revamped with conservation features.

In the domestic and urban sector, conservation efforts focus on improvements in efficiency, resource management, repair, control and monitoring of municipal water systems. Public water conservation campaigns coupled with technical and economic measures are also being applied to reduce consumption and to increase awareness to water scarcity and water quality conditions Citizens are urged to save water. The slogan "Don't waste a drop" is known in every home in Israel. Parks have been placed under a conservation regime, including planting of drought resistant plants and watering at night.

Optimal use of available resources. Optimal exploitation and conjunctive use of available surface and groundwater should be pursued. Also reuse of marginal sources should be considered including reuse of drainage and sewage water, brackish water and rain harvesting. Treated wastewater should constitute an increasing part of agricultural water supply.

Artificial Recharge. Overall storage capacity can be increased by the recharge of sub-surface groundwater reservoirs in suitable geological zones. Also techniques for efficient rainfall harvesting (concentrating the water in the root zone) are well known and have been used in some regions. General and geo-hydrological knowledge about artificial recharge is widely lacking while widespread implementation and spatial distribution of artificial recharge would lead to improved management of groundwater, both in terms of quantity and quality.

Improving water efficiency. Surface irrigation is currently by far the most common technique used by small farmers. Surface irrigation covers 87 % of the irrigated domain and one can expect that surface irrigation will still be dominant in 2025. However, irrigation water at field level is by large still used with low efficiency in many countries. Improvement of irrigation efficiency at field level is technically possible, including: sprinkler irrigation, drip irrigation and modernized surface irrigation Modern surface irrigation techniques should be considered as crucial including improved leveling techniques and even distribution at field level**.** Recently, a satellite linked valve control was installed to control distant water systems.

Cropping intensity. In most production systems, the average cropping intensity (crops/year/ha) is only slightly greater than 1. Potentially there is a scope to increase the cropping intensity provided that water is available.

Supplementary irrigation. Solutions to improve water productivity (Kg/m^3) on rainfed land have been tested and supplementary irrigation shows a high return for water. An increase in productivity of 1.5 to 2.5 Kg of grain per m^3 was reported when supplementary irrigation was applied to cereals at critical vegetative stages.

Crop Diversification. Market forces at home and abroad, and a scarcity of land, labour and water are inducing a shift from extensively farmed mass produced crops to intensive production systems, including greenhouses with climatic control systems, soil-less culture and biological pest control**.**

Israeli science supports large scale production of innovative products, such as:
- production of hybrid seeds and other propagation material,
- production of medicinal plants for the extraction of natural plant extracts for use in medicine and food industries.
- production of engineered organisms for crop protection, substituting expensive and environmentally harmful chemical pesticides
- utilization of reclaimed wastewater for the irrigation.

Biotechnology. Genetic intervention and crop breeding help in developing crops to meet various objectives: lower inputs (chemicals and fertilizers);. lower water use and/or greater yield; tolerance to brackish and saline water; drought and diseases resistance. Plant metabolism can be manipulated, changing crop leaves radiative characteristics, to reduce the transpiration rate per unit of yield and biomass.

Aqua-culture. Intensive form of aquaculture, using saline and sea water are extensively used in man-made ponds and reservoirs and off-shore floating cages. Advanced water purification techniques, oxygen diffusion and protein rich food are used to increase production rate from 0.5 kg per cum to 20 kg and more in a controlled system.

Section 5/6 - OPTIONS ASSESSMENT – PROCESSES AND FRAMEWORK

5/6.1 Sectoral Master Plans

The first master plan for water resources development in Israel" was drafted in 1950 and approved by a Board of Consultants on March 8, 1956. The plan was prepared by Tahal - Water Planning for Israel Ltd., a public corporate body, specialized in planning of water resources. The main features of the first master plan were the construction of the National Water Carrier (NWC), and the integration of all major regional projects into a national grid.

Subsequent planning and development have been mainly aimed at the rational and conjunctive use of available and fully utilized natural resources, to cope with the increasing domestic water demand and inter-sectoral competitive demand. Major works include expansion of the main distribution systems, runoff interception, reclamation of wastewater. The operational efficiency of water distribution networks has greatly improved due to automation and remote control operation.

5/6.2 Major Water, Wastewater and Irrigation Projects

The National Water Carrier (NWC). The Carrier, the backbone of the national system connects regional surface and groundwater sources to bridge spatial and temporal gaps between supply and demand, over 180 km from north to south. The system is characterized by heavy investments in pumping, pipes and treatment plants An integrated network of pumping stations, reservoirs, canals and pipelines is used to supply water under pressure for all the domestic, industrial and irrigation consumers.

The NWC, commissioned in 1964, conveys surface water from Kinneret Watershed, pumped through Lake Kinneret pumping station (Sapir Station -218m), in conjunction with groundwater sources exploited from two main aquifers: the Pleistocen (Coastal Aquifer) and the Cenoman Turon Aquifer, thus supplying a blend of surface and groundwater. Surface water from the Kinneret contributes, on average, about 380 MCM, fluctuating drastically from year to year, due to erratic rainfall. Water not required by consumers is redistributed to two aquifers via recharge basins and dual-purpose wells. Recharging of aquifers helps to prevent evaporation losses and, in the coastal area, intrusion of sea water. Once underground, the water is available for re-pumping as needed.

Lake Kineret on an area of 168 square kilometer holds almost 4000 million cubic meters of water. The Lake is fed mainly by the Jordan River which forms a confluence of three tributaries providing about 520 MCM of an average inflow of about 650 MCM/year. Out of this, some 420 MCM per year (20 cum/sec.) are withdrawn through the National Carrier.

Water from the lake is lifted by the Sapir Pumping Station (4x6.75 cum/sec) from -213 m to +44 m, discharging via an open canal (Jordan Canal), along 17 km into the Tsalmon Reservoir with a volume of 1 MCM. From the reservoir, a second pumping station - Tsalmon Pumping Station lift the water from +37 m to 152 m through Yaakov Tunnel (850 m long) into Bet Natufa Canal 17 km long discharging into Eshkol Reservoirs, from which it flows all the way to the south. In an effort to cut costs, most pumping operations are carried out during off-peak and mid-peak hours.

At the Eshkol Site, the canal widen up to form a settling basin with a volume of 1.2 MCM (600x500x4.5m). This basin is followed by an operational reservoir with storage volume of 3.8 MCM. From the reservoir water flows into a closed pipeline 108" laid over a distance of 86 km, branching near Rosh Hayin into two Yarkon branches (66" and 70") until it reaches Mitzpe Ramon 280 kilometers south of Lake Kinneret.

The NWC supplies a total of 1,000 major consumers, including 18 municipalities and 80 local authorities, with a total of 730 MCM of water, of which 450 MCM for domestic and industrial purposes.

Dan Region Wastewater Reclamation Project. This project, which serves the Tel Aviv Metropolitan Region, is the largest wastewater reuse project, serving a population of about 1.2 million and generate a current volume of 110 MCM/year. After biological treatment in an activated sludge system, the effluents are infiltrated through ground basins employing an intermittent flooding and drying regime. The effluents are pumped back for unrestricted irrigation after a detention period of about 400 days. A network of observation wells surrounding the recharge area monitors the quality and also checks that the treated water does not flow towards fresh water wells beyond the confined recharge area. In the following, the effluents are pumped through a battery of production wells and conveyed 100 km to the irrigation fields in the southern part of Israel. The tertiary effluents are used to substitute fresh water used presently for irrigation.

The aquifer treatment provides additional purification, partly by oxidation in the near-ground region, and then by absorption, ion exchange and sedimentation at lower depths. Percolation and absorption by the sandy soils provide additional treatment, yielding effluents of a suitable quality for unrestricted irrigation and for a variety of industrial and non-potable municipal uses. The aquifer also serves as a seasonal storage avoiding water losses through evaporation.

The expansion of the Dan region Project from the current volume of 110 MCM/year to a capacity of 160 MCM/year has been approved by the Government and is underway. The ongoing works are primarily directed to the construction of a series of end-tail reservoirs with a total volume of 20 MCM at the far end of the project - the Bsor Region, and the related pumping stations and conveyance systems to the irrigated fields. The added storage will allow a year round utilization of the main system irrespective of the irrigation requirements. Additional investment will be required for the expansion of the headwork including the addition of infiltration basins and recovery wells.

Haifa Kishon Complex Irrigation Project. In this scheme, as well as in a number of other schemes, a less sophisticated. A less costly approach is applied for treatment and reuse of effluents from smaller cities, towns and settlements. The schemes produce effluents restricted for the irrigation of non-edible crops.

The Haifa Kishon Complex renovates the wastewater of the Haifa Metropolitan Area (30 MCM/year), after conventional activated sludge treatment, the effluents are conveyed to the Yiszre'el Valley, some 30 km east of Haifa, where they are impounded, in a 12 MCM surface reservoir for summer irrigation of cotton and other crops. A total of 50 MCM/year is being used by this irrigation scheme, including about 15 MCM of fresh water from the National Carrier.

With the increase in wastewater generation, the scheme is to be expanded, increasing the capacity of the pumping units and the extension of the main conveyance system, allowing the connection of new consumers, while further reducing the use of fresh water in the mixed supply.

Medium and Small Wastewater Reuse for Irrigation Projects. Other schemes employing different treatment processes have been developed for the treatment and utilization of sewage from medium-sized towns. In these schemes, the level of treatment ranges from advanced treatment of the activated sludge type to aerated and oxidation ponds and less. The effluents are subsequently diverted directly or from open channels to a series of surface reservoirs and later on used for irrigation.

Seasonal Storage. This major element in the treatment process is the large detention reservoir which regulates between the relatively constant flow of wastewater and the seasonal demand for irrigation, six to eight months a year. There are more than 150 surface reservoirs, seven to 10 m deep with a capacity ranging between 0.1 MCM and 12 MCM turning in more than 150 MCM of sewage effluents and drainage water. These deep reservoirs have proved to be of significant improvement of the effluent quality, polishing the biological treatment thus providing high quality effluents without environmental nuisances.

5/6.3 Water Resources and Water Supply Development Plans

Development of fresh water resources. Low water quality and over exploitation of replenishable resources limit the development of additional resources, despite the availability of agricultural land. The development plan is therefore limited to the exploration of new well fields for fresh and brackish water in the peripheral regions of Israel, the rehabilitation of old boreholes and optimization of exploitation by spatial re-allocation of existing boreholes.

Expansion of the water delivery infrastructure. The continuous growth in urban population requires improvement and expansion of the water delivery infrastructure within the cities, semi-urban and rural settlements

Improving drinking water quality. To conform with new drinking standards, treatment of water at source and in the reticulation systems is being improved. Major treatment plants are being planned to improve the quality of surface water resources supplied for drinking purposes.

Separation of drinking and irrigation delivery systems. The stringent standards for drinking water on one hand and the need for utilization of low quality and marginal sources for irrigation on the other hand, requires a complete separation of drinking water delivery system from those used for irrigation. The partition of the two systems allows conformity with drinking water standards without interfering with the expanded use of treated effluents and other marginal sources for irrigation.

Non - Conventional Water Resources Development

***Reclaimed Wastewater Effluents*.** The use of reclaimed and treated municipal wastewater is becoming an increasingly important source of water for agricultural and industrial purposes as the other conventional sources are far reaching a complete exploitation. Currently, about 275 MCM of effluents, about 60% of the generated wastewater, treated to varying degrees are already utilized for irrigation after surface or underground storage. Wastewater effluents are gradually becoming the main water resource for agriculture. It is estimated that by the end of the millennium about 300 MCM (25%) of the total amount of water supplied for irrigation will be in the from of reclaimed sewage effluents, increasing to about 600 MCM in the year 2020.

***Intercepted runoff and artificial recharge*.** Surface runoff is sporadic and infrequent, observed only for a few days in a good rainy year. Despite the low occurrence, several regional schemes were established to divert storm flows from the rivers into surface reservoirs from where they are pumped into the supply system, or left to percolate into the underground aquifer (mainly along the coastal plain). At present, approximately 40 MCM are intercepted out of a potential of 135 MCM/year of storm water. In addition, they are more than 300 hundred small reservoirs used for the interception of storm flow and storage of treated effluents.

***Artificially-Induced Rainfall - Cloud Seeding*.** Cloud seeding with silver iodide crystals or brine using special air-crafts has been practiced in Israel for last 30 years. Countrywide, as a routtine operation. Controlled experiments that were conducted between 1960 and 1975 indicated that a significant increase of 10 - 15% in rainfall in the northern part of the country - Kinneret Basin - is obtained. . Internal and external sources (World Meteorological Organization) have cited the Israeli seeding program to statistically showing significant success. Although, lack of clouds in draught years limit the benefits of cloud seeding when most needed.

***Desalination*.** Many small and medium plants for desalination of brackish and sea water for domestic water supply are operating mostly in the Arava Valley and the Gulf of Eilat. Brackish water sources obtained by shallow wells in the Coastal Aquifer, drainage and seepage of fish ponds as well as deep wells drilled in saline water bodies will be further developed, after desalination. Also desalination of sea water along the Mediterranean coast and the Red Sea will become more and more important. The first sea water desalination unit on the Red Sea produces 10,000 cum/day and more units will be installed to produce 200 - 250 MCM by the year 2020, as compared to current production of 10 MCM/year. The first sea water desalination plant, on the Mediterranean coast with a capacity of 150,000 cum/day is planned for the early years of the next millennium.

Section 7: RECOMMENDATIONS AND LESSONS FOR WCD

Global trends

- A genuine need for the expansion of irrigation, coupled with improved water productivity
- Increasing demand for water for all uses
- Decreasing allocation of fresh water for irrigation
- Recycling and use of marginal water resources for irrigation
- Modern technology acquisition and institutional reforms
- Global transition towards a market economy with varying pace and degree in different regions and economic structure.
- Steady and progressive integration of regional and international markets

Sustainability Targets

Sustainability should be viewed in the context of the economic and social development, going far beyond natural resources.

- Further development of water resources to improve drinking and industrial uses, as first priority,
- Improvement of water use efficiency and productivity in all sectors
- Further development for multi-purpose dams, hydro-power and expansion of irrigation
- Protection of water resources and environment from pollution
- Improved management of water facilities including dams and other natural and man-made water storage

Social Stability and demography. Demographic pressure is the underlying determinant of the developing world. Rural development and food production are therefore conditional for social stability in many important countries. Efficient farming systems and irrigation are detrimental while other potential sectors are still embryonic to generate jobs and absorb rural migration.

Global climate change and long term storage. Decreasing precipitation, higher frequency of extreme rainfalls and droughts—is already apparent in many regions and the impact of global change is a quantifiable risk. Rising average annual temperatures and lowered average rainfall and wider fluctuation and variability of precipitation would jeopardise the sustainability of resources and threatens the existence of both rainfed and irrigated farming systems. In addition to the need for better predictions and thorough monitoring of the climate, such conditions emphasize the importance of annual and inter- annual storage which has to be greatly improved.

Cloud seeding. Cloud seeding to artificially increase rainfall is being used with some success in Israel and elsewhere. Its potential must be expanded to wider areas and meteorological conditions. In addition to increased water volume, rain enhancement in critical periods of the crop cycle can save the entire crop in drought stricken areas.

Water Resources Quality Degradation. The quality of water is a growing concern given current measurable negative effects on water quality of pollution generated in all sectors. The degradation of surface and groundwater resources can be worsened by the accelerated industrialization and recycling of wastewater leading to an increase of undesirable chemical loads. Vigorous actions will be required by national and international organizations to reduce the associated risks.

Risk of a food crisis. Indiscriminate global food trade can exert a great concern on social stability in regions and countries sensitive to any food crisis, especially those which cannot , lift food prices to meet the marginal cost of production in the western world. It can be assumed that a fair level of self-sufficiency in staple food would be generally maintained to alleviate the effect of unforeseen food crisis.

Financial and economic considerations. Water should be assigned a higher value, and appropriate incentives should be given to attract investments.

International and Regional cooperation. Increasing regional and international cooperation on water transfers, research and technology. Further, more effort should be given to joint planning for climatic variability: plans to combat drought and flood and on increasing subsurface and groundwater storage.

Wider regional cooperation in river basin management could ensure that regional interests are properly protected within the national food market, privatization, structural and institutional re-organization A regional outlook of water resources should be considered, whenever possible, by national institutions in regulating and allocating resources together with local management issues and involvement of the private sector and water users associations. Regional cooperation must reach a high level of efficiency to cope with the challenges. This implies an efficient institutional framework, including exchange of reliable information systems about withdrawal and water uses and recharge of groundwater.

Information and Knowledge. Develop a proper information and monitoring system to feedback to decision-makers in developing water for food and investment in R&D to support the necessary development in agriculture and water resources.