OPTIMIZING THE ALLOCATION OF SCARCE WATER RESOURCES: A CASE STUDY OF THE GAZA STRIP

by

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ABSTRACT

The water situation in the Gaza Strip has now reached the dimensions of a crisis, possibly one of the most serious in the world. In 1948 Gaza had a population of 80,000. Today that population has swollen to one million, making it one of the most densely populated territories on Earth. This population explosion has contributed directly to the current water crisis. Current water consumption is estimated at 135 million cubic meters per year, of which two-thirds goes to agricultural use. To meet this demand, Gaza's only resource is a shallow aquifer which recharges at approximately 60 million cubic meters per year. Over-exploitation of the aquifer has led to falling groundwater levels and deteriorating water quality due to seawater intrusion. Only 7 percent of domestic water pumped into the network is potable according to WHO standards. Water problems have a direct effect on the quality of life for the Gazans, and also on the economic prospects of the Strip.

The purpose of this thesis is to assess the water situation in Gaza, define possible options, sketch various scenarios, and evaluate how analytical tools, particularly optimization models, can assist in the appraisal of alternatives. The thesis concludes with proposals that could contribute to the formulation of a water policy for the Gaza Strip. A major issue with models is that they do not account for the highly unpredictable social, economic, legal and political processes which influence water planning and management in the Gaza Strip. A technically and economically optimal solution may be unacceptable to policy makers because it contradicts immediate political imperatives. Therefore, while models can help in discovering tradeoffs and joint gains, it should be recognized that there is no one uniquely correct solution, and that the traditional decision-making approach is incremental.

This thesis contends that the current water crisis is mainly the product of misallocation of water resources due to historical, economic, and political factors. The long term solution to the Gaza's and the region's water problems will rest in the reevaluation of agricultural policies. If this is done, additional water resources will be freed up for urban uses, and opportunities for regional water trading – based on economic principles – will open up. A social and political crisis is looming in the Gaza Strip, which will be compounded by the destruction of the aquifer. However, as discussed in this thesis, solutions to the water problem do exist. They will depend on the financial support of the donor community, Israel's goodwill, and, the political will as well as the management ability of the Palestinian leadership to formulate and implement a sound water policy.

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Chapter 1

Introduction

The Gaza Strip is facing an acute shortage of fresh water supply. The water situation has now reached the dimensions of a crisis, possibly one of the most serious in the world. In 1948, Gaza had a population of 80,000. Today that population has swollen to one million, making it one of the most densely populated territories on Earth. This population explosion has led to the current water crisis. Current water consumption is estimated at 135 million cubic meters per year, of which two-thirds goes for agricultural use. To meet this demand, Gaza's only resource is a shallow aquifer which recharges at approximately 60 million cubic meters per year. Over-exploitation of the aquifer has led to falling groundwater levels and deteriorated water quality due to seawater intrusion. Only 7 percent of domestic water pumped into the network is potable according to WHO standards, and at many locations water consumption is posing a serious hazard to human health.

Water problems have a direct effect on the quality of life for the Gazans, and also on the economic prospects of the Strip. The water shortage affects the quality of agricultural output, and reduces the scope for the development of water-using industrial processes. According to many experts, if the extraction rate continues to grow unabated, it is a matter of a few decades, if not years, before the aquifer is irreversibly destroyed and unfit for both agricultural and human use. However, the looming disaster can be averted if proper measures are rapidly taken.

At this early phase of Palestinian empowerment, water resources planning is still at a very preliminary phase. Since its establishment in 1994, The Ministry of Planning and International Cooperation (MOPIC) has performed a rapid assessment of the water situation in the Gaza Strip. According to the MOPIC, investment needs in the water and sanitation sector are in the order of US$500 million for the next 10 years. However, the definition of an investment program requires planning and policy formulation within the water sector. To this end, the Palestinian Water Authority (PWA) was created in 1995 with the support of the UN system. As stated in the September 28, 1995 PLO-Israel agreement, the Palestinian National Authority is granted the power to operate, manage and develop water and sewerage systems and resources in the self-ruled areas. Accordingly, the PWA will assume policy-making and regulatory responsibilities for the territories administered by the Palestinian Authority.

Little investment took place during the period of military occupation and the existing infrastructure is in desperate need of rehabilitation and expansion. The Emergency Assistance Program prepared in 1993 defined initial investment priorities to be supported by various multilateral development agencies and bilateral donors. However, there is no national strategy yet to cope with the water situation and the multiplicity of actors in the water sector has led to a fragmented approach that fails to address water resources in a comprehensive manner. The formulation of a sound water policy is indeed an urgent matter.

1.1 Outline

The purpose of this thesis is to assess the water situation in Gaza, define possible options and scenarios, and evaluate how analytical tools, particularly optimization models, can assist in the appraisal of alternatives. Implementation issues and non-quantifiable constraints are identified. The thesis concludes with proposals that could contribute to the formulation of a water policy for the Gaza Strip. The thesis is divided into seven chapters:

- Following this introduction, Chapter 1 outlines the analytical framework used in this thesis

- In Chapter 2, economic, financial, political, social and institutional issues are evaluated to form the overall context of the water situation.

- Chapter 3 provides a description of the current water issues in the Gaza Strip and assesses the overall performance of the water sector.

- In Chapter 4, demand scenarios, as well as a summary of the issues and challenges that the water sector will face in the future, are presented.

- Chapters 5 and 6 review possible demand- and supply-side options, including management of existing water and development of new sources.

- In Chapter 7, various optimization models are reviewed, including technical, microeconomic, macroeconomic and multi-purpose models. Analytical tools are proposed to evaluate the options and scenarios developed in Chapter 4

- Finally, in Chapter 8, using the conclusions drawn from previous chapters, policy recommendations are formulated, and future directions for further research are proposed.

1.2 Analytical framework

At the heart of the proposed approach is the development of a comprehensive analytical framework for water resources management. A possible framework is displayed in Figure 2:

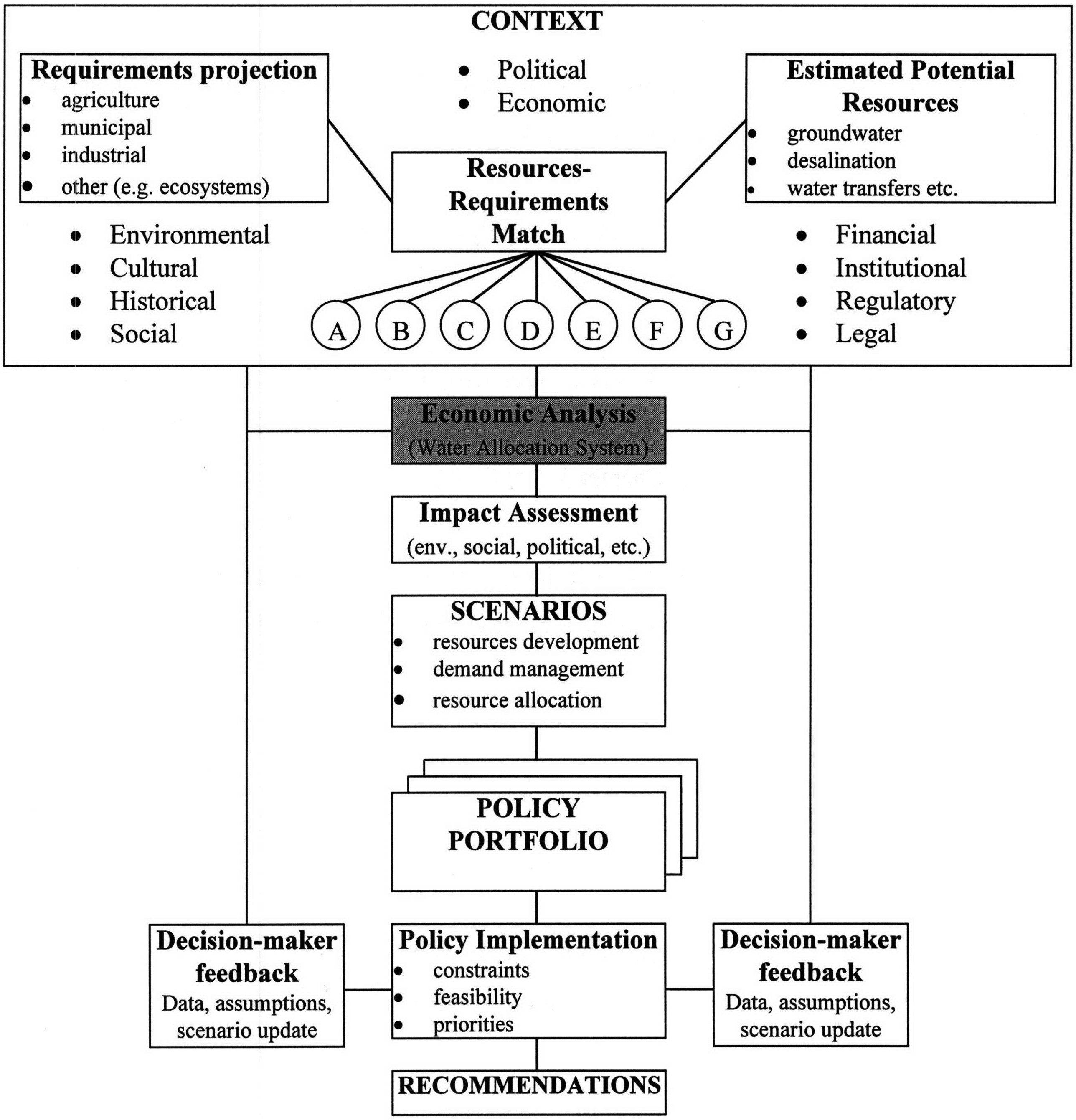

Figure 1 - Analytical framework

1.3 Hypothesis

The subject of water allocation and use has gained increasing prominence in the period since 1990, partly because of recognition that some regions have run out of water permanently, at least for some uses. This thesis contends that the current water crisis is Gaza is the product of misallocation of existing water due to historical, economic, and political factors. Various options have been proposed to solve the water problem in Gaza. However, all these options need to be placed in an integrated framework optimizing the allocation of water. For instance, viewed individually, desalination may appear to be the long-term solution to Gaza's problems. On the other hand, if we look at water use in agriculture, we realize that the Gaza Strip is currently exporting more than 30 million m^3 of water per year in the form of citrus, at prices an order of magnitude below the cost of desalinated water. The prime importance of allocation in any management policy is typically deemphasized. The problem with any allocation policy is that it requires that political as well as economic priorities be taken into account. Reallocation normally means that some party will lose the resource in order that it be made available to another. Allocation of new resources calls for the evaluation of tradeoffs aimed at maximizing economic efficiency.

Chapter 2
Context

In the almost fifty years since it became an internationally recognized entity, the Gaza Strip has been called "the forgotten man of the Middle East", "the black hole of the Arab world", and "Israel's collective punishment". This tiny, artificial entity has been occupied by foreign powers - Egypt and Israel - since its creation. This is where the Palestinian uprising (intifada) began in 1987, and where self-rule for the occupied territories began in 1994. As such, the Gaza Strip has remained a critical part of the Palestinian-Israeli conflict.

The Gaza Strip is an area of extreme complexity-geographic, demographic, economic, social, political, and legal. Demographically, it is an area with both the highest fertility rate and the highest population density in the world. Two-thirds of the residents are refugees, and more than half are younger than fourteen years of age. Economically, Gaza is facing a deepening crisis and at present has virtually no economic base. Socially, Gazan society is deeply divided between groups of different origin: refugees, indigenous Gazans, Bedouin, and recent returnees. Politically and legally, the territory has been under Israeli military occupation from 1967 to 1994, and was under Egyptian occupation before that. Everyone in the Strip is stateless, and no one can leave the territory without permission from the Israeli military authorities.

2.1 Geography

The Gaza Strip (Figure 2), a 40 km by 10 km strip of land on the Mediterranean coast, where Israel meets the Sinai Peninsula, encompasses a total area of approximately 360 km2. This is

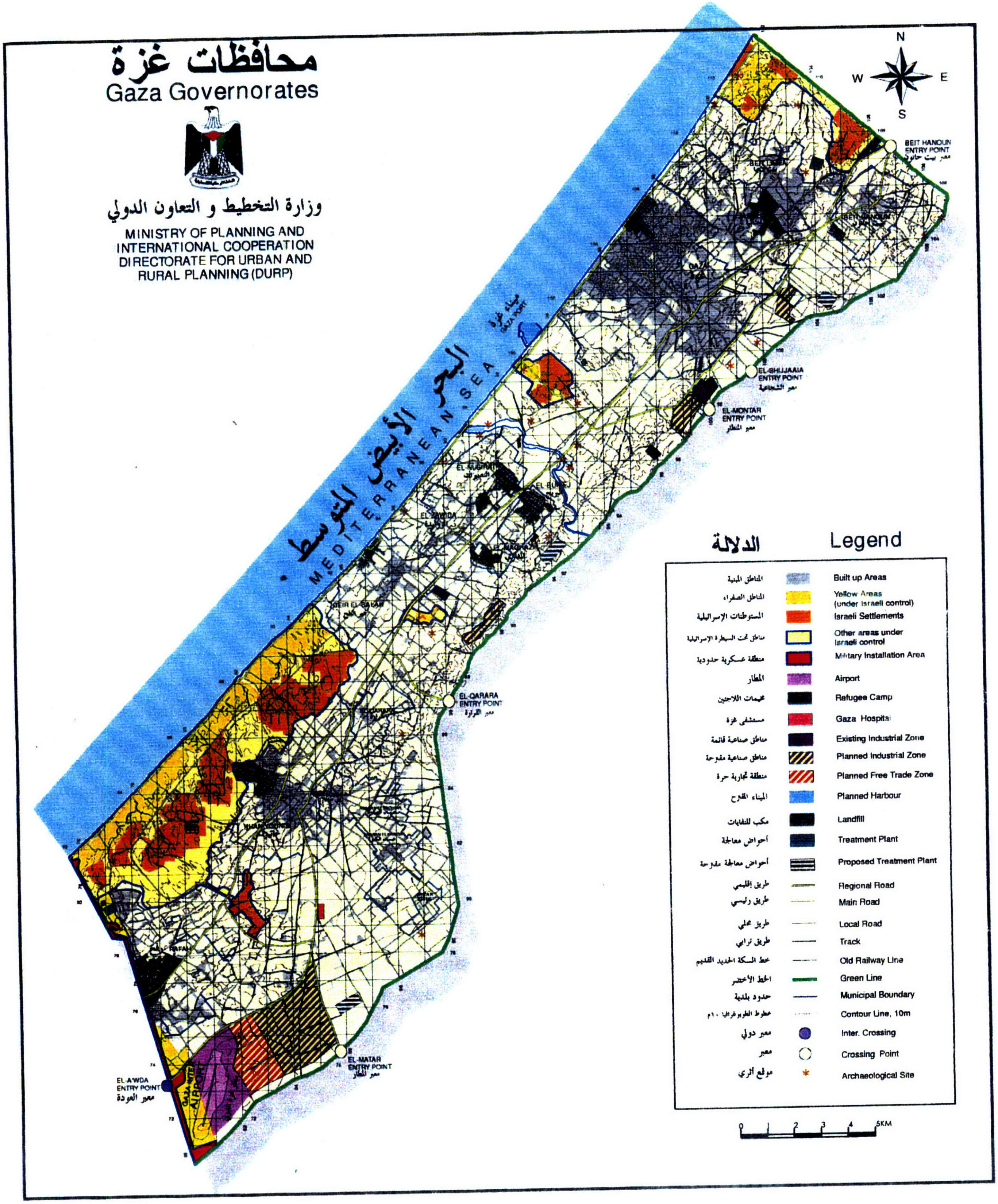

Figure 2 - Map of the Gaza Strip
(Palestinian Ministry of Planning and International Cooperation, 1996)

slightly bigger than Martha's Vineyard in Massachusetts, or twice the size of Washington DC. Gaza has three narrow, distinct bands of land that extend the length of the territory, a sand dune ridge 40 m above sea level; a central depression with highly fertile alluvial soils; and a sandstone ridge in the east extending into the northern Negev. The climate is distinguished by its proximity to both the sea and the Negev desert, with hot and humid summers and damp and chill winters. Gaza's climate ranges from semiarid in the north to arid in the south. The warm climate causes high potential evapotranspiration, between 1,040 and 1,900 millimeters per year (mm/year) for Gaza as a whole (Kelly, 1996). Annual rainfall ranges from 200 mm in the South, on the fringe of the desert, to 450 mm north of Gaza City.

2.2 History

The city of Gaza experienced a continuous succession of conquerors and occupiers beginning with the Egyptian pharaohs and ending with the Israeli army. The city of Gaza has been attacked and destroyed by a succession of invaders - Isrraelites, Egyptians, Assyrians, Scythians, Babylonians, Persians, Romans, Muslims, Crusaders, Mamelukes, Ottomans, French, British, and Israelis - struggling for its control (Roy, 1995). As the key commercial outpost and the first source of freshwater north of the Sinai Desert for caravans traveling between Asia and Africa, Gaza was once considered to have great strategic value. The declaration of Israeli statehood in May 1948 precipitated the birth of the Gaza Strip. Within days of its creation, the territory was besieged by 250,000 refugees fleeing the war; the Strip's population tripled almost overnight. The territory fell under Egyptian rule until the Six Day War. From 1967 until the establishment of the Palestinian Authority (PA) in 1994, the Gaza Strip was military occupied and administered by the Israeli government. The intifada, the Palestinian uprising, broke out in Gaza in December 1987. The shift in PLO strategy from armed struggle to the pursuit of negotiations with Israel provided a basis for the US peace initiative in 1991 and the mutual recognition by the PLO and

Israel in 1993. The interim agreement (Oslo II), signed in September 1995, extended self-rule already granted to Gaza and Jericho to other populated areas of the West Bank. The negotiations on the final disposition of the territories were to have begun in May 1996. Terrorist incidents in Israel, and the subsequent election of a right-wing government in May 1996, put the peace process under considerable strain. The groundbreaking of a housing project in East Jerusalem in February 1997 plunged the peace talks into crisis. As of May 1997, the political process was stalled.

2.3 Population

By early 1997, the Gaza Strip was home to about 1,000,000 people, the overwhelming majority of whom (99 percent) are Sunni Muslim Arabs. There is also a tiny and dwindling minority of Arab Christians (0.7 percent). About 5,000 Israeli Jews (0.5 percent) live in sixteen settlements spread across the entire length of Gaza's coastline. These settlements comprise about 25 percent of the territory's total area. About 70 percent of Gazans are refugees of the 1948 war and their

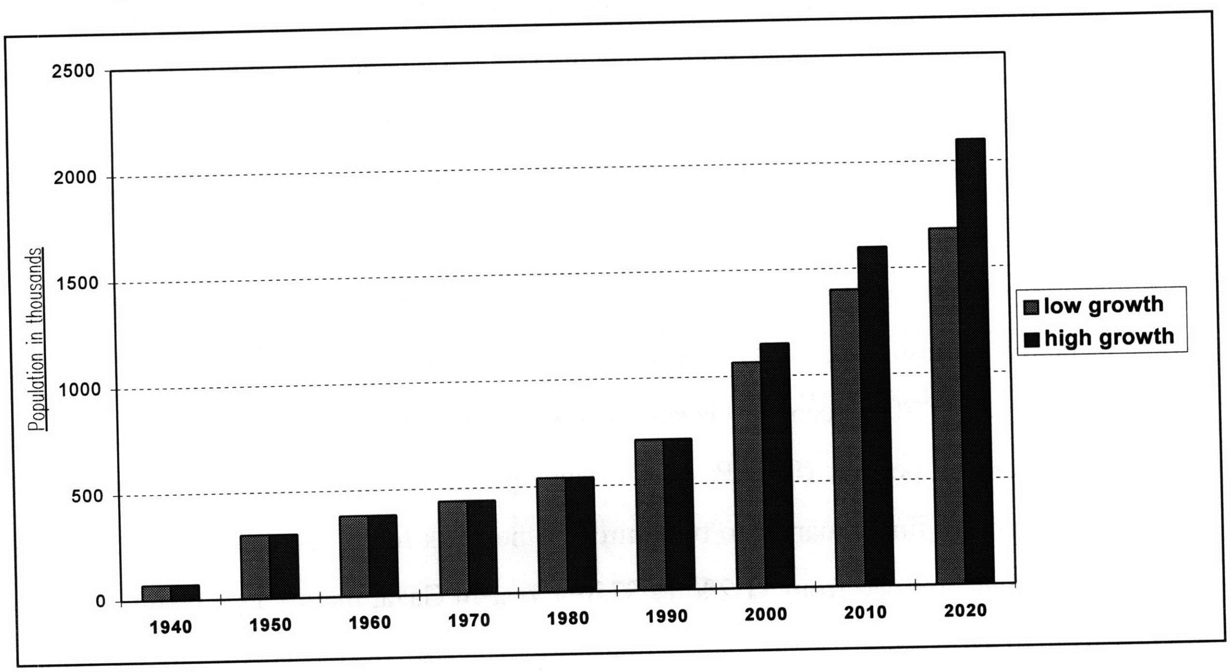

Figure 3 - Population of the Gaza Strip - Actual and Forecasts

descendants. Over half of the refugees still live in camps. Comparisons with other areas of the world underline the gross overcrowding in the Gaza Strip. When calculated on the basis of Arab-owned land alone, Gaza's population density exceeds 4,000 people per km^2. The density levels in the refugee camps are far higher: Jabalya, the largest camp, has a population density equivalent to 80,000 people per km^2, over twice of Manhattan. The current fertility index - 8.5 live births per woman - is the highest in the world. The current annual population growth rate exceeds 5 percent and if the rate is sustained, population will double every 15 years. Approximately 10,000 workers are added to the labor force each year. Figure 3 illustrates the tremendous population growth that took place in the Gaza Strip over the past 50 years.

2.4 Economy

Contrary to popular belief, economic and social conditions in the Gaza Strip have substantially deteriorated in the more than three years since the Oslo agreement was signed. Gaza Palestinians are living in a state of economic and social decline never experienced. Many Gazans are experiencing genuine poverty, unprotected either by an adequate social safety net or by personal savings; poorer families appear to have used up most accumulated savings to cope with other recent periods of high unemployment (World Bank, 1996). At least 20 percent of all Gazans now live at or below an absolute poverty level of between $500 and $600 per capita annually. Prior to the intifada, close to 70 percent of Gaza's workforce was employed in Israel. In January 1997, this number was 11 percent (UNDP, 1997). Unemployment has reached crisis proportions in Gaza, with figures at times soaring to two-thirds of the work force. Over the past three years per-capita income has dropped from $1,200 to $750 a year in Gaza, mainly as a result of the loss of employment in Israel and the decline in trade flows caused by the Israeli closure policy. Per capita GNP is now well below the average for all less developed countries ($950), not to mention Israel ($15,000). Exports to Israel, or via Israel to other markets, dropped by 50 percent. Worst affected was the agricultural sector, which makes up 30-40 percent of Gaza's GDP. Industrial output still accounts for only 7 to 8 percent of GDP (compared with one-quarter in Jordan), indicating an unusually low level of industrialization. Overall public investment has been very low, at 3 to 4 percent of GDP a year, which has led to the decay of basic infrastructure (World Bank, 1997). As a result of the closures, daily losses for the local economy are estimated to have risen to $10 million per day in 1997. The collapse in exports forced a downward spiral of prices of agricultural products as stocks built up. In 1995, the total loss amounted to over $600 million, more than all 1995 pledges by the donor community (EIU, 1996). What is especially worrying are the consequences of prolonged permanent status negotiations -if the next phase is to be implemented in stages, each stage becoming a test case - on the Palestinian economy (Kassis, 1996).

According to Sara Roy, a Harvard research fellow recognized as an expert on the Gaza Strip, "Israel's economic goals in the West Bank and Gaza Strip always aimed to preserve the structural integration of the Palestinian economy with that of Israel, thereby insuring its continued dependency and removing all possibility of economic competition (Roy, 1995). Indeed, the Gaza Strip economy is critically dependent on Israel. Israel's policy vis-à-vis labor and commodity mobility is central to determining growth rates and, therefore, family and living conditions. The trade deficit of the PA with Israel is enormous. Israel's exports to the PA stood at $1.55 billion in 1996, with $235 million imported, giving a $1.315 billion trade deficit (EIU, 1997).

Due to falling wage rates and higher consumer prices, a single average worker's monthly income could only cover 59.6 percent of basic needs and only 42.1 percent of overall expenditures by mid-1996, indicating that Palestinian families are experiencing significant economic distress (UNDP, 1997). Evidence suggests households are responding to falling incomes by drawing down savings, borrowing money, and falling behind on utilities payments. The latter fact is particularly of concern for water pricing. Assuming a per capita consumption of 100 liters, and a price of $\$1/m^3$, an average household would be billed $40 per year for domestic water, that is, 6 percent of per capita GNP, or 10 percent of household income.

2.4.1 Agriculture

The agricultural sector has historically played an important role in the Gaza Strip, where citrus were traditionally marketed through Egypt for export to European markets. The agricultural share of GDP calculated in 1996 stand at about 30 percent. Although Gaza was traditionally self-sufficient in food, in 1996 the value of local consumption exceeded the value of local production by 20 percent (Ministry of Agriculture, 1997). Wheat, barley, rice, sugar and certain fruits are mostly imported. Since 1967, the composition of agriculture output in Gaza has changed considerably (Figure 4). Although traditional crops like citrus have, in the past, been the major part of Gaza's traditional economy, this role has been taken over recently by vegetables and animal husbandry.

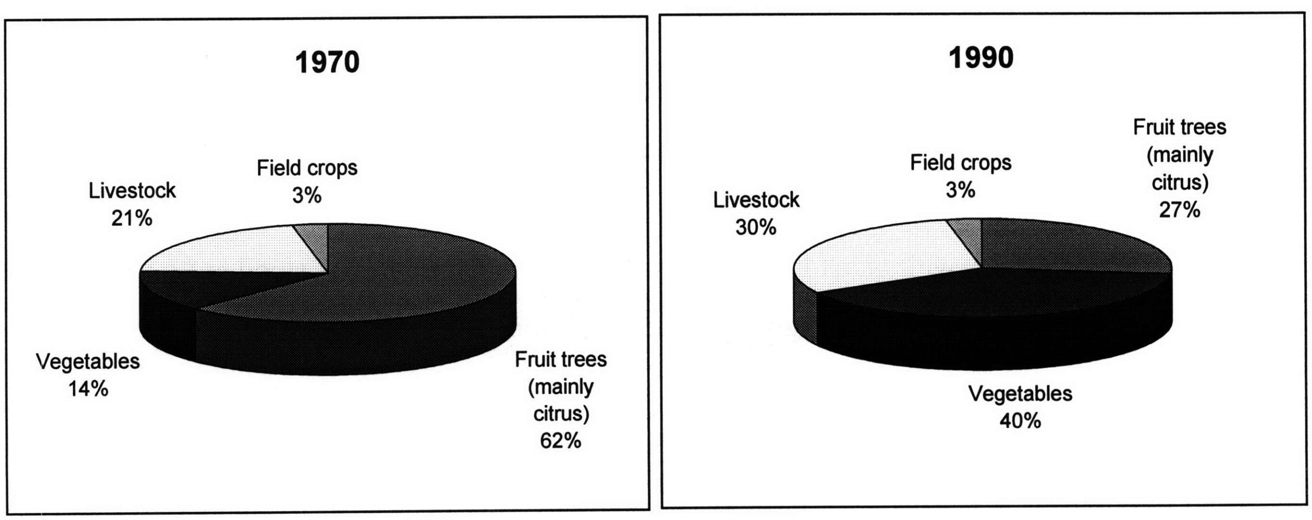

Figure 4 - Value of agricultural output (World Bank, 1993)

Agricultural decline in Gaza is in part a result of water scarcity. The contraction and degradation of the water supply has led to significant reductions in crop yields. Production is heavily influenced by trade imbalances that have their roots in the occupation. While Israel restricts

Israel exports substantial quantities of fruits and vegetables at prices with which Gazan farmers have been unable to compete.

Palestinian agriculture is at disadvantage vis-a-vis their Israeli counterparts because of the generous subsidies Israel gives to both sectors. For example, Israel's support for its agriculture averaged 32 percent of the value of that sector's output during 1984-90 (Elmusa, 1995). Future access to European and Arab markets will provide potential for higher exports, in turn stimulating infrastructure development and new investments. However, the water problem will remain a very significant constraint. The interim agreement did not provide for an increase in water allocated to Palestinian agriculture, and Israeli restrictions on water use remain in place in water-rich areas. The accords reached with Israel so far do not address the water resources issue since it was agreed that there would be no discussion of sovereignty over water (and land and settlements) before final status talks.

2.4.2 The role of water in the economy

As shown in Figure 5, water plays a significant role in the Gaza Strip, but much less in Jordan and Israel. The chart below illustrates the relative contribution of irrigation water to the economy. In Gaza, 65 percent of total water demand generates 35 percent of the GDP and provides jobs to 40 percent of the workforce. By contrast, 65 percent of total water consumed in Israel contributes only to 2 percent of the GDP. The role of water in the industrial and service sectors is much more difficult to establish. In Chapter 4, analytical tools and evaluation methods that may enable such an analysis are discussed.

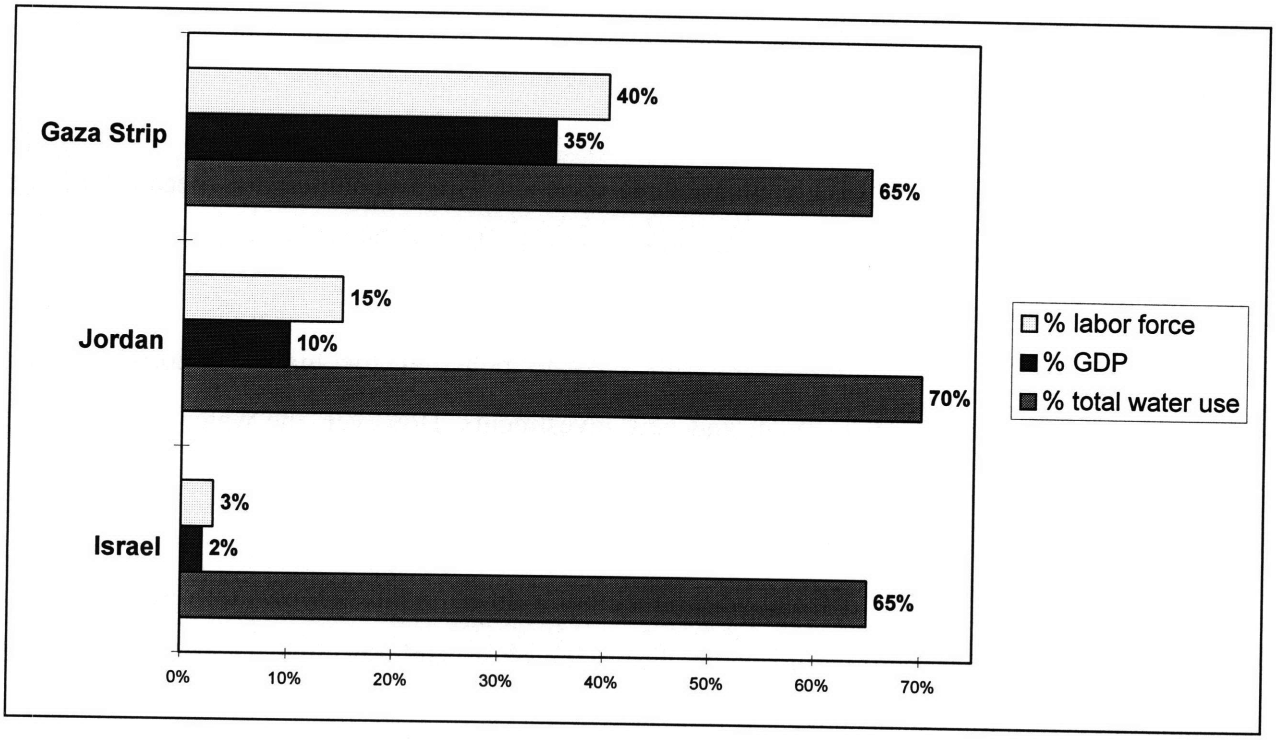

Figure 5 - Relative contribution of the water sector to the agricultural sector (World Bank, 1993, UN, 1994)

2.5 Social issues

For some time, Gazan society has been deteriorating, a result of continuous economic decay and political repression. This deterioration, still unabated, is characterized by the erosion of critical support structures such as the extended family, the school, and the political faction and the breakdown of the community as a social actor (Roy, 1995).

Despite positive changes toward greater personal safety and freedom of expression, the arrival of the PA has neither healed the internal fractures nor lessened the violence that have characterized Gazan society for some time (Roy, 1995). The militarization trend is reflected by the presence of uniformed men everywhere. Almost half the PA employees are members of at least seven security services. PA's abuses have been widely documented. While in Gaza, the author was repeatedly told of instances of abuses by PA officials, ranging from traffic cops to ministry officials. As one Gazan complained: "under the Israelis the law was bad, but there was a law. Now, there is no law anymore". Adding salt to the deepening social wound is the popular perception that the "Tunis people[1]" are behaving in socially unacceptable ways, refusing to accommodate the standards of the very conservative society in which they now live (Roy, 1995). More and more Gazans are wary of the corrupting and perverse changes in society that are believed to have been introduced and institutionalized by the PA. For example, bribery is said to have become a way of life in Gaza. One Gazan, a key player in the multimillion-dollar deal to build a Marriott hotel in Gaza, indicated that one reason for the project's continued delay was that ministry officials are waiting for bribes from project developers.

Confusion in Gazan society is great. To many people, the future seems less visible now that at any time of the past; the resulting alienation is palpable. In Gaza, it is normal to go out, especially during Ramadan; it is a Mediterranean culture. However, during the Ramadan nights of 1997, Gaza's streets were empty, reflecting the depth of the social and economic crisis. There were few Palestinian shoppers on the formerly busy Omar Al Mukhtar Street, Gaza main thoroughfare. There is, in Gaza, a profound sense of end of the dream, of having nowhere to go and nowhere else to look, something Palestinians have never contemplated. A major factor producing support for the Islamists is the ongoing economic crisis of the territory. Palestinians agree that their turn to religion symbolizes a plea of the hungry, although most of them stress their prayer is not meant to identify with Islamic extremists. As one Palestinian explained:

> "There is a rising religious fervor in Gaza. There is nothing wrong with prayer but this is praying because of being poor. Under these circumstances, going to the mosque is the first step toward a revolution".(Jerusalem Post, 11/27/96).

Amira Hass, the only Israeli journalist living in Gaza, mocks Israelis who say "Go to Gaza" (Lech le'Aza) as a way of saying "Go to hell". As she describes the situation:

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[1] Tunis was Yasser Arafat's last headquarters in exile, and "the Tunisians" is a nickname which Gazans gave to those, officially known as "returnees", who came with him when, following the Oslo accord he established himself here instead. There are about 10,000 of them, and they dominate the Palestinian Authority and its security apparatus.

> "Gaza is a big jail and you are confined to a very small area. People can't move (only married persons older than 30 are allowed to cross into Israel, provided they hold proper entry permits). They see television and they are connected to the Internet, and they see the big differences between what life offers, and what actually happens in reality" (Jerusalem Post, 1/5/97).

However, while in Gaza the author also met Palestinians that still wanted to believe in a bright future. When peace will be achieved and economic development takes place, they say, Gaza – given its unique location - may well become a major center of international trade and industry, indeed the Hong Kong or Singapore of the Middle East.

2.6 Politics

Political affiliation is the most important form of organization in the Gaza Strip. Political divisions are deeply felt and cut across social class distinctions. Everyone in the Gaza Strip is a political being. Politics directly and immediately influence daily life. One cannot understand Gaza without understanding its politics - not only what is said, but also what is meant (Roy, 1996). In the 1990s, at least seven political factions claimed the allegiance of Gaza's highly politicized population. Five of them, including Fateh, Gaza's largest party, espouse a secular, democratic ideology, and fall under the umbrella of the Palestine Liberation Organization (PLO). The last two are based on religious belief and espouse the same objective - the creation of an Islamic state in all of pre-1948 Palestine. The Islamic movement is far stronger in Gaza than in the West Bank. Socially, Gazans are far more traditional than West Bankers, whose continuous exposure to foreign visitors has bestowed a sophistication and a worldview not often found in Gaza (Roy, 1996). The strength of Islamism is rooted in Gaza's extreme poverty, isolation, social structure, and a profound sense of popular despair over the steady disintegration of daily life. The signing of the Israeli-PLO Declaration of Principles in September 1993, which the Islamists fiercely oppose, intensified existing divisions with Fateh and led to a cycle of violence and repression. Since then, however, Palestinian support for Islamic radicals has fallen. Every time a bomb explodes in Israel - and Israel responds by closing its borders to Palestinian workers and trade - there is a popular reaction against the Islamists within Gaza. The result of Palestinian disillusionment with both the PLO and the Islamists has been rising political apathy and disengagement. While the majority of Gazans continue to hold Israel accountable for the conditions under which they live, it is clear that Arafat's administration is being held accountable as well. The survival of the PA in Gaza rests on its ability to balance the dual objectives of achieving legitimacy in the eyes of Gazans and achieving the stability demanded by Israel (Kelly, 1996). Many Gazans Palestinians see Arafat as an autocrat committed to a peace process that ignores their immediate economic needs. However, despite all the criticisms directed at the PA, the possibility that Arafat could suddenly disappear from the scene causes considerable anxiety among Palestinians. Arafat's absence could unleash frozen or suppressed conflicts between the authority and the opposition, and among and within Palestinian factions (Roy, 1996).

2.7 Institutions

The Palestinians are faced with the enormous task of nation building. Although significant progress has been made in establishing central government institutions, staffing ministries, and facilitating the reconstruction process, the Palestinian Authority is already plagued by structural and institutional problems common to most developing countries. There are administrative and bureaucratic problems that may impede the planning and implementation of infrastructure projects. Some of these inefficiencies can be attributed to the fragmented nature and composition of the Palestinian society itself. Cultural, historical and political factors strongly influence the decision-making process. Strong family ties and obligations, unwillingness to delegate and coordinate decisions, and long periods of insecurity and uncertainty impinge upon governmental actions and decisions (Roy, 1996).

Much of the criticism directed at the PNA involves appointments, said to be made more on the basis of favoritism and nepotism than competence and performance. Such appointments, according to critics, have taken a serious toll on the PA's efficiency. Moreover, monopolization of decision making is encouraged by the political divisions and polarization of the Palestinian public into supporters and opponents of the peace agreement. The major concern is the impact of all these practices on institution building (Abu-Amr, 1995).

Critics - Palestinian and foreign alike - claim that while Yasser Arafat boasts of creating a free market, he is running a command economy, dominated by state-run monopolies and choked by corruption and favoritism Wusta, or bribery, is said to flourish, and the economic mismanagement worries the international community. (Business Week, 04/07/1997).

Many Palestinians are concerned that the opportunity to lay the solid infrastructure needed to make the transition to a Palestinian state may be lost. Some go so far as to wonder whether the failure to create appropriate institutions is due to unpreparedness, which could be resolved given enough time, or to an intrinsic Palestinian inability to establish an organization transcending individuals. In any case, the comment is frequently heard that while appointments on the basis of loyalty may be common in many states, the Palestinians cannot afford this luxury in the early, crucial stages of state formation, where vision, experience, energy, and efficiency should take precedence over party politics (Abu-Amr, 1995)

There is a clear risk that the nascent bureaucratic structure may potentially hamper project planning and implementation. For example, there is duplication and competition between governmental implementing agencies. The Ministry of Planning and the Palestinian Water Authority are both involved in water resources planning, although the latter should be the only implementing agency as stipulated by the 1995 bylaws. There is also the problem of fragmentation of authority among governmental agencies working in the water sector. Donor funding strategy also leads to the concentration of power in a few Ministries, with the inherent risks of empire building. Finally, governmental institutions are hierarchical and centralized, thus limiting empowerment and accountability. Although the directly elected Legislative Council has been given a significant role, including approving laws, budget and cabinet members' appointments, in reality Yasser Arafat is the ultimate authority, and he is increasingly bolstered by the security services he has created. It has been said that the President of the PA, Yasser Arafat, selects projects according to his own priorities (Abed, 1996). For instance, the Gaza Airport project was quickly implemented - although not yet operational yet due to a political wrangle with Israel regarding security arrangements - because it was one of Arafat's pet projects.

The extent to which the Palestinians take advantage of the opportunities and mitigate the constraints will depend on the ability of the PA to build the institutions and legal environment and to formulate proper policies. It will also depend on the security situation, on Israel's goodwill, and on the PA's relations with other Arab countries.

2.8 The role of the donors

The Gaza Strip is totally dependent on outside support to finance infrastructure projects, and, increasingly, recurrent costs. The international donor community pledged a total of $2.9 billion for 1994-98 at the 1994 Paris Conference. The major pledges have come from the EU and the European Investment Bank ($600 million over five years), the United States ($500 million) and Japan ($247 million) (EIU, 1996). With a Palestinian population of 2.4 million in the West Bank and Gaza, this represents a collective pledge of about $240 per person each year, which is generous by international standards. Donor pledges at the Consultative Group meeting in Paris on November 19-20, 1996 exceeded Palestinian expectations. Donors committed $880 million to the 1997 investment program, which will be entirely foreign-financed. Of this total, $215 million has been allocated for water and wastewater projects (EIU, 1997). Among the projects approved for Gaza, the Gaza Seaport, the upgrading of Gaza's road network and the construction of a coastal parkway, and a $100 million power plant. In the water sector, funds have been allocated to the rehabilitation of water infrastructure in Gaza City, the Gaza Water Management Project, the construction of a sewage system in Khan Yunis - the second largest city in the Strip, and the renovation of wastewater treatment plants in Gaza and Rafah. Donor differences over funding priorities are marked and were aired at the Paris meeting. The PA continues to rely on donors to cover its growing budget deficit and to offset economic hardships through emergency employment programs. Despite the pressures on donors to fund the budget deficit and its public investment program, there is growing unease among some over funding the costs of Israeli closure. Some donors argue that their funds, intended for long-term development, are being used to subsidize Israeli government policy. The sense of indignation is the greater since Israeli restrictions imposed on project material and personnel are also compromising the donor-assistance program (EIU, 1996). In the coming years donors are likely to show some sign of fatigue over funding for a Palestinian-Israeli peace process if it remains at its present impasse.

More than 60 aid agencies operate in the Gaza Strip. Each agency is pursuing its own political agenda and is advocating its own technologies and design criteria. The challenges represented by the coordination of the aid effort are daunting. Some coordination mechanisms have been put in place by the UN agencies and the Palestinian Ministry of Planning and International Cooperation, but they are so far largely unsatisfactory. The technical and organizational problems are compounded by the political factor which plays an overwhelming role in the design, selection and implementation of projects. The US aid program, the largest in the Gaza Strip, exemplifies this problem.

Because of the American preeminent role in the peace process, the US aid program is overshadowed by political constraints. According to senior-level officials in the State Department, the political and policy decisions are made at a very high level while lower-level development decisions are left the US Aid Agency. Not only is the aid program centralized in the Department of State, which defines its magnitude and direction, it appears to be under direct supervision of Dennis Ross, the coordinator of the Middle East peace process (Roy, 1996). For example, the Gaza stormwater/wastewater project illustrates the highly political nature of policymaking and project selection:

> The Gaza stormwater/wastewater project was chosen only after Dennis Ross visited the site of an earlier USAID-funded stormwater project that failed disastrously and lay dormant for several

years - the reservoir supposed to receive stormwater was actually filled with sewage. Apparently outraged over what he saw, Ross ordered that the project be redone correctly, and the Gaza project was funded for $40 million, despite the lack of Palestinian involvement and the lack of local implementation capacity (Roy, 1996).

Political pressures extend to the World Bank as well. Senior-level World Bank officials with responsibility for the Palestinian territories described the pressure imposed by Mr. Ross and the State Department generally on the Bank's West Bank/Gaza program as unprecedented, atypical, minutely detailed and unacceptable (Roy, 1996).

In certain sectors such as water, the Israeli government continues to approve all new project development, but now within the legal framework established by the Oslo agreements. For example, USAID's project work in the water sector, which is a central focus of its overall program, occurs within a clearly defined framework based on water agreements reached between Israel and the Palestinians. The water agreements are administered by a joint committee of Israelis and Palestinians (in which Israel retains veto power) who approve all new projects. A point worth noting in this regard is that the US-funded Gaza stormwater project does not include the treatment of sewage water, which could be used for agricultural purposes. This is consistent with the Israeli policy which discourages agricultural activities that would involve reclaiming and securing land for Palestinian use, and apportioning large amounts of water to the Palestinian sector (Roy, 1996). The Oslo agreements are completely silent on the question of water allocation for the Palestinian agricultural sector (and do not provide for additional water for irrigation, for that matter).

The overall aid strategy is motivated by the necessity to demonstrate political progress and the immediacy of economic need. Hence, the overall approach is one that is informed not by any economic vision or long-term planning to which assistance is adapted, but one in which niches of need are identified within a larger economic and political status quo. The neglect of projects in agriculture, industry, and trade - where the possibilities of creating long-term sustainable employment are real - is due, in part, to that fact that donors prefer to concentrate in areas less subject to Israeli interference and where the probability of project success - defined as immediate and visible results - is greater. One senior State Department official involved with the West Bank & Gaza program said: we go where we can and do what we can while we can" (Roy, 1996). It should be noted that while more than $300 million has been allocated for water-related projects, there is no known master plan for water in the Gaza Strip (and the West Bank).

The political struggles inherent in the policy-making process are compounded by the involvement of foreign donors and governments. Not only does the Palestinian Authority compete within and against itself, and with the donors; the donors also compete within and against themselves, as they have different goals for their governments' aid program the Gaza Strip. Donors and consultants must deal with turf battles, organizational and personal rivalries within or between ministries, and try to implement what they consider to be sound policies. Sometimes competition between ministries is so stiff that there is little discussion between them and at times it requires an outsider to act as a catalyst for change (Roy, 1996).

This highlights the negative aspects of the foreign-assistance program: the problematic nature of technology transfer -buying foreign equipment and supplies-, the lack of understanding on the part of donors of the country's real needs, and the fostering of dependence on foreign consultants to the detriment of Palestinians. There is a real need to implement more efficient means of solving development problems and enhance the technical and managerial capacities of Palestinians..

2.9 Cultural Factors: Importance of Water

Since ancient times, water has been a central political factor in the Middle east. Water is deeply rooted in both Islamic and Jewish religions, and evoke feelings that transcend its strictly economic value.

The mezuzah, a precise Hebrew parchment placed on the doorpost of Jewish homes, refers to both the problems of water and the key crops in ancient Israel: grain, wine and oil. The Talmud teaches that since the temple was destroyed, the table in a Jewish home replaces the temple altar. The challah bread (flour), the candles (olive oil flames), and the ever present wine (grapes) symbolize the most crucial and problematic crops of ancient Israel. "If there is no flour, there is no Torah; if there is no Torah, there is no flour", said Rabbi Elazar ben Azaria, a third-century sage (Starr, 1995).
Ibn Manzur, the most famous Arab lexicographer, mentions in his dictionary Lisan al -'Arab under the root "sh r" that shari'a in the acceptation of Arabs is the law of water concerning the source which is regulated by people who drink, and allow other to drink, from. The same word is also used for what God has decreed for the people in terms of fasting, prayer, marriage etc. The connection between shari'a as a generic term for Islamic law and shari'a as the law of water illustrate the centrality of water in Islam (Lowi, 1993). Antecedents to rules regulating water allocation can be found in Islamic law, which had evolved a sophisticated set of principles to regulate water management in order to minimize conflict (Hillel, 1993).

After the Holocaust in Europe and the progressive assimilation of their Diaspora elsewhere, the Israelis considered their Zionist enterprise to be the last chance for Jewish survival and rebirth (Hillel, 1993). To the Zionist movement, water was important because it was part of the "ideology of agriculture" in Zionist thought. Encouraging agricultural activity in Palestine was central to the achievement of its goals. Water, because it is an essential ingredient of agriculture, was and continues to be considered important to the State of Israel, and has always been linked to ideological, economic, political and security-related concerns. Water would help to make possible the absorption of increasing numbers of immigrants and develop the land. In addition, with water Israel could implement its policy of population dispersal, spreading Jewish settlements throughout the country and, after 1967, the occupied territories, as well (Lowi, 1993).

Prior to 1948, the Arab population of Mandate Palestine constituted a largely agricultural society that worked and lived off the land. Given that traditionally, agriculture was the principal economic activity, water, whether in the form of rainfall or groundwater, was vital to the livelihood of the Palestinian peasant. Zionist efforts at buying up land in Mandate Palestine during the first half of the century caused the gradual alienation of Arab farmers from their land. The establishment of the State of Israel following the 1948 war exacerbated this process. Palestinians were restricted access to land and water, and this denial was viewed as a threat to their survival (Lowi, 1993).

Chapter 3
Current water issues

The water issue in the Gaza Strip is extremely compelling. The importance of water for human survival and economic growth makes it an issue of extreme political importance and sensitivity. The water situation has already reached the dimensions of a crisis, possibly one of the most serious in the world. What makes the water problem especially pernicious is that there is no shortage of water, but rather a gradual decline of quality. Therefore, there is no sense of real emergency and the political will to tackle the problem is lacking.

3.1 Water resource

Groundwater is the only current source of water for the Gaza Strip. Gaza does not have access to any permanent source of fresh surface water.

3.1.1 Water sources

The water resources of Gaza are by and large restricted to the shallow coastal aquifer. The aquifer consists mainly of recent dune sand and calcareous sandstone and clay layers of limited thickness (MOPIC, 1996). Fresh groundwater typically occurs in the form of lenses that float on top of brackish and saline groundwater (see Figure 6). This characteristic explains why deeper wells - designed for higher discharges - produce a more saline water than shallow wells. The shallow aquifer contains roughly 5 billion m^3 of groundwater. It was estimated in 1994 that around 1.4 billion m^3 of fresh groundwater was left in the shallow aquifer, roughly one third of its total volume (IWACO, 1995).

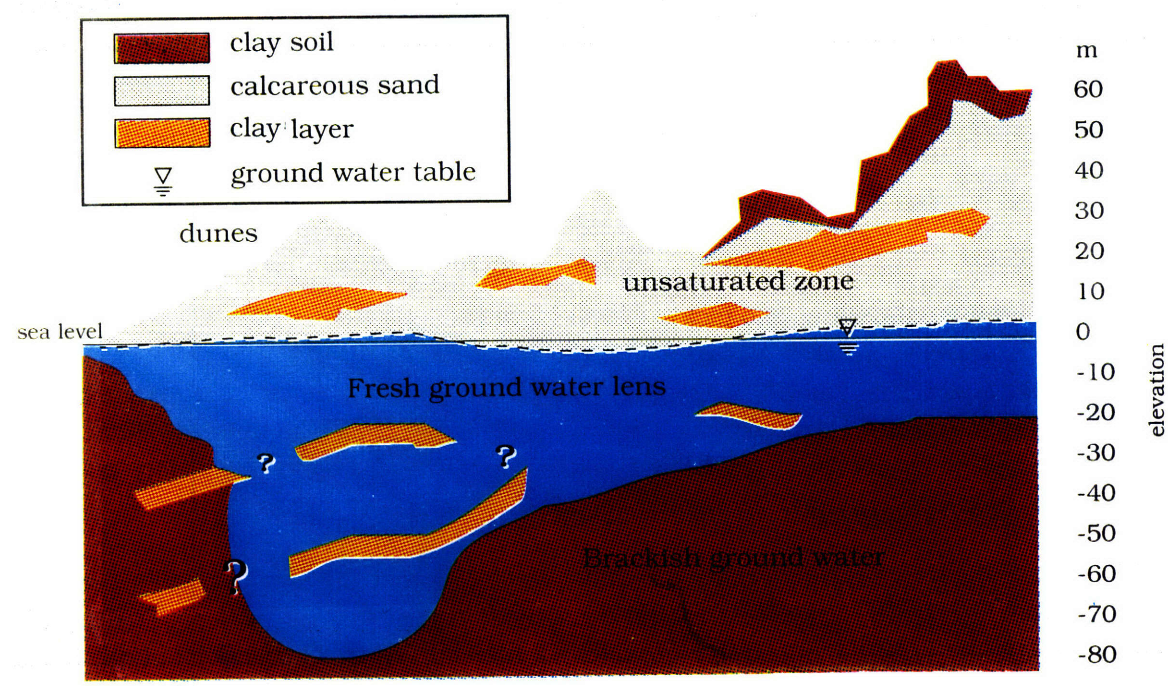

Figure 6 - Hydrogeological cross-section (MOPIC, 1996)

The major source of fresh groundwater in Gaza is rainfall. Rainfall records indicate that annual rainfall ranges from 200 mm/year in the south to 450 mm/year in the north, giving an average of around 315 mm/year. Only 40 percent of total rainfall replenish the groundwater. The remaining 60percent evaporate or flow to the sea as runoff. A minor source of fresh groundwater is the inflow from Israel - about 7 million m^3/year (WRAP, 1994). Palestinians claim the natural groundwater inflow has been significantly reduced due to the drilling of wells directly to the east of the border of the Gaza Strip, within Israel. This has, however, been a point of contention among hydrologists. Israeli sources argue that these wells are blocking the flow of saline water which could damage the aquifer. Others contend that these wells draw on a separate part of the coastal aquifer system and do not affect Gaza's aquifer.

The groundwater pumped in Gaza originates from a mix of rainfall, seawater, deep stagnant groundwater, and inflow from the surrounding areas of Israel and infiltrating surface water. In addition there is wastewater that infiltrates and irrigation return flow. As a result, groundwater quality varies greatly over small distances, reflecting the origin of groundwater. For instance, in rural areas where recharge is high and abstraction is limited, rainwater dominates. In urban areas, a mix of rain and wastewater is found. Sea water or deep brackish water can be expected where well density and pumping rates are high (MOPIC, 1996).

In 1995, 3,000 wells of which only 2,100 are registered and licensed tap the aquifer in the Strip and abstraction is estimated at 135 million m^3 of groundwater per year. The average production for domestic use can be estimated at 130 l/c/d (47 m^3/year) for the whole Gaza Strip. 11 percent of this water is purchased from Mekorot (the Israeli National Water Company), 85 percent produced directly by municipal departments and the remainder provided by UNRWA or purchased from private owners (LYSA, 1995). Because water can be cheaply extracted from shallow wells from the highly permeable coastal aquifer, over pumping has resulted. Assuming a freshwater safe yield of 65 million m^3/year, the negative balance is around 70 million m^3/year (WRAP, 1994). Pumping at a rate larger than replenishment leads to declining groundwater levels, reduction in well capacities, and increasing salinity, caused by the seawater intrusion and upconing saline groundwater (see Figure 7). If overexploitation continues, salinity will continue to rise and a situation where damage becomes irreparable could easily be reached. According to the Director of the World Bank-funded Gaza Water Management Project, the aquifer will become completely unusable in less than 10 years if no action is taken (Odièvres, personal communication, 1997).

3.1.2 Water quality

The advice given to visitors to Gaza today is: "Don't drink the water!". Poor quality is one of the Gaza Strip's most serious problems. Much of the coastal aquifer could be classified as saline. Contamination from various sources is chiefly reflected by increasing chloride, fluoride and nitrate levels.

Salinity

The increasing salinity is the best known and best monitored groundwater problem in Gaza. The two main reasons are seawater intrusion and brackish water upconing. Seawater intrusion occurs when hydrostatic pressure in the aquifer drops below hydrostatic pressure in the sea as a result of overpumping. In the Southern and Central parts of the Strip, groundwater levels at a distance of 1-2 km from the shoreline have dropped to more than two meters below sea level (IWACO, 1995). Assuming an average flow rate of 30 m per year, seawater could have reached around 900 m inland in the last 30 years. Brackish upconing is the mobilization of brackish water - ancient seawater that intruded in the aquifer thousands of years ago when the sea was at a higher level - due to increased groundwater abstraction. In 1995, 17 wells supplying 27 million m^3 per year of water to Gaza City had, on average, a chloride content of 750 mg per liter (MOPIC, 1996). Figure 7 shows the chloride concentration reported in pumped water in 1994. According to the WHO, chloride concentration should not exceed 250 mg/l. Concentrations above 600 mg/l are harmful. The increase in salinity depends on the recharge conditions and the intrusion of brackish or seawater. A recent survey showed that the average rate of salinization was close to zero in the north of the Strip, whilst in the central and southeastern parts it exceeded 40 mg/l per year. Aquifer deterioration can be very fast; in Gaza, groundwater chloride content increases by 50 mg/l per year. In Deir Al Balah, groundwater salinity increased by 600 mg/l between 1988 and 1994 (LYSA, 1995).

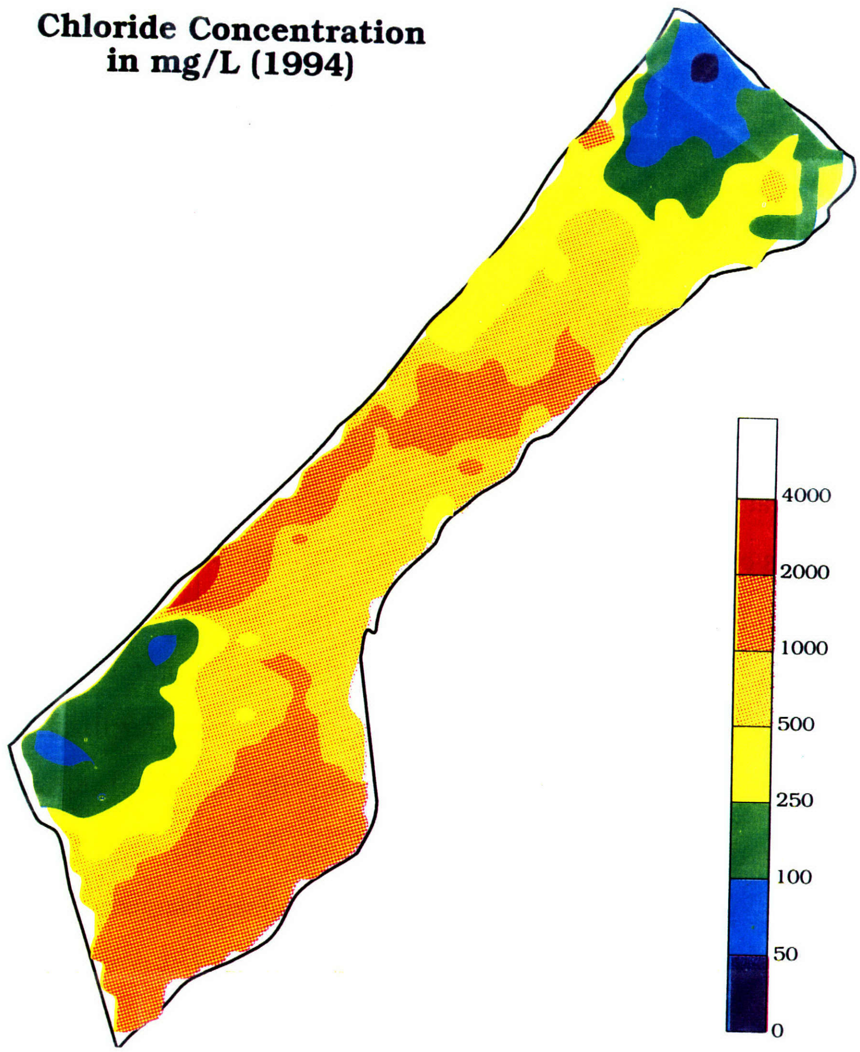

Figure 7 - Groundwater Salinity (MOPIC, 1996)

The desirable quality of water for agriculture should include at the most 500 ppm of chlorides per liter, and for such important crops such as citrus and avocado the salinity should be between 130-250 mg. As a result, agricultural products are drying up, in particular Gaza's major crop: citrus fruits. Many orchards lie abandoned because water salinity is too high for the crop. Today it is uncertain whether Gaza citrus production can utilize the full capacity of a newly constructed UNDP-funded orange juice production plant. As salinity of the irrigation water continues to increase as a result of overabstraction, farmers are forced to apply even more water in order to leach salts that would otherwise accumulate in the soil, thus worsening the already precarious situation (Ministry of Agriculture, 1996).

Nitrate

In recent years, nitrate contamination of Gaza's drinking water has increased rapidly: in 1987, 84 percent of Gaza's drinking water wells were considered suitable for drinking in terms of nitrate levels; by 1994, not a single safe well remained. The two major components that cause nitrate pollution are infiltration of domestic wastewater flow and irrigation return flow. In areas where domestic wastewater infiltrates, high nitrate concentrations are found. For instance, in Khan Younis and Jabalya refugees camps, which are not sewered, concentrations of nitrate in domestic water exceed 500 mg/l, or 10 times the WHO guideline of 50 mg/l. In 1994, more than half of the wells in Gaza City contained more than 150 mg/l (MOPIC, 1996). Irrigation return flow is rich in nitrogen because farmers in Gaza apply far more nitrogen in the form of fertilizers than plants require. A typical strawberry-farmer applies more than ten times the amount of nitrogen required for plant growth.. Unregulated use of pesticides, herbicides, and fertilizers contributes to severe pollution, especially since the aquifer is close to the surface. Chemicals banned from use in Israel and elsewhere, such as DDT, are often used in Gaza. In certain agricultural areas, this has lead to a nitrogen load that is similar to that in unsewered urban areas. However, if concentrations in the groundwater exceed 100 mg/l of nitrate, then there should be almost no need for nitrogen fertilization, as the irrigation water itself would contain enough nitrogen to support plant growth (MOPIC, 1996).

Other compounds

A survey conducted in 1991 (Palestine Center for Research and Information, 1993) showed that:

- 10 percent of the Gaza City wells, samples showed water containing more than 900 ppm of sulfur.
- 16 percent of the wells were found with more than 1.7 ppm of fluoride. A study by the Gaza Health Department Research Center revealed that the fluoride level in drinking water in the

whole of the Gaza Strip averages between 0.8 and 3.8 ppm. The normal ration allowed in drinking water in accordance with WHO recommendations is 0.7 to 1.2 ppm.

- 12 percent of the wells were contaminated with bacteria.

These percentages have certainly increased during the past 5 years, but no recent study is available.

Table 1 identifies three categories, whilst Figure 8 shows graphically how much domestic water of each quality category is supplied: only 7 percent of domestic water pumped into the network is potable according to WHO standards!

Water quality category	**Chloride concentration (mg Cl/l)**	**Nitrate concentration (mg NO_3/l)**
Potable (WHO)	< 250	< 50
Deteriorated	< 500	< 150
Poor	> 500	> 150

Table 1 - Categories of Water Quality (MOPIC, 1996)

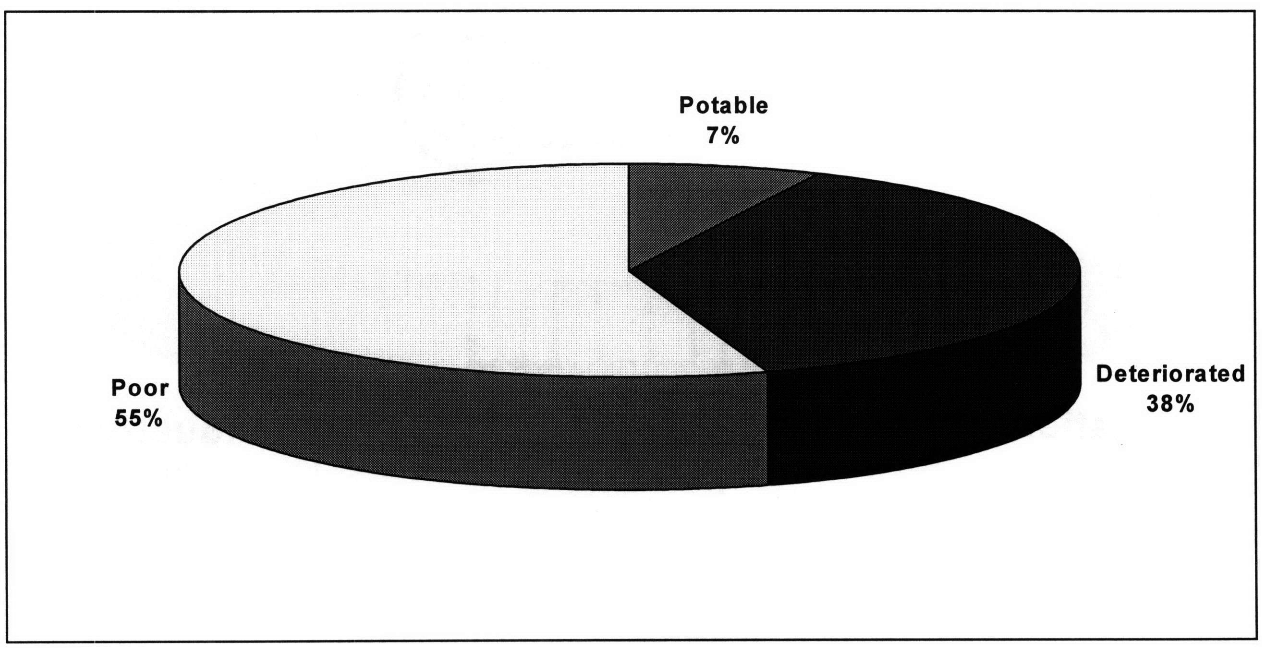

Figure 8 - Domestic Water Quality (MOPIC, 1996)

3.2 Water demand

3.2.1 Introduction

In 1995, 46 million m^3 (35.5 percent) were consumed by households, 2 million m^3 (1.5 percent) by the industrial sector, and 81 million m^3 (63 percent) were used for irrigation (Figure 9). Currently, more than 135 million m^3 are withdrawn every year (MOPIC, 1996). Some experts suggest that with rapid population growth in Gaza, demand for drinking water alone may soon outstrip safe supply. It is also possible that Israeli settler demand will increase even if settlement population remains stable, due to `increasing per capita demands for both irrigated acreage and domestic amenities, such as grass and swimming pools. Even if demand remains stable, Gaza's present water inventory may be in far worse shape than is implied by official figures: some experts suggest that pumping rates in Gaza are 1.5 to 2 times officially declared levels (Kelly, 1995).

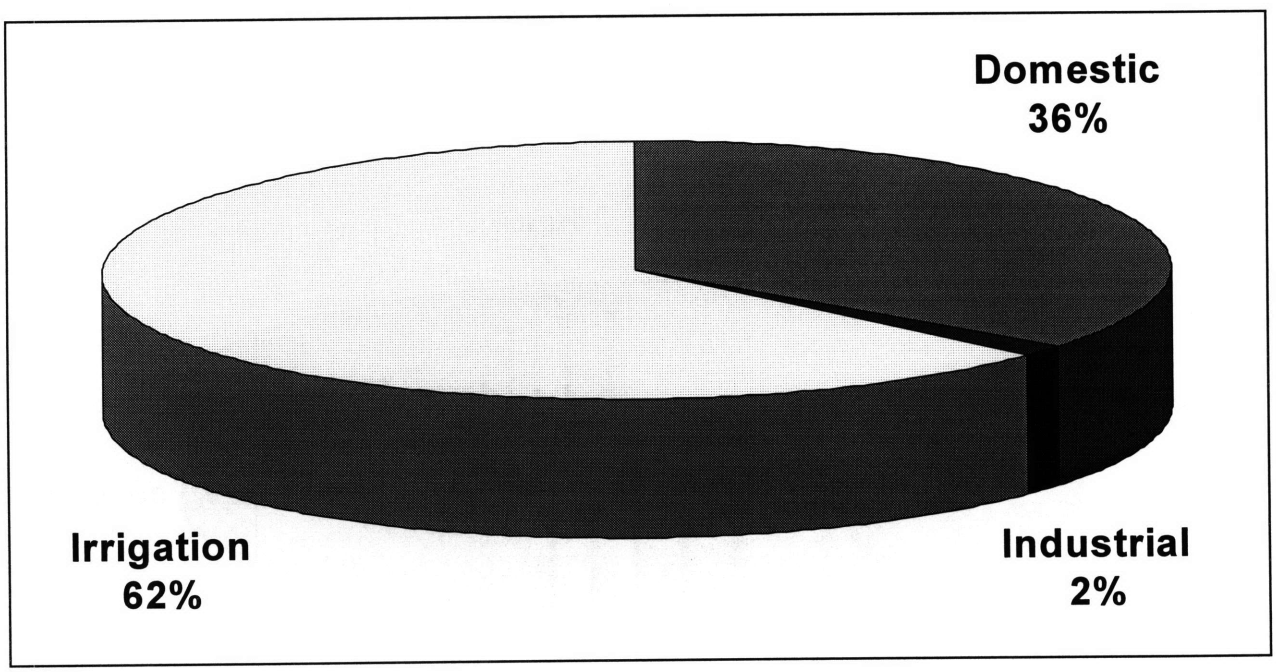

Figure 9 – Water Demand (MOPIC, 1996)

3.2.2 Domestic demand

Average daily consumption of water in Gaza is below 80 liters per person per day (lcd), compared to 300 lcd in Israel and 400-500 lcd in the United States.. While low current income levels constrain increasing levels of domestic consumption, despite the low prices of water in Gaza, income levels should rise in the future. Effective demand for water will increase to provide per capita consumption levels approaching those of Israel, placing enormous pressure on resources. Viewed individually, the difference in total water consumption between the Arab sector and the Jewish settlements in the Gaza Strip is striking. In 1986, annual per capita water consumption among the Arab population averaged 142 m^3; it was 2,240 m^3 among Jews, or more than 18 times greater (Roy, 1995). This per person difference has not narrowed significantly since 1986.

The effective demand for water by the Palestinians, given their per capita income level, is probably much higher than current low usage levels indicate, because of past quantitative restrictions on irrigation water use and shortages of finance for investments. The real demand, at economic prices, is not possible to establish precisely due to the above restrictions, intermittent supply, and current pricing practices which do not have any particular relationship to economic costs..

3.2.3 Industrial Demand

Industrial demand for water is very low at present (2 percent of total consumption). However, Palestinian and Israeli authorities are currently cooperating on a plan to build a $50 million Gaza Industrial Estate at Carni (see Figure 2) to take advantage of Gaza's skilled work force, low labor costs, and proximity to the Israeli market. Thus industrial demand for high quality water is expected to increase substantially in the coming years.

3.2.4 Agricultural Demand

Irrigation water use has dropped from 1967 to 1990 (from 120 million m^3 to 90 million m^3) due to the reduction of the irrigated area from 100,000 to 57,000 dunums and a shift from water-intensive crops (i.e. citrus) to water-saving crops (i.e. vegetables). Also, because of the relatively high costs of water ($ 0.14-0.17 per m^3) and limitations imposed by the Israeli Civil Administration – prohibition of new well drilling, strict quotas, uprooting of citrus trees, Gaza farmers have used water more efficiently. The reasons were a change in cropping patterns and a rapid and effective transfer of new technology and knowledge from Israel, notably in the area of water-efficient irrigation techniques and production under plastic. In Gaza, water use per dunum has fallen by 58 percent since 1966 (World Bank, 1993). Today citrus still makes up 55 percent of the total irrigated area, consuming roughly half of Gaza's agricultural water supply. Out of the 86 million m^3 used by the agricultural sector, 47 percent were applied to citrus (orange, lemon and grapefruit), 51 percent to vegetables and flowers (strawberry, tomato, cucumber, potato, etc.), and 2 percent to other fruits (olives and others) (Ministry of Agriculture, 1996). Agricultural consumption increased immediately after the military orders concerning water exploitation were canceled (1993). Recent data show a 40 percent increase in water withdrawals between 1993 and 1996. This is due to population growth (+38 percent over the same period), and increased agricultural use following the implementation of the self-rule agreements. In agriculture, present demand per dunum (approximately 1000 m^2) of irrigated land is equivalent to Israeli levels (600 m^3 per dunum per year). However, total potential demand is much greater. In Gaza a further 80 to 100,000 dunums could be irrigated, even though total agricultural area is expected to shrink gradually due to rapid urbanization (WRAP, 1994). This implies that annual demand in Gaza agriculture could rise to 120 million m^3.

In the future, agricultural water users will have to compete with water users in other sectors, who may produce higher value products per unit of water and who would be able to pay more for water. Consequently, farmers will basically have only two options: they will have to continue with their efforts to maximize the returns from the limited water available to them through water-saving techniques and crop selection, or they will have to use treated wastewater which will be available in increasing quantities.

3.3 Water balance

The groundwater balance is presented in Table 2 and Table 3. Fresh groundwater represents only one third of the total freshwater volume in the shallow aquifer, but it accounts for 100 percent of settlement abstraction (settlements appear to have been deliberately placed in areas where groundwater quality is the best (WRAP, 1994)), 74 percent of domestic abstraction, and 49 percent of irrigation abstraction. The deficit in the fresh groundwater balance amounts to 22 million m^3/year and is compensated by brackish and seawater intrusion (20 million m^3) and falling water table (2 million m^3) (MOPIC, 1996).

Inflow Component	**Total Water (M m^3/yr)**	**Fresh[1] water (M m^3/yr)**	**Comments**
Recharge from rainfall	46	21	Difference lost to saline sinks
Recharge from wadis	2	0	Difference lost to saline sinks
Groundwater inflow from Israel	10	7	Difference lost to saline sinks
Return flow (domestic)	27*	13	* Domestic wastewater and leakages
Return flow (irrigation)	30	18	
Saline/brackish inflow	16	0	Seawater intrusion and brackish water upconing
Purchased from Mekorot (Israeli National Carrier)	4	4	
TOTAL	**135**	**63**	

1) Groundwater with a chloride content less than 500 mg Cl/l

Table 2 - Groundwater Balance (Inflow Component) (MOPIC, 1996)

Outflow Component	Total Water (M m^3/yr)	Fresh[1)] water (M m^3/yr)	Comments
Domestic abstraction	46	36	
Irrigation abstraction	81	40	Not included 5 million m^3 supplied by domestic water
Industrial abstraction	2	1	
Settlement abstraction	6	6	
Groundwater outflow	2	2	
Evaporation Mawasy area	1	0	
Drop in groundwater table	-3	-2	
TOTAL	**135**	**83**	Excess fresh water abstraction is 22 million m^3/yr

Table 3 - Groundwater Balance - Outflow Component (MOPIC, 1996)

Out of the 26 million m^3 of wastewater produced annually, 8 millon m^3 end up in the sea, 4 million m^3 evaporate from open pools and gardens (where wastewater from kitchens is used for watering plants), and 14 million m^3 recharge the aquifer. The tables above explain the major reason why groundwater quality deteriorates. Almost half of the water that replenishes the aquifer every year is of poor quality: 14 million m^3 per year of domestic wastewater, 30 million m^3 per year of irrigation return flow, and 16 million m^3/year of saline water (MOPIC, 1996).

3.4 Level of service

Living conditions in the Gaza Strip are much worse than per capita incomes would lead one to expect. Nearly three-quarters of the population are registered refugees, and 55 percent of these people live in refugee camps (WRAP, 1995). Environmental conditions in the camps are generally poor. Most of the camps have no organized system of sewage collection, and none has an adequate system of sewage treatment for collected wastes. The sewage system, meant to be temporary, has remained largely open and exposed an extremely unsanitary playground for children, especially in the summer. Pools of stagnant wastewater frequently develop in the flatter sites of the Gaza Strip. All of the camps are provided with solid waste collection facilities, but properly designed sanitary landfills have not been constructed anywhere in the Gaza Strip. Wastes often leach into the aquifer, thereby contaminating drinking water supplies. More than a half of households in camps are served by a piped water supply in the dwelling, and two-thirds have good access to some source of piped water. However, piped water usually contains unacceptable levels of salts, nitrates and other contaminants. In more than 90 percent of the cases, the water is disinfected at the source (PWA, 1996).

In the current institutional framework, Municipalities are entrusted for Water and Sanitation utilities, and face problems with very limited means. With the exception of the Municipality of Gaza, most local utilities have not reached the critical size to structure their activity and to develop a technical competence, resulting in a very low level of service. Water undertakings have serious problems in maintaining systems, reducing unaccounted-for water, maintaining adequate pressure and in supplying the available water to customers. 20 percent of the nearly 100,000 connections are unmetered or illegal, and estimates indicate that about 50 percent of water in municipal distribution networks is lost through leakage, illegal connections and inaccurate, or lack of metering (LYSA, 1995). If 50 percent of the water pumped into the distribution network, or 26 million m^3 in 1995, actually reached the households, then the average water consumption is around 80 liters per person per day (Odièvres, personal communication, 1997)

Water can only be supplied in rotation in certain urban areas, sometimes only for a few hours once or twice a week. This endangers the quality of the water as contaminated water can infiltrate into supply pipes when the water pressure drops drastically.

3.5 Benchmark analysis

The following table presents a selection of performance indicators. For the purposes of the analysis, data for the Gaza Strip are compared to Israel's current performance as well as internationally acknowledged benchmarks.

Benchmark analysis underline an overall very poor performance of the water and sanitation sector in Gaza. For instance, only 7 percent of domestic water pumped into the network is "potable" according to WHO standards. In many locations, water can be considered as harmful to human health. However, large populations are consuming this water due to lack of affordable alternatives.

Indicator (1995 data)	Gaza (average)	Gaza (range)	Acceptable limit	Israel (average)	percent vs. Israel (benchmark)	Performance
Chloride concentration (mg/l)	700	50-2000	max. 250 (WHO)	100	700	very poor
Nitrate concentration (mg/l)	150	20-500	max. 45 (WHO)	15	1000	extremely poor
Water availability per capita (liters/day)	50		250	500	10	very low
Water treatment (percent)	2			80	3	extremely poor
Households with access to piped water (percent)	35	0-80	100 (target)	100	35	poor
Households with sewerage (percent)	10	0-40	100 (target)	80	12	extremely poor
Unaccounted-for water (percent)	50	up to 65	15	15	330	very poor
Water considered "potable" (WHO guidelines) (percent)	7		100	100	7	extremely poor

Table 4 - Benchmark Analysis (MOPIC, 1996, Shuval, 1995, WRAP, 1994, LYSA, 1995)

3.6 Water infrastructure

Under Israeli rule since from 1967 to 1993, basic infrastructure has remained primitive and is in desperate need of rehabilitation. This has had major impacts on the management and sustainable development of water resources (WRAP, 1994). Years of economic and political dislocation, neglect of local institutions and under-investment in the public sector have contributed significantly to the present grossly inadequate level of infrastructure and services. Overall public investment has been very low, at 3 to 4 percent of GDP a year or less—as compared to 6 percent in Jordan and 7 percent in Egypt in the 1980s—which has led to the decay of basic infrastructure (World Bank, 1996). Most areas in the Gaza Strip suffer from recurring and severe flooding problems, and some have the double problem of flooding and inadequate septic pits. In the rainy season, low-lying areas experience sewerage discharge into floodwaters on the streets. Some 50 percent of the roads in Gaza are unpaved and virtually all streets and footpaths are unpaved, and extremely difficult to transit in the rainy season. With respect to wastewater, less than half the urban area is sewered, and untreated or inadequately treated wastewater presents serious health and environmental risks. A few municipalities have wastewater collection systems but only about 60 percent of houses are connected. Moreover, the few treatment plants that exist have generally failed to operate as designed. In most cases, sewage is discharged untreated into wadis or the sea.

3.7 Public Health Issues

The routine consumption of contaminated or saline water by Gaza Palestinians contributes to deterioration of the overall health of the population, and are likely to cause permanent health damage to a large segment of the population.

Some experts think that high salt concentrations are already producing adverse health effects: Gaza physicians are convinced that salty water is responsible for the high incidence of kidney and liver complaints among Gaza residents (Saleh, personal communication, 1997). Salinity has also been linked to hypernatremia, ought to be responsible for a large percentage of `crib deaths' and early brain damage (Kelly, 1996). Elevated nitrate levels are also suspected of contributing to infant mortality by causing acute anemia or blue baby disease. Nitrates have also been linked to cancer and to increased incidence of spontaneous abortion, both in humans and in animals (Kelly, 1996). Gazans are exposed to high fluoride concentrations in their groundwater and also in the fish and the tea that are staple foods. When consumed in large amounts, fluoride is toxic and contributes to ulcers, kidney failure, soft-tissue calcification, and skeletal and dental fluorosis. The fluoride content of the groundwater in the area north of Gaza City is reported to be high enough to lead to the mottling of teeth and bone disease (WRAP, 1994). Studies in the West Bank show that absorption through the skin or ingestion of groundwater chemical polluted with fertilizers, pesticides, and herbicides can damage the nervous system.

The most prevalent and serious health problem in Gaza is infectious disease caused by waterborne bacteria, viruses, and parasites. In Gaza, waterborne diseases, especially diarrheal diseases, are second only to respiratory diseases as a cause of mortality and morbidity among children in the age group 0-14 (World Bank, 1997). Intestinal parasites are prevalent. A recent UNRWA report stated that at Beach Camp (the largest refugee camp in Gaza) by the age of four years, from 50 to 85 percent of children are infested with roundworms and other intestinal parasites (Roy, 1995). The Union of Palestinian Medical Relief Committees, which operates clinics in the Gaza Strip and in the West Bank, reported that three-quarters of all clinic patients suffered from infectious diseases, which were responsible for 74 percent of all childhood deaths. These diseases largely result from poor personal hygiene and inadequate sewage disposal, which are, in turn, exacerbated by insufficient water for washing and waste removal. Moreover, open sewers are common in urban areas. Thus in November 1994, heavy rains caused sewage to mix with freshwater supplies, producing an outbreak of cholera in Gaza City, with fifty cases and one death in a week (Saleh, personal communication, 1997).

World Bank estimates for the Arab region show that nearly 8.4 million DALYs (disability adjusted life year) are lost due to waterborne diseases (Table 5). Although data is lacking for the

Gaza Strip, it is very likely that the incidence of waterborne disease is at least as high as in the Arab region as a whole.

	DALYs lost per year (1990)	
Principal diseases	**Arab Region**	**Gaza (extrapolated)**
Diarrhea, Dysentery, Cholera and Typhoid	7,700,000	154,000
Trachoma, Hepatitis, Intestinal Helminths, Schistosomiasis	690,000	13,800

Table 5 - Principal Diseases Related to Unsafe Water and Sanitation in MENA and Gaza (World Bank, 1996)

3.8 Pricing

Tariffs do not encourage conservation, are generally inadequate to recover O&M costs due to the high level of unaccounted-for-water, and are subject to poor collection efficiency. In the Gaza Strip, tariffs are flat or very mildly progressive and set well below marginal cost, providing little incentive to conserve the very limited water available. . However, due to the poor quality of water, sales of bottled mineral water at a price of \$ 200-500 / m^3 are rapidly increasing, and impact on households' budgets, especially the poorest, is significant. There is no uniform pricing policy in the Gaza Strip, but a rather disparate mix of fixed and progressive rates. Prices for the first 10 m^3 range from \$0.30/m^3 (Gaza) to \$0.60/m^3 (in areas supplied by Mekorot) (LYSA, 1995). In the South of the Strip, local administrations have had no other option than to purchase water from Mekorot, undermining the financial viability of water services and requiring the highest tariffs in Gaza. Extraction costs from wells are estimated at \$ 0.15-0.20 / m^3, and are a good approximation of current irrigation water cost. The World Bank (1990) mentions costs around US\$ 0.10 / m^3 for irrigation water in Gaza. However, tariffs for irrigation water are non-existent. The significance of these low costs becomes more pronounced when compared to the subsidized cost of water to Israeli farmers, which was estimated at US$ 0.14 / m^3. The implication here is that present costs in the Gaza Strip do not reflect the true value of water, its scarcity and externalities such as environmental damage due to the over-exploitation of the aquifer. The PWA is currently working on the establishment of a uniform tariff policy for the entire Gaza Strip. Pricing should reflect O&M expenses to ensure the managerial and financial autonomy of the water sector. Currently, more than 5 million m^3 of domestic water is used for crop irrigation: a heavy surcharge would dissuade subscribers from using the municipal piped water for irrigation. According to LYSA, the new price should not be very far from the current one (LYSA, 1995). On the one hand, the rehabilitation of production and system installation would enable the municipalities to reduce significantly their O&M expenses. On the other hand, illegal connection reduction and metering would increase income to the water utility. However, tariff standardization will require a significant increase of the cost of water in Gaza City, a politically difficult step to take (Odièvres, personal communication, 1997).

3.9 Water law

The extent of water scarcity in the region is an important factor in the designing of water distribution laws. In areas of the world where water is plentiful, water is usually allocated according to the riparian rights doctrine, which states that anyone who possesses land next to a flowing river or stream may take its water as long as enough is left for downstream users. In arid regions, such as Israel and the Palestinian Territories, the doctrine of appropriative water rights prevails. The doctrine of appropriative water rights, or prior appropriation, permits diversions to and allocated quotas among specified parties. The quotas are allocated on a first-come, first-serve basis and are subject to the "use or loose it" rule. The amount of water initially used determines the size of a user's quota, and there are severe restrictions on trading in water rights once they are assigned. (Howitt, 1995). The rigidity of these nonmarket methods of determining water allocation is a major reason for the relatively excessive water used by agriculture in the region.

The laws in force today in the Gaza Strip come from 5 different sources, reflecting the 5 different authorities (Ottoman, British, Egyptian, Israeli, Palestinian Authority) which have controlled the Gaza Strip in the twentieth century. The Palestinian Water Authority is currently preparing a new water law for the Palestinian self-ruled areas. The principles which are about to be promulgated by the PWA consist of the following (Box 1):

Box 1 - Water Law – Principles (Abu Hijleh, personal communication, 1997)

1. All sources of water should be property of the State;
2. Water has an unique value for human survival and health, and all citizens have a right to water of good quality for personal consumption at costs they can afford;
3. Industrial and agricultural development and investment must be compatible with the water resource quantity available;
4. Water is an economic good;
5. Water supply must be based on a sustainable development of all available water resources;
6. The development of the water resources of the Palestinian territory must be coordinated at the national level, and carried out at the appropriate local level;
7. The national water sector management should be carried out by one responsible body, with the separation of institutional responsibility for policy and regulatory functions from the service delivery function;
8. Public participation in water sector management should be ensured;
9. Water management at all levels should integrate water quality and water quantity;
10. Water supply and wastewater management should be integrated at all administrative levels;
11. The optimal development of water supply must be complemented by a consistent water demand management;
12. Protection and pollution control of water resources should be ensured;
13. "Polluter pays" principle;
14. Conservation and optimum utilization of water resources should be ensured;
15. The government will pursue Palestinian interests in connection with obtaining the right of water resources shared by other countries.

Israel retains a veto over all Palestinian legislation "which might jeopardize major Israeli interests whose overriding power is recognized by the Declaration of Principles (Cairo Agreement). Consequently, Palestinian legislation cannot "seriously threaten other significant Israeli interests protected by this agreement and to which the entry in force of the legislation could not cause irreparable damage or harm" (Cairo Agreement, May 4, 1994).

3.10 The Oslo Agreement on Water

On the Israeli-Palestinian track, water was one of the major sticking points in the negotiations leading to the signing of the interim agreement in Washington in September 1995 (Oslo II). Water is referred to under article 40 of Annex 3 "Protocol concerning Civil Affairs" of the Agreement. Article 40 of the agreement recognizes Palestinian water rights, transfer additional resources and responsibilities to the Palestinians, and establishes a Joint Water Committee to coordinate water resources management. The relevant articles read as follow (Box 2):

Box 2 - Oslo II Agreement - Article 40

Principles

Art. 1 Israel recognizes the Palestinian water rights in the West Bank. These will be negotiated in the permanent status negotiations and settled in the Permanent Status Agreement relating to the various water resources.

Art. 2 Both sides recognize the necessity to develop additional water for various uses.

Art. 3 While respecting each side's powers and responsibilities in the sphere of water and sewerage in their respective areas, both sides agree to coordinate the management of water and sewage resources and systems in the West Bank during the interim period, in accordance with the following principles:

- a. Maintaining existing quantities of utilization from the resources, taking into consideration the quantities of additional water for the Palestinians from the Eastern Aquifer and other agreed sources in the West Bank as detailed in this article
- b. Preventing the deterioration of water quality in water resources
- c. Using the water resources in a manner which will ensure sustainable use in the future, in quantity and quality
- d. Adjusting the utilization of the resources according to variable climatological and hydrological conditions.
- e. Taking all necessary measures to prevent any harm to water resources, including those utilized by the other side.
- f. Treating, reusing or properly disposing of all domestic, urban, industrial, and agricultural sewage
- g. Existing water and sewage systems shall be operated, maintained and developed in a coordinated manner, as set out in this article
- h. Each side shall take all necessary measures to prevent any harm to the water and sewage systems in their respective areas
- i. Each side shall ensure that the provisions of this Article are applied to all resources and systems, including those privately owned or operated, in their respective areas.

The quantities of additional water are specified in the following articles:

Art. 6 Both sides have agreed that the future needs of the Palestinians in the West Bank are estimated to be between 70-80 million m^3/year

Art. 7 In this framework, and in order to meet the immediate needs of the Palestinians in fresh water for domestic use, both sides recognize the necessity to make available to the Palestinians during the interim period a total quantity of 28.6 million m^3/year

Regarding the Gaza Strip, Art. 7 provides for an additional supply of 5 million m^3 per year from the Israeli National Water Carrier, to be charged at the full cost incurred by the supplier, including cost of production at the source and the conveyance all the way to the point of delivery. Article 8 stipulates that the Palestinians will be responsible for constructing a new pipeline to convey the 5 million m^3/year from the existing water system to the Gaza Strip. Article 8 also mentions that "in the future, this quantity will come from desalination in Israel".

Art. 25 and Schedule 11 deal with the Gaza Strip specifically:

Art. 25 The existing agreements and arrangements between the sides concerning water resources and water and sewage systems in the Gaza Strip shall remain unchanged, as detailed in Schedule 11.

Napoleon once described a treaty as being more striking for the things that it omits than for those it contains. When contrasted to the Helsinki and International Law Commission Principles (described in section 6.3.3) Article 40 shows a clear concern for the principle of prevention of harm, but is silent regarding the principle of equity. The article does not provide for the mitigation of the disastrous water situation in Gaza. The fundamental principle of Article 40 is the preservation of the status quo in the Gaza Strip, particularly the continuous supply of existing water quantities to the settlements. "All pumping from water resources in the settlements and the Military Installation Area shall be in accordance with existing quantities of drinking water and agricultural water. Without derogating from the powers and responsibilities of the Council, the Council shall not adversely affect these quantities". While the recognition of the Palestinians water rights can be considered as a breakthrough, the second and third principles in the agreement attempt to undermine the significance of this issue by talking about maintaining existing utilization and recognizing the necessity to develop new resources, tacitly accepting that more water is needed to satisfy the needs of both populations (Issac, 1996 [36]). The agreement states that any additional water made available to the Palestinians will have to come from undeveloped sources, without consideration for the technical feasibility and economic cost. In addition, no provision is made in Article 40 for additional quantities of irrigation or industrial water for the Palestinian sector. Interestingly, the article mentions that the additional 5 million m^3 allocated to Gaza "will have to come from desalination in Israel in the future", and not from Israel's existing resources. The agreement does not allocate sources or aquifer but rather defines a quantity considered as adequate by the parties. It is clear that, in face of the growing Palestinian population, a fixed quantity will result in increasing constraints on economic and social development.

The Oslo II agreement has set in motion a process with an unclear and undefined outcome – permanent status of water rights and allocations - about which the two protagonists (three if Jordan is included) have widely differing views and ideas. As a result, the present situation is one of transition towards an unknown destination.

3.11 Institutions

Since the establishment of the Palestinian Authority on May 4, 1994, a full complement of ministries has been created and a major effort has been made to consolidate these ministries and to develop administrative capacity. More recently, the Palestinian Water Authority, a separate national agency, has been established to manage the water sector. Earlier the Ministry of Planning and International Cooperation (MOPIC) had established the Environmental Planning Directorate which was responsible for environmental policy making, including land and water management. With the development of specialized national agencies, EPD was supposed to have been restructured or absorbed into one or another of the new agencies, including the Palestinian Water Authority and the soon-to-be Environmental Protection Agency. For political and organizational reasons, this has only partially happened. Consequently, there is now a considerable lack of clarity regarding roles and responsibilities in the water sector at the central level. This has slowed institutional consolidation significantly and complicated policymaking in the water sector. There are also clear signs of competition for power and funds between the Ministry of Planning and the Palestinian Water Authority, and, on a regional level, between the Ministries in Gaza and the West Bank (which are virtually cut off from each other). The Palestinian Water Authority - created with the support of the UNDP and the World Bank - lacks access to financial resources and the political support that the Ministry of Planning enjoys.

The water sector has long been characterized by the weakness of the institutional sector. 16 municipalities and Village Councils are in charge of the Water and the Sewerage public service on their territory. Neither the Agriculture department nor the Municipalities are supervised for these activities (LYSA, 1995). Until 1995, no institution had the responsibility of the water sector; the situation changed with the establishment of the Palestinian Water Authority on April 15, 1995. Among the important tasks of the newly created PWA are the definition of a water policy, the preparation of a water law, the management of the water resource and the implementation of the policy. The PWA will have full responsibility for planning development, legislation and monitoring of the various water resources. However, water distribution will be delegated to water utilities. The coordination between the PWA and the Ministry of Agriculture has been guaranteed by the formation of the Palestinian Water Council which comprises representatives from the Ministries of Agriculture, local government, planning and international cooperation, in addition to PWA and universities (Abu Hijleh, personal communication, 1997). Monitoring stations and information networks will be developed to feed the PWA with vital data required for planning and policy formulation.

Water supply and sanitation services are delivered by a variety of government agencies: water departments of municipal governments, village councils, and a UN agency. UNDP and UNICEF, as well as numerous foreign charity organizations also helped deliver water and sanitation. Some 900 to 1,000 local NGOs, responding to a political and institutional vacuum, provided a vast array of services, particularly in the health, housing and higher education sectors, but also in the water and sanitation sector. Most governmental agencies are too small to develop adequate capacity and have little incentive to perform efficiently. Funding of maintenance is inadequate, and separate financial accounts for water sector services are generally not kept and performance monitoring is limited. There is no proper accounting separation of the water departments. Revenues collected go into a central government fund, with no link to the amounts which can then be spent on operations and investment. To add to these problems, over 30 percent of revenue remain uncollected (LYSA, 1995).

The World Bank is supporting a project in Gaza with a focus on improving the performance of water and wastewater services by merging the existing sixteen service providers into a single utility serving the entire Gaza Strip. A contract - binding each municipality with the PWA - would formalize the commitment of the Municipality to implement the water policy, and include production ratios, quality control, metering, system efficiency, customer management, tariff, financial balance, maintenance and staffing ratios. In order to strengthen the technical and managerial competencies of the Municipalities, a "Coastal Services Support Company (CSSCo)" would be created under the PWA supervision (LYSA, 1995). The CSSCo would provide the Municipalities with technical services and enable them to fulfil the Performance Contract signed with the PWA. The proposed autonomous utility would be based on the model of the well-functioning Jerusalem Water Undertaking (JWU) serving the Ramallah area in the West Bank.

3.12 Human Resources

Historically, Palestinians have always been known as the most educated people in the Arab world. For those in the West Bank and Gaza, this is no longer true. A recent UNESCO study comparing 35 developing countries in math and science achievement and aptitude found that Palestinian students in the West Bank and Gaza scored very close to the lowest out of the 35 developing countries sampled. Classroom education quality is rapidly declining in Gaza due to poor teacher training and overcrowding and access to higher education has also been severely curtailed (Roy, 1995).

In the water sector, there is a critical dearth of skilled professionals. According to the director of the Gaza Water Management Project, recruitment of qualified people is extremely difficult and water professionals are in desperate need of appropriate skills training. (Odièvres, personal communication, 1997). There are very little water programs offered by local universities and Israel current security arrangements prevent Gaza students from traveling to West Bank universities, let alone to universities in other Arab countries or Israel. The main problem of the donors' program is its lack of emphasis on developing human resources, the Gaza's primary if not sole asset. In 1995, in response to the sharp rise in unemployment, mainly due to border closures, the donor community shifted funding towards projects that produce immediate and visible results. The emphasis remains on infrastructure, not on people. However, a constructive step that some donors have taken is to assist in the training of the next generation of water experts in the region. In this regard, the establishment of a program allowing Gazan water professionals to attend courses in several European countries, including the Netherlands and Norway, is positive and encouraging. However, this relationship will not be sustainable in the long term. It is more important to create a regional and informal network of individuals in Israel and the West Bank/Gaza with personal relationships and shared understanding of the region's management issues. Water research institutes in Israel, including Technion and Ben Gurion University of the Negev, rank among the best in the world. Talented Palestinian students and professionals should be granted access to their water programs.

Chapter 4
Future

4.1 Demand forecasts

Demand forecasting in the Gaza Strip is highly subject to uncertainty. Domestic water demand will depend upon population growth and, therefore, will be closely related to social and political developments. In addition, the demand for water is a factor of economics, specifically the quantities of a commodity that consumers are willing to purchase at various prices. The agricultural sector is currently the largest consumer of water and will have a significant impact on water demand scenarios. For the time being, industrial demand is almost negligible, but water-intensive industries could potentially develop in the Gaza Strip. The following scenarios are based on information provided by various sources, including the PWA, the Harvard Middle East Water Project reports, the UN and the World Bank. They do not differentiate between the various water qualities (freshwater, brackish water, recycled water). It is important to note that these scenarios are not written in stone and are subject to further updates. The estimated projections of population for the Gaza Strip are shown in Figure 10 for the low, base, and high scenarios. Due to the limited land and resources in Gaza, it was assumed that only 100,000 refugees will return gradually to Gaza by the year 2005. However, there is a possibility that the time frame might change according to political negotiations.

The estimated per capita consumption for all scenarios is listed in

Table 6. The values in the table include 25 percent unaccounted-for-water. It was assumed that efforts to improve the delivery efficiency and the rehabilitation of the water systems would take place by the year 2000.

Year	*Low scenario* (m^3)	*Base scenario* (m^3)	*High scenario* (m^3)
2000	50	50	50
2010	50	57	65
2020	50	65	83
2040	50	83	120

Table 6 - Projection of per capita demands per year (Palestine Consultancy Group, 1995)

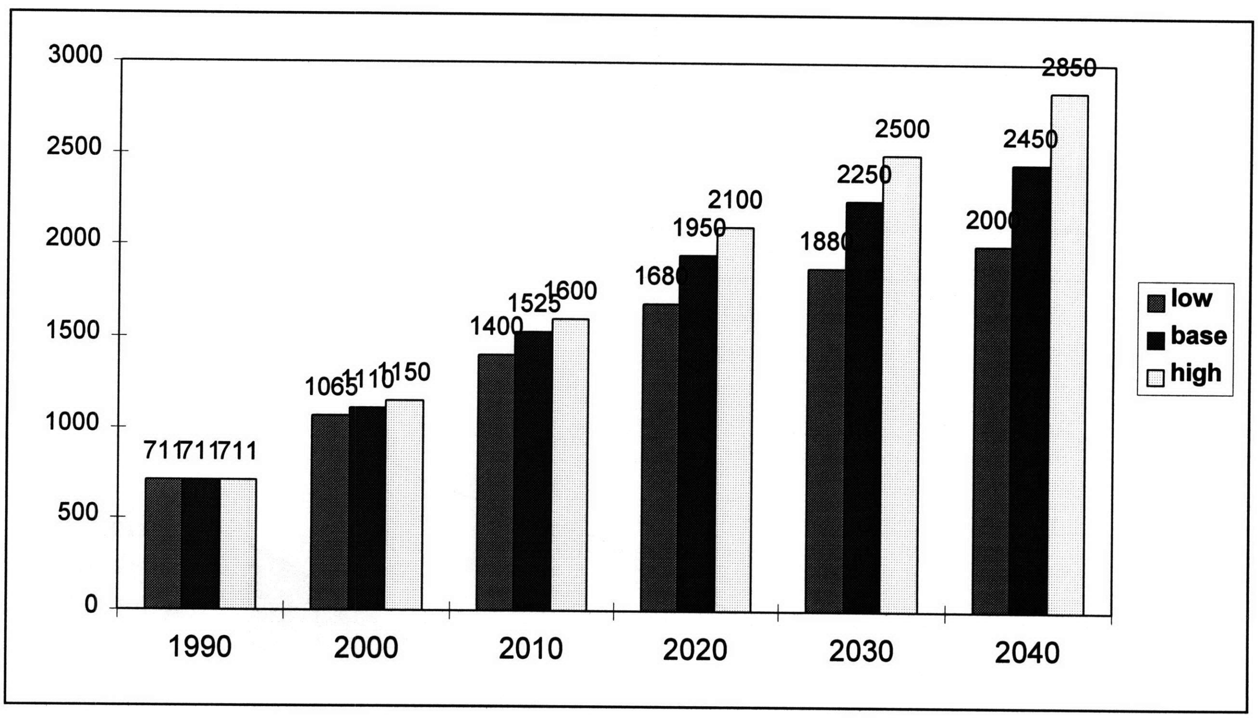

Figure 10 – Population projections for the Gaza Strip (thousands)

The total demand for domestic, industrial and irrigation water is projected as listed in **Table 7** for all scenarios, based on the projected per capita consumption and total population.

Demand	Scen.	1995	2000	2010	2020
Domestic	Low	**46**	**52**	**68**	**82**
	Base	**46**	**55**	**81**	**118**
	High	**46**	**58**	**97**	**166**
Industrial	Low	**2**	**3**	**7**	**9**
	Base	**2**	**5**	**12**	**22**
	High	**2**	**7**	**17**	**35**
Agricultural	Low	**81**	**80**	**70**	**55**
	Base	**81**	**80**	**80**	**80**
	High	**81**	**90**	**100**	**120**
TOTAL	Low	**129**	**135**	**150**	**161**
	Base	**129**	**140**	**173**	**220**
	High	**129**	**145**	**214**	**321**

Table 7 – Projected Demand for the Gaza Strip

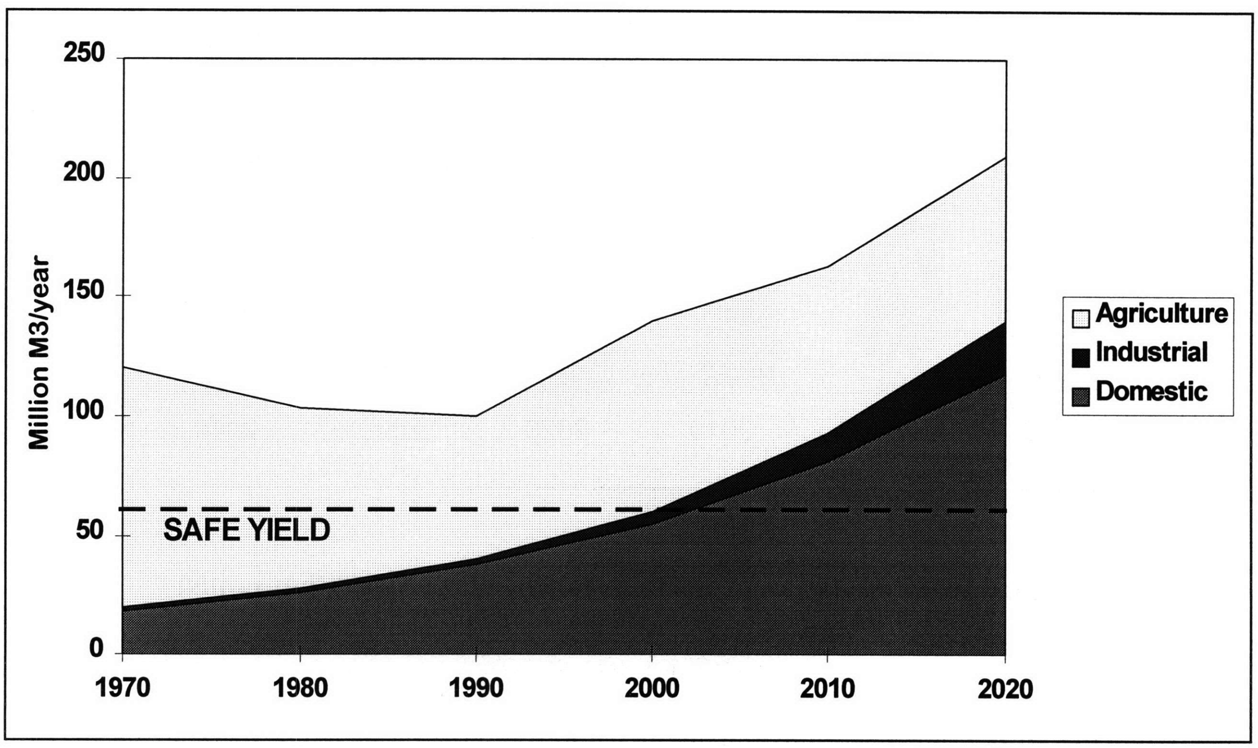

Figure 11 - Projected Demand (million m^3/year) (Base Scenario)

Figure 11 shows that the anticipated doubling of domestic demand within 15 years will only increase the gap between supply and demand, thus further deteriorating the aquifer. Possible options and alternatives to close the gap are reviewed and assessed in Chapters 5 and 6.

4.2 Matching supply and demand

It is clear that solutions to water problems in the Gaza Strip can only be achieved through a broad approach to resolving many issues: technical, economic, institutional and social. As a first step, priorities have to be set, given resources constraints and the still limited capacity of the Palestinian institutions in the field of water and sanitation.

The challenge for the coming years will be twofold (MOPIC, 1996):

- Establish clear and sound priorities. What should be achieved, whom should be supplied with what quality and quantity of water, and which investments are needed. These priorities need to be reviewed at regular intervals and may change over time.

- Coordinate activities of the many actors in the field of water. One aspect in this coordination is to make sure that all different "building blocks" that are currently available are used effectively within the framework of Integrated Water Resources Management.

In the short-term, the following objectives should be pursued:

- improve the quality of water to acceptable levels
- improve the operation and maintenance of existing systems, with particular emphasis on the reduction of unaccounted-for water through gradual network rehabilitation
- strengthen regulatory controls over groundwater extraction

- rehabilitate and expand wastewater collection and treatment, while laying the basis for agricultural reuse
- expand piped water and sewerage coverage
- initiate awareness programs to promote conservation practices
- investigate short-term solutions to increase the quantity of water
- improve data collection and develop an efficient monitoring system
- pursue the institutional reform initiated with the creation of the Palestinian Water Authority

For the medium-term and long-term objectives, a strategy for supply and demand-side management will have to be developed by establishing an analytical framework for integrated water resources management. Water planning in a strategic context must have at least three components: supply augmentation, demand management, and institutional development:

Supply Augmentation

Supply augmentation deals with technical methods to ensure a greater supply of water to users. Building canals, pipelines, well fields, recycling and reuse plants, groundwater storage and desalination are among the approaches taken. However, over time the availability of inexpensive supply augmentation projects becomes smaller and smaller as the best options are constructed first. It finally becomes apparent that the demand for water cannot be satisfied by continuing to build more and more expensive surface water facilities (Rogers, 1995). This typically leads to the examination of other approaches such as demand management.

Demand management

Demand management is the policy component most preferred by economists and other social scientists. They claim that, as the cost of supply augmentation increases, the most efficient approach to meeting water demands is to bring demand into balance with supply rather than increasing supply to meet the demand. This is to say that, by increasing prices the demand can always be made to match the supply. Not only do price increases reduce the demand for water, they also expand the supply, since sources that were too expensive to develop in the past now become economically feasible due to the increased price of water (Rogers, 1995). An increased price also makes the conservation options more economically attractive. Pricing policy can, therefore, lead to the introduction of new technologies and practices on both the supply and the demand sides of the water availability equation (Rogers, 1995).

Institutional Development

In order to plan and manage water resources a set of appropriate institutions must be in place; these are the indispensable third component of water resource management. Important functions of water institutions are research, planning, management, public education, and implementation. Future water investments will be beyond the budgetary capacity of the donors and the public sector and will require private financing, involving private ownership and/or management. This new approach will require extensive institutional reform and the establishment of a modern regulatory framework.

In Chapters 5 and 6, supply-side and demand-side options are reviewed and evaluated.

Chapter 5

Options: Existing Water

This chapter deals with water allocation policies, which are actions affecting the distribution of given quantities of water among different uses and users.

- reallocation of irrigation water to industrial and domestic uses
- dual system (high quality water for drinking/cooking, lesser quality water for other domestic uses)
- water system rehabilitation
- pricing and conservation measures

5.1 Fresh groundwater

Given the current political situation, it is unlikely that new water resources will be made available to the Gaza Strip in the near future. Importation of water from Israel and seawater desalination are long term options that will not be implemented in the coming 10 years. Due to population growth, groundwater withdrawals will continue to rise, and as a result deterioration of groundwater quality will continue unabated. Assuming a 180 m^3/hour capacity well (i.e. 1.3 M m^3/year), a new well should be drilled each year to balance the population growth and maintain a steady allocation per capita. According to the director of the Gaza Water Management Project, no potable groundwater will be left in less than a decade (Odièvres, Personal Communication, 1997). Current withdrawals should be decreased dramatically in order to replenish the coastal aquifer and restore the quality of the water. However, a return to a normal situation would be very long and would require very important hydraulic resources, disproportionate compared with abstracted volumes that have caused the deterioration (LYSA, 1995).

Recharge through ground flow from the east could be significantly increased if Israeli wells installed on the perimeter of Gaza reduce their withdrawals. The additional quantities at stake could be as high as 44 million of m^3 per year (Palestine Consultancy Group, 1995), although this figure has been the subject of much controversy. This issue should be part of the negotiation between Israel and the regarding the establishment of water rights.

Groundwater protection

There is a portion of the Gaza aquifer that still complies with WHO water quality guidelines. These semi-natural areas are located in the far north and in the southwest of the Gaza Strip (see Figure 7 in section 3.1.2.). These unique potable resources constitute less than 5 percent of the total groundwater volume in the shallow aquifer (MOPIC, 1996). In the Emergency Resources Protection Plan they were all included in the so-termed “Water Catchment 1” category (Figure 12). Their combined surface is just a few percent of the total surface area of the Gaza Strip. This calls for a specific strategy where these fresh groundwater resources would be reallocated in order to ensure that high quality water be abstracted for drinking purposes only, and consequently minimize the need for new water development. Under the current conditions it is unrealistic in the short- and medium term to aim at a supply of all domestic water based on fresh groundwater. Only 2 to 4 percent of all domestic water requires drinking water quality. With a current domestic demand of 46 million m^3 and a population of one million, that is 1 to 2 million m^3 per year, or 3 to 6 liters per capita per day (MOPIC, 1996).

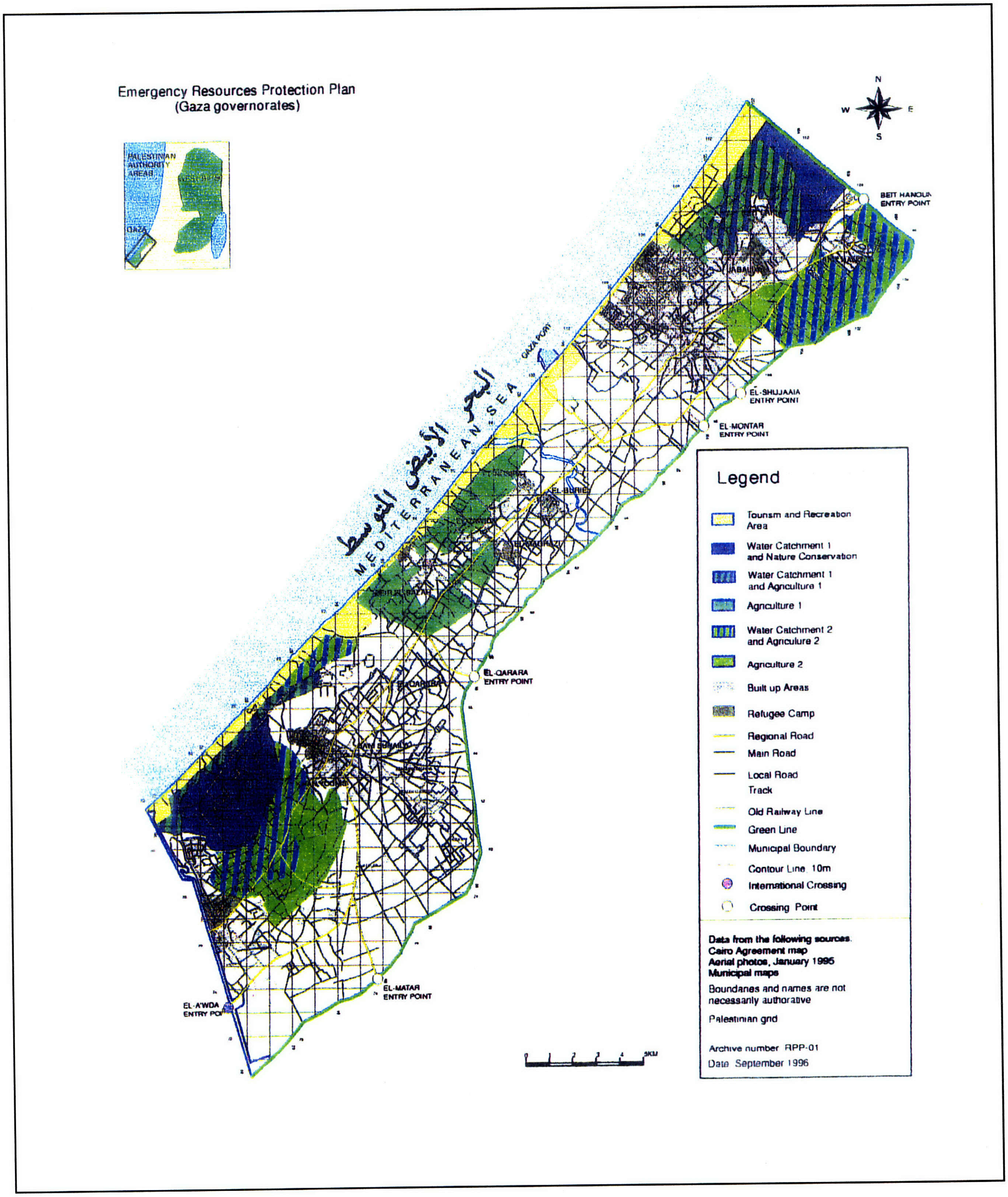

Figure 12 – Potential Groundwater Protection Areas

Table 8 shows the potential safe yield that could be withdrawn from the proposed groundwater protection areas. It should be noted that protecting a unit area in the north is more efficient than protecting a unit area in the south as the rate of renewal (recharge) in the north is twice as high as in the south.

Aquifer	*Recharge Area (km2)*	*Rainfall (mm/year)*	*percent recharged*	*Safe Yield (m^3/year)*
Northern	20	450	40	3,600,000
Southwestern	25	250	40	2,500,000
TOTAL	**40**			**6,100,000**

Table 8 – Fresh (Potable) Groundwater Potential (adapted from MOPIC, 1996)

Figure 13 shows the projected demand for drinking quality water, assuming the population projections estimated in Section 4.1 Demand forecasts and a per capita consumption of 5 liters per day. Provided both aquifers are managed in a sustainable manner, drinking water demand could be satisfied from those sources for the next 50 years.

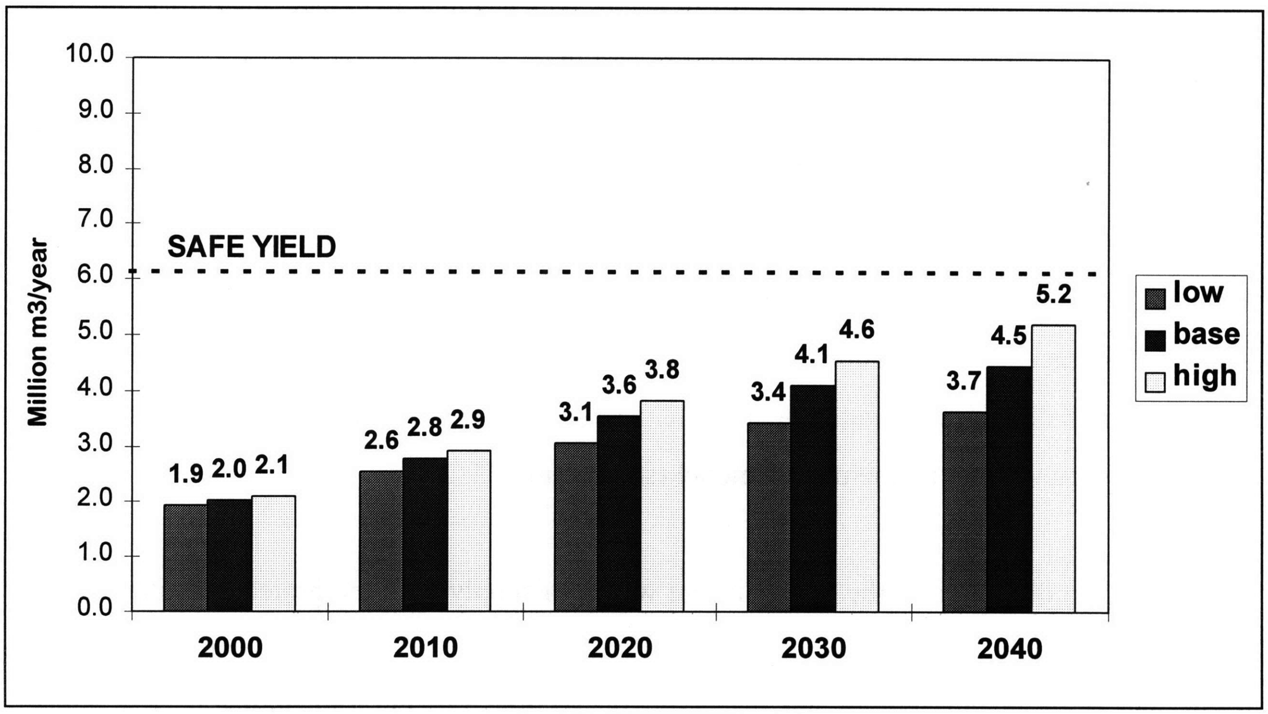

Figure 13 - Demand for Drinking Quality Water (million m^3/year)

The challenges in implementing this strategy are technical, political and economic. In part, they relate to the Israeli settlements: more than 80 percent of the areas that meet the criteria for groundwater protection are located within current Israeli settlements. At present, the Palestinian authority has no sovereignty over these settlements, and considering the current deadlock in the peace talks, this situation is unlikely to change in the near future (MOPIC, 1996). In addition, most of the potential groundwater protection areas outside the settlements are privately owned. A set of incentives will have to be designed so that landowners will be willing to protect and trade the water underlying their properties. Land acquisition by the government is probably not feasible as the cost will be prohibitive. Communal ownership is also an important issue: the municipalities of Rafah and Beit Lahia – where the potable groundwater resources are located – will certainly object if the use of their "own" water is restricted (MOPIC, 1996). Incentives and compensation mechanisms will have to be designed in order to mitigate potential impact on third parties (see also Section 5.7.3).

Technically, two issues should be studied in detail: (1) sustainable management of groundwater abstraction. (2) alternatives for distribution to consumers.

A restrictive policy for groundwater abstraction should probably be implemented in a certain radius around the protection area in order to fence off effects of overabstraction in surrounding areas. A permanent monitoring of the quality of underground waters - static level, physio-chemical characteristics - should be installed in order to gain immediate information on the localization of deteriorated water. A management scheme should be established for the aquifer based on a groundwater mathematical model (see Section 7.2.2).

With regard to distribution, the questions are whom to supply with the protected water and how. The strategy should aim at providing every individual household with a safe supply of drinking water. Distribution alternatives are discussed in Section 5.9: (1) Development of a separate infrastructure for potable water, completely independent of the current network (that will supply increasingly brackish water). (2) Construction of water stations –supplied by pipeline or truck -

in neighborhoods. (3) Development of a system of containers to be distributed by the private sector. Selection of the appropriate alternative will depend on technical, economic and social factors. Issues of acceptance and willingness-to-pay are discussed in Section 7.2.4.

Costs

Cost of extraction is estimated at US \$ 0.15 - 0.20 / m^3. Additional costs would include transactions costs, land acquisition, compensation to third parties, and distribution costs. Estimated costs of distribution for each alternative are provided in Section 5.9.

5.2 Reduction of Unaccounted-For-Water

Efficiencies of the networks are everywhere particularly poor, with an average unaccounted-for-water (UFW) of 48 percent, and 63 percent in Rafah and Jabaliya. Considering the very low efficiency of the systems, the quantity really available to households is about 70 liters per capita per day (lpcd), ranging from a low of 33 lpcd in Nuseirat and El Bureij to a high of 84 lpcd in Gaza City (LYSA, 1996). Municipal distribution systems that have losses exceeding 50 percent as a result of years of neglected maintenance might suffice for the distribution of low-value non-potable water but are quite unsatisfactory for water costing up to \$ 1 / m^3. Often just 20 per cent of the leaks account for 80 per cent of leakage (Secretariat for the Global Consultation, UN, 1990). World Bank research suggests that, as a rule, if more than 25 percent of the water is not accounted for, a program to control the losses may prove to be cost-effective. Implementing a formal policy to reduce both physical losses (through leakage detection and repair) and non-physical losses (through improved management practices) can allow investments in new works to be deferred or at least reduced in scope, with significant savings. In addition, by improving the system of meter reading and billing or by detecting and charging for illegal connections, revenue can be greatly increased to pay for the costs of treating and distributing the water, as well as the costs of operation and maintenance of the system. Also, if illegal connections are found and charged, willingness to pay by all may improve. For example, in urban areas of Thailand, each 10 per cent of unaccounted-for water saved would immediately generate an additional US$ 8 million per annum from the 3.5 million people served (UN, 1993).

A strategy for reducing water losses would include:

- metering policy, with systematic metering on the production sites and installation of meters in buildings
- evaluation and reduction of leakage by setting out a leak detection program to define priorities in pipe replacements
- reduction of non-physical losses by identifying unregistered consumers and detecting fraudulent connections (more than 20,000 illegal connections have been reported in the Gaza Strip)
- public education campaigns to encourage voluntary conservation, domestic device retrofitting efforts, and cooperative programs with industry.

Unaccounted-for-water is usually comprised of physical losses and commercial losses. In Gaza, it was estimated that commercial losses and physical losses account for 20 percent, respectively 30 percent of total water production. Given the current tariff structure and consumption pattern, efficiency increases - resulting from the reduction of UFW from 48 percent to 30 percent and the reduction of accounts receivable from 32 percent to 10 percent - would translate in an additional annual revenue of $2.5 million (World Bank, 1996). A reduction of physical losses from 30 to 20 percent would save more than 5 million m^3/year of water in year 2000, and 10 million m^3/year in 2020. Assuming a marginal water cost of $1/ m^3 , these figures would translate into savings of $6 million in 2000, and $12 million in 2010 (Table 9).

MILLION m³*/year*	*Scen.*	*2000*	*2010*	*2020*	*2040*
Domestic demand	Base	**55**	**81**	**118**	**200**
Leakage reduction	10percent	**6**	**8**	**12**	**20**
Savings ($million/yr)	$1/ m³	**6**	**8**	**12**	**20**

Table 9 – Benefits of leakage reduction

Assuming a project life of 40 years and a discount rate of 10 percent, water savings would warrants investments in leakage reduction of more than $300 million (net present value, base year 2000). In Gaza City, the costs of rehabilitation may well exceed the cost of installing a second reticulation for potable water (WRAP, 1994).

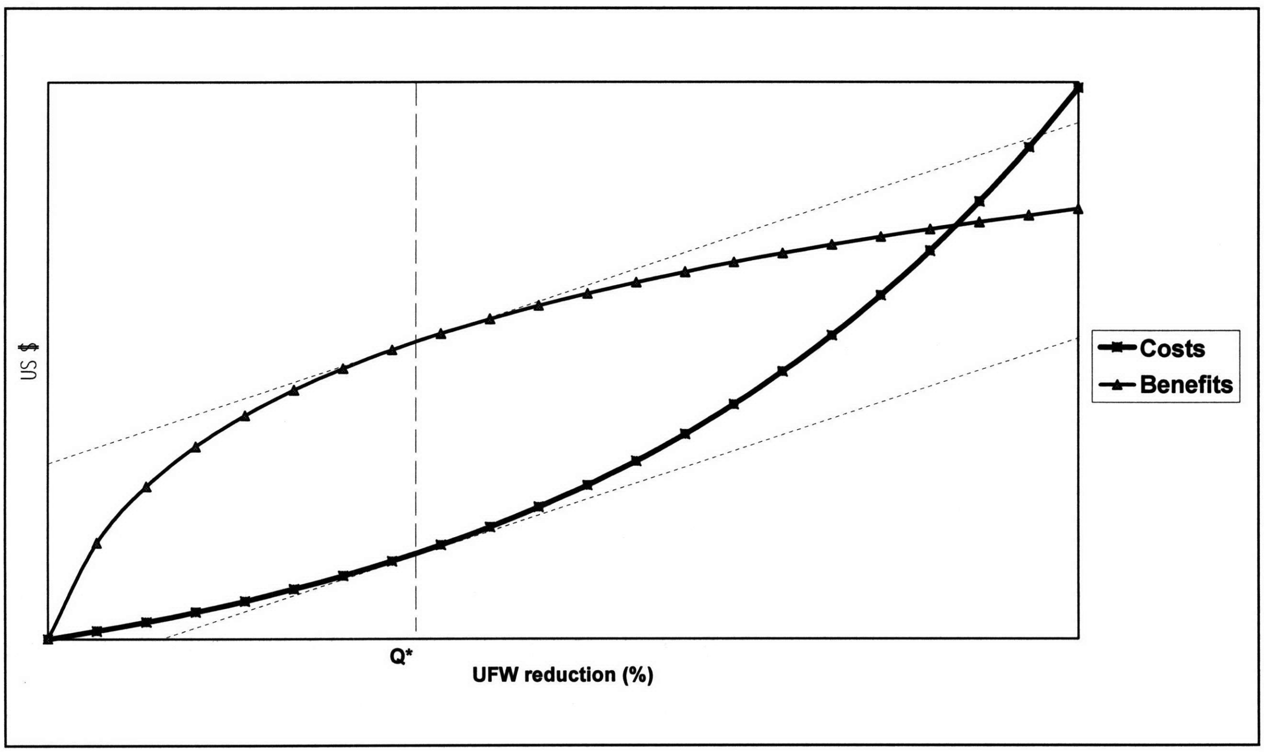

Figure 14 – Benefits of Unaccounted-For-Water Reduction

Neither a benefit-cost ratio greater than 1.0 nor a positive net benefit ensures optimality. The net benefit is maximized when Q* is supplied. At this point the marginal benefit is equal to the marginal cost, so that total benefits exceed total costs by the largest possible amount (Figure 14).

Costs could be further reduced if major rehabilitation of wells is permitted. Well owners in the Gaza Strip were historically denied permits to carry out rehabilitation. As a result, the condition of most operating wells is poor; with pumps and well casings not refurbished for 30 years, using inefficient engines to power pumps (WRAP, 1994). According to specialists, priority should be given to the rehabilitation of most ancient wells, after a detailed evaluation of current characteristics of the borehole. New high-capacity well drilling may further exacerbate the situation by triggering the ascent of brackish water from inferior layers of the aquifer.

Costs

Research conducted in Israel and California show that the costs of water saved through leakage control vary significantly, from $0.15-0.35 per m^3 (UN, 1993).

5.3 Water conservation

This endeavor includes continued efforts (technological as well as economic credits and incentives) to further reduce water use in industry and urban centers as well as to improve the efficiency of water use in agriculture. The levels of direct and indirect water production through savings and improved efficiency of water use are very important as they represent permanent demand reduction. Water conservation means large-scale application of adequate technology, changes of industrial water processes and the application of demand-management policies in the cities. Training, public education and effective extension systems must accompany the promotion and implementation instruments._Demand management efforts in Israel, Singapore, California and the Boston area and in other regions with water conservation kits, have produced significant results. The kits (including toilet flush reduction, two-volume flushing, regulated shower heads, flow regulators in kitchen and bathroom sink taps, leakage control as well as improved irrigation in gardens and parks) achieve demand reductions of 10 to 20 percent (sometimes 20-40 percent) at an approximate cost of US$ 0.10 - 0.15 / m^3. Retrofitting is appropriate for both households and commercial buildings (Singapore stands as a very successful model of this strategy). These efforts could produce millions of m^3 of water at one of the lowest marginal costs in the region. If the total urban population in Israel used demand management appliances, the water savings could have reached 100-150 million m^3 in 1994 (Palestine Consultancy Group, 1995). Water conservation policies should be rapidly defined in the Gaza Strip in view of the future increased water supply, in order to maximize the efficiency of water utilization.

As with water quality and pollution, there is a general lack of understanding and concern about the value and scarcity of water, especially in the communities that are served with piped supply systems, even when volumes delivered are small or intermittent supply common. There are specific practices that suggest limited perception of water scarcity and value, such as illegal connections and the general misuse of water in both the agricultural and domestic sector (WRAP, 1994). The general lack of understanding and concern about the value and scarcity of water resources is likely to be a major constraint to sustainable water resources management. Public awareness campaigns are needed to raise public concern for and understanding of this valuable resource.

5.4 Improving Efficiency in Irrigation

Water saving technologies in agriculture can lead to a reduction in the demand for water through substitution of capital for water. Gravity irrigation can be eliminated, old pipes can be replaced and replaced with modern sprinkling, drip and automation systems. Modern pressurized irrigation technologies can save 30-35 percent of water per land unit area, in comparison with the traditional irrigation. An additional 25-30 percent can be saved in the conveying system (Yaron, 1994). A study of the modernization of a traditional irrigation water project in the Jiftlik area of the West Bank indicated a considerable saving of water per hectare in the modernized project, which, at the same time, was accompanied by a rise in yields and income

Box 3 - Introducing Drip Irrigation To A Traditional Agricultural Community In The Jordan Valley (Van Tuijl, 1993)

In Jiftlik (West Bank), the total arable land was about 1,800 ha, and was supplied from a spring through a system of concrete canals. The large land owners allocated water to the tenant farmers (previously nomadic) on a fixed rotation, once every 8 to 10 days in accordance with traditional water rights. Water was wasted, soils eroded, and yields declined sharply.

In the early 1970s drip irrigation hardware was provided to tenant farmers by the Ministry of Agriculture through a loan from an NGO. As the system gained popularity, farmers began to purchase the equipment themselves. The hardware components included:

- small, earth-built water reservoirs with capacities of 1,000 to 5,000 m^3 to enable uninterrupted flow for the drip systems
- simple, modular, portable drip systems that did not require investments in land not belonging to the tenant farmers
- peripheral components, including pumps, fertilizer units, filtration system, fittings and valves seeds, plastic sheets (for mulching, low tunnels), farm machinery, fertilizers and chemicals

The farmers soon mastered the technology with assistance from a limited extension program. Extension workers and the equipment manufacturer's field service team instructed the farmers in cropping and irrigation practices and in the operation and maintenance of drip systems. Within seven years, yields increased three to four times, water use declined from 12,000 to 6,000 m^3 per hectare and the area under irrigation doubled.

In the Gaza Strip, the Israeli occupation introduced efficient methods of irrigation, including sprinkler and especially drip irrigation. Consequently, output increased greatly. Water use per dunum is now half the Egyptian average. However, the water needed for irrigation in the Gaza Strip could be further reduced if irrigation technologies were to be introduced on a larger scale. The current water usage per dunum is about 800 m^3 per dunum per year. This quantity can be lowered by at least 30 percent once sprinkling irrigation is introduced, and by 40 percent if drip irrigation were introduced. On an annual basis, assuming 8 percent interest and Israeli prices, the capital recovery costs are $47/dunum and $57/acre for sprinkling and drip technologies, respectively (Fishelson, 1994). Correspondingly, the cost of saving one cubic meter of water by converting to these technologies, depending upon the suitability of crops, is only $0.20/ m^3.

However, that improved agricultural efficiency will yield substantial quantities of new water is perhaps the most common misconception concerning the potential sources to meet future water demand (Frederiksen, 1996). In Gaza, individual irrigation projects may have an efficiency of only 40 percent. However, most projects pass the other 50-60 percent of project "losses" to the underlying aquifer, for subsequent uses. The same can be said about urban water where leakages can be as high as 50 percent. The rest infiltrate the aquifer. This results in a very high overall efficiency.

Only in situations where irrigation returns discharge into saline sinks is there potential water savings through improving project efficiency. And it is in these conditions that water-saving technologies are effective in reducing basin water demand.. The fundamental fact to remember is that it is basin efficiency that counts, not project efficiency, except where return flows discharge into the sea or saline sinks (Frederiksen, 1996).

5.5 Optimizing crop mix

Introduction of water-saving technologies and incentives can lead many farmers to alter and greatly improve their cropping patterns. There is a great deal that can be done with improved soil and extension systems and further applied research. The concept of measuring the value of water by its incremental contribution to yields can be developed. For instance, in Israel the trend is toward higher-value crops, especially as a result of the fluctuations in world prices for cotton (a major irrigated crop), citrus, oil seeds, export vegetables and others. Pricing, credit mechanisms and possibly water trading would play a dominant role in the optimization of crop mix , as well as the availability of incentives and proper technology.

Figure 15 shows that there is scope for crop mix optimization in Gaza. The trend is already toward the replacement of citrus by higher-value crops such as tomatoes or other vegetables and will likely continue in the future. Citrus consume more than half of total irrigation water (or 40 million m^3 per year) but generates only 13 percent of total agricultural income (Ministry of Agriculture, 1996). Figure 16 is even more explicit. For instance, for the same amount of water, crops such as strawberry and tomatoes yield almost ten times more income than citrus. This suggests that optimizing the allocation of water would mean switching production to crops shown in the upper part of Figure 16. That is, if the change in cropping patterns is not limited by land constraints, local demand, restriction on exports, or prices decline resulting of increased supply. Agricultural optimization models and macroeconomic models presented in Chapter 7 may assist in the appraisal of alternatives.

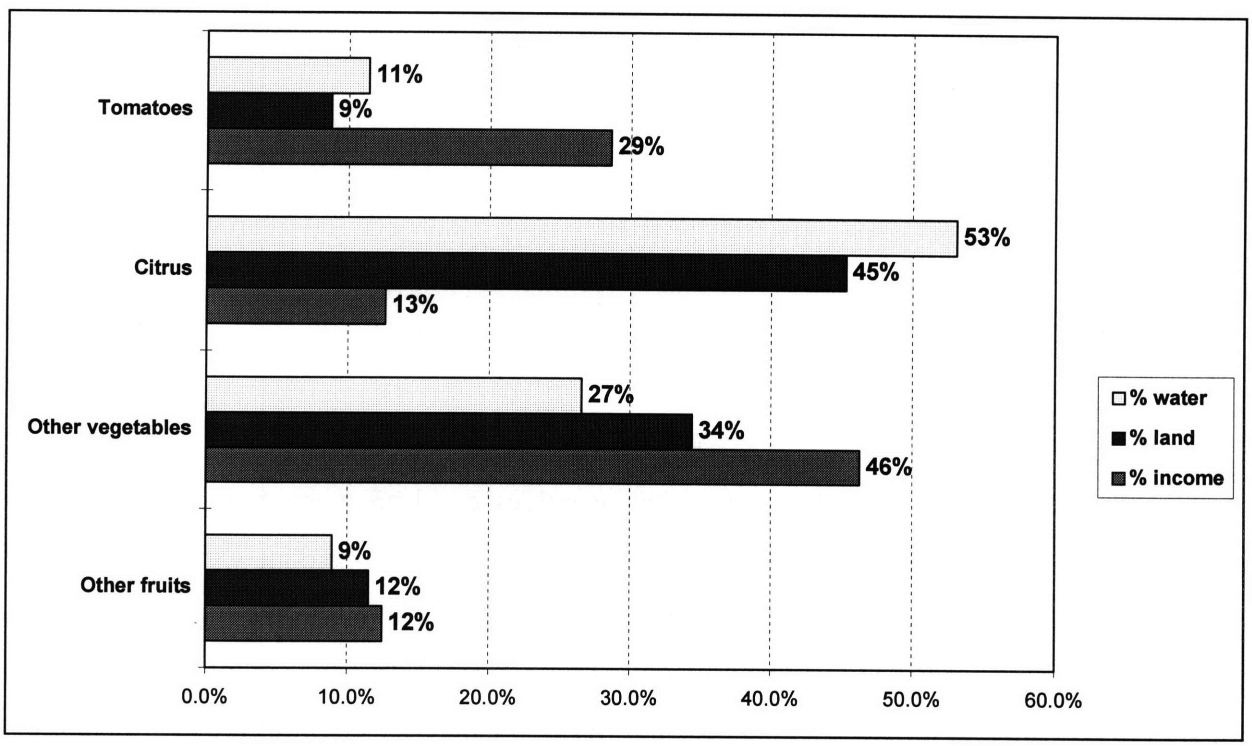

Figure 15 – Gaza Strip - Relative Income and Use of Water and Land for Selected Crops (data from Ministry of Agriculture, 1996)

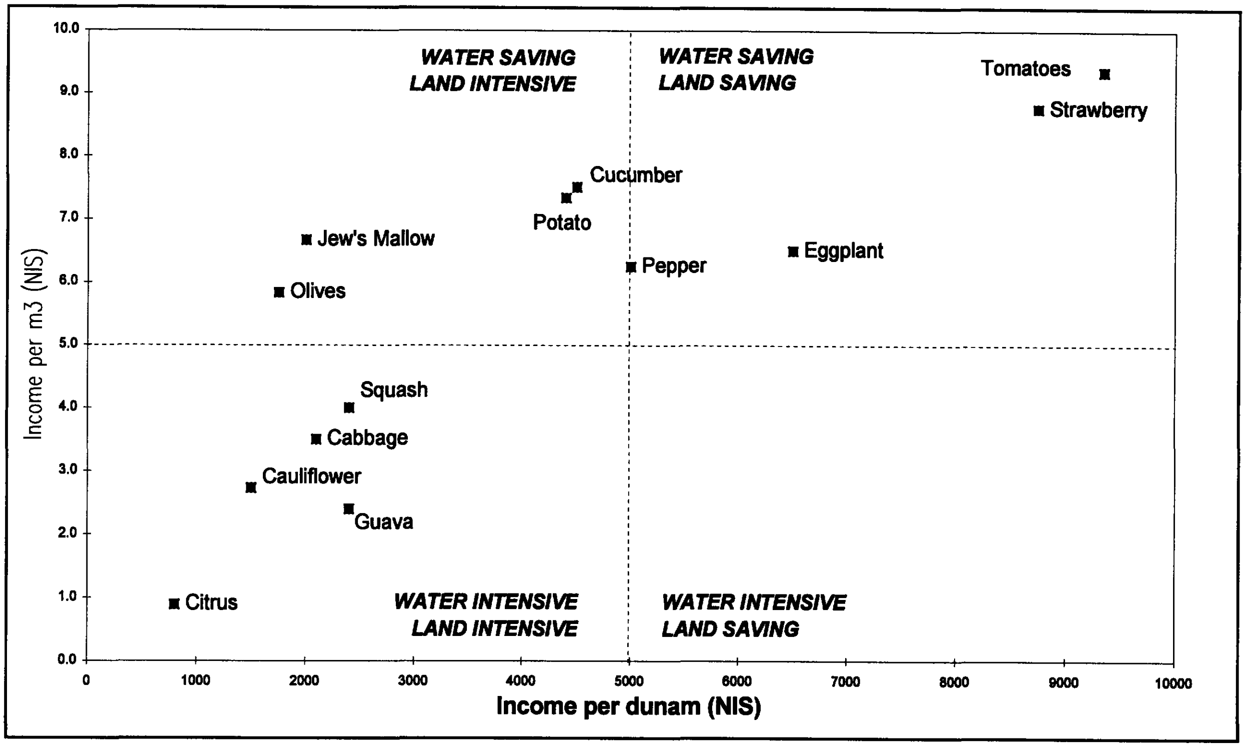

Figure 16 – Relative Income from Crop Production per Unit of Land and Unit of Water (data from Ministry of Agriculture, 1996)

Water use for citrus irrigation appears to have a very high opportunity cost. Income per cubic meter of water is less than 1 Israeli Shekel (NIS) or \$0.30 (US\$1=NIS 3.3). The marginal benefit from water – obtained after deduction of the non-water inputs such as labor and fertilizers – is therefore much smaller than \$0.30/ m^3, possibly zero or even negative. This important fact suggests that a reallocation of water from citrus grove irrigation to cities may be possible at a much cheaper cost than any other supply-side alternative. Clearly, benefits from such a trade may be substantial. In addition, water currently used for irrigation of citrus groves – located for the major part in the North of the Gaza Strip, near Beit Hanoun - is of relatively high quality. By selling water at prices equal or slightly above \$0.30, farmers would be able to maintain or even increase their income while urban consumers would receive water at a cost well below the marginal cost of new supplies such as desalinated water (around $1/ m^3). Provided conveyance systems are built, farmers would then have to choose between several alternatives: grow citrus, sell water to urban consumers, or swap freshwater for recycled water. Institutional mechanisms would be needed to promote, monitor and regulate such transfers. In particular, property rights should be clarified, and third party effects – such as impact on labor and compensation schemes – should be thoroughly investigated. Possible designs and issues related to water trading and reallocations are reviewed in Section 5.7.

5.6 Water Pricing

Throughout the world and the Middle East, the absence of price mechanisms has led to substantial inefficiencies in water utilization. Subsidizing irrigation water creates a "rent seeking" operation for the development of new resources and higher demand leads to overpumping from underground sources. Overpumping leads in turn to the development of new expensive resources where unit cost is higher than marginal benefits. Overpumping is causing quality damages to existing resources as well (Palestine Consultancy Group, 1993). In 1991, the Israeli State Comptroller issued a harsh criticism of what she termed "irresponsible water management for 25 years", which had resulted in overpumping and deterioration in the country's water quality (Gruen, 1992, Issac/Shuval, 1993). The report called for a comprehensive national policy and a shifting of priorities for water use, conservation, and ending the subsidies on water supplied to agriculture. Israel, and to a lesser Jordan, have already begun to deal with their water problems in a manner that may be forced upon the rest of the region in the near future. The drought years of the late 1980s forced Israel to rethink its agricultural sector. The rethinking involves increased water charges to improve efficiency, shifting from water-intensive to less water-demanding crops, and taking acreage out of production (Waterbury, 1994).

While water for household use should be available to all, its pricing should reflect its value as a limited resource to be utilized carefully. In the Gaza Strip, several districts already use a block rate policy, by which several volume levels correspond to a different tariff. The lowest bracket is so priced so that minimum household water requirements can be met reasonably. By this system, homes are equitably supplied with the basic requirements for drinking, cooking, and hygiene, while incurring higher costs for use beyond that which is considered the minimum daily requirement (LYSA, 1995).

Agricultural water should not be subsidized, but assistance in the form of capital and technology inputs should be provided to restructure and manage crop growth in the agricultural sector. Other means might include negotiating for the opening of international markets for certain crops. A third is assistance in capital investment through loans and grants.

It has been suggested that water should be charged at its opportunity cost (or shadow price). Price mechanisms would promote the efficiency of the sector and possibly eliminate the "rent seeking" impact and potential political conflicts. In addition, the system would enable transfer of water among various users, from agricultural consumers to cities, and within the region, with minimum conflict with the entities, who would sell part of their allocation. The parties would voluntarily trade water with the expectation of profiting from the trade. As illustrated by the citrus case (see Section 5.5), parties would benefit by obtaining water at costs lower than other alternatives or by selling water at a cost higher than its marginal value to them. One option would involve the exchange of water based on the shadow price at the transaction site. The assessment of the adequate shadow price could be done using an economic simulation model like the one developed by the Harvard Middle East Water Project (see Section 7.2.3). Revenues from transactions could be used for investments to improve and expand the water transfer systems or to decrease transaction costs. The economic model could assist in the appraisal of alternatives.

The great challenge in irrigated agriculture is how to ensure that farmers take into account the opportunity costs, which are often an order of magnitude higher than current charges. A recent review by the International Commission on Irrigation and Drainage concluded that it was inappropriate, on a number of counts, to think of rolling opportunity costs into water tariffs. This is so for three main reasons (Briscoe, 1997):

- Because the information requirements are very onerous (opportunity costs vary dramatically by place and season)
- Because the levying of such charges would be perceived as expropriation by those who currently use the water
- Because it would defy common sense – using the numbers cited in the earlier section it would mean that farmers in the Gaza Strip would be asked to pay more than 10 times the cost of providing the services they receive

Emerging international experience is clear – from a conceptual, practical and political perspective, the appropriate approach for ensuring that the scarcity value of water is transmitted to users is to clarify property rights and to facilitate the leasing and trading of these rights (Briscoe, 1997).

Market-based pricing can achieve significant results: in the USA industrial water use in 1980 stood at 45 billion gallons per day. By 1990 it declined 33 percent to 30 bgd, largely as the result of tightening controls on effluents and effluents charges imposed over the period. In a study of industrial plants in Sao Paulo, water use in manufacturing dropped between 42 and 62 percent, depending on the industry, between 1980 and 1982, after effluent charges were introduced. Consumption of water in the former East Germany dropped from 400 to 120 liters per capita per day, or 70 percent, between 1989 and 1994, primarily as a result of cost-based pricing (World Bank, 1995).

5.7 Reallocation: water markets

5.7.1 Introduction

The early recognition of market mechanisms may be traced back to Coase. He argued that allocation by means of markets is a favorable solution. He showed that market allocation will be efficient, given well-defined and nonattenuated initial property right and zero transaction costs. This means that property rights are to be completely specified, exclusive, transferable, and enforceable (Shabman, 1995). While the use of pricing to influence allocation of water has received a lot of attention in future directions for water allocation, very little attention has been given to the potential for markets in tradable water rights in the Middle East. This fact reflects the lack of belief of some policy makers in market mechanisms. Policy makers express strong reservations about market decisions on intersectoral transfers because of the importance of water to the economy. There is a strong feeling among many that, given the significance of water to life and security in the region, water is simply too important to be given over to free market forces (Shatnawi, 1995). Some believe that water policy use is not best achieved by considering water or water rights as a commodity. It is also argued that if supply and demand were the only forces that governed the allocation of water, these two mechanisms could eliminate diversified agriculture and drive out small farmers in the competition for scarce water.

The possible introduction of market-based mechanisms for water allocation in the Middle East is viewed with considerable suspicion by policy-makers. Agriculture and water resources ministers from 22 member states of the Arab League have recently rejected proposals to set up water banks as a way of dealing with regional water shortages:

> Egyptian state-run al-Ahram daily quoted the conferees as agreeing that water is a "free natural resource that may not be sold", and that they reject all projects which promote banks that would sell and buy water in the Arab region "owing to the dangers these projects pose to Arab economies". Arab officials called the idea, which the paper described as forwarded by foreign parties, as an evident attempt "to put poison in the

honey". This and other positions were included in a "Cairo declaration" issued by the conference. (United Press International, May 1997).

However, many analysts (Seckler, 1996, Briscoe, 1997) note that water markets could instead encourage diversification into a variety of watersaving crops that are more appropriate to the agroclimatic environment. Given the reservations about a full market approach to water allocation, an appropriate approach in the short-to-medium term might be a combination of integrated water resources planning with market incentives to induce water users to consider the true opportunity and social value of water.

5.7.2 Water markets: principles

In the Western United States, water initially was allocated simply by putting it to a beneficial use, mostly irrigation; the doctrine of prior appropriation was indifferent to the economic value of use. This is the situation that currently prevails in the Middle East. However, as competition for water has increased, economists and others have argued that water should be transferred "from low-value irrigation use to high-value noncrop use". The classic rationale for all economic activity - gains from trade - motivates most water transfers. Buyers – utilities, municipalities - perceive that the cost of purchasing existing water rights is less than the cost of alternative means of securing needed supplies. Conversely, sellers - generally farmers - sell when the price offered is greater than the economic value of the crops or livestock they produce. The economic theory of water transfers is simple, but for transfers to occur, two conditions must be met. First, the benefits to buyers must be great enough to outweigh the costs of obtaining water by alternative sources or by reduced demand, plus all the transaction costs. Second, the costs of buying water, which can include political costs and legal uncertainties, must be less than the costs of obtaining water - such as desalination (National Research Council, 1992).

A water buyer and seller are the two primary parties in a water transfer and are not typically concerned with the interests of third parties, that is, those who are affected by the transfers but are not represented in the negotiations and lack control over transfer processes. The impacts of transfers and the parties affected are many, diverse and potentially substantial. The types of impacts felt by third parties can be broadly thought of as economic, social and environmental. Economic effects include impacts on incomes, jobs and business opportunities. Social impacts include changes in community structure, cohesiveness, and control over water resources. Public policies must be concerned with the interests of third parties, because neither the buyer nor the seller will be burdened with these externalities (National Research Council, 1992).

Several different types of transactions may be used to transfer water use from one party to another, including water leases, water banks, dry year option arrangements, and transfers of salvaged water (National Research Council, 1992).

Water lease

A water lease occurs when a water rights owner and a new user negotiate an agreement to use a fixed quantity of water over a specific period of time, instead of purchasing a permanent right. For instance junior rights irrigators with orchards sometimes lease water for their late summer irrigations from neighboring seasonal crop growers who hold more senior rights.

Water banks

Water banking is a formal mechanism for pooling surplus water rights for rental to other users. In 1991, California responded to a 5-year drought by establishing a water bank to facilitate market-like transfers of water. One reason the bank worked well was that transaction costs were very low, estimated by some parties at $5 per acre-foot (water price was fixed at $125 per acre-foot). An initial study of the operation of the bank showed that it generated a net benefit in excess of $92 million. Although there are many ways in which the bank's operation can be improved, it seems clear that water markets will be part of the solution to California's competing demands in the future.

Dry year option arrangements

Dry year option arrangements allow the senior rights holders to continue to use the water (in most cases for farming) in normal years and give the option holder (often a municipal user) a cost-effective way to make its supply more reliable during dry years. For example, the Metropolitan Water District (MWD) of southern California has proposed a dry year option arrangement to farmers in the Los Angeles area.

Transfers of salvaged water

Transfers of salvaged water is a variation of a water sale, in which a city or business that needs additional supplies finances irrigation improvements in exchange for rights to use the water that is conserved. In California in 1989, MWD and the Imperial Irrigation District (IID) reached an agreement calling for MWD to pay for irrigation system improvements within IID in exchange for rights to use the water conserved. Through a multi-million dollar canal-lining project, MWD hopes to salvage up to 37 million m^3 annually for municipal use.

In the United States, many environmentalists, water experts, and urban suppliers have endorsed water marketing as a desirable reallocation policy. Water marketing can help promote both efficiency and fairness. Markets respond to price signals and move resources from lower to higher-valued uses. They also respect existing property entitlements and thus allow water rights holders both to set the pace of transition and to receive compensation when water is transferred. In addition, transfers can be used to correct inefficiencies that are the result of a long history of subsidized irrigation water. Wahl (1989) argued that rather than attempting to reduce the subsidies embodied in existing contracts, policymakers should seek to make the current property rights more secure and to allow voluntary market trading of the resource among users.

In the U.S. Southwest, tens of millions of dollars were spent on western water rights during the 1980s. Prices in the late 1980s ranged from \$0.80/ m^3 of water rights to more than \$4.00/m3 in some areas that have few alternative supplies (National Research Council, 1992).

5.7.3 Water markets: issues and opportunities

Allocation of water through markets in tradable water rights offers a number of potential advantages (Schleyer and Rosegrant, 1996):

- empowerment of water users by requiring consent to any reallocation of water and compensation for any water transferred
- security of water rights tenure, which improves incentives for investment in water-saving technology
- establishment of incentives for water users to consider the full opportunity cost of water, including its value in alternative uses
- provision of incentives for water users to take account of some of the external costs imposed by their water use, reducing the pressure to degrade resources
- flexibility in responding to changes in crop prices and water values as demand patterns and comparative advantage change and diversification of cropping proceeds

However, a number of possible problems with markets in water rights have also been identified (Lund and Israel, 1995):

- high transactions costs to water trades that could limit the scope of trading
- water rights are often poorly defined
- water transfers can have high transaction costs
- water markets will often consist of relatively few buyers and/or sellers
- water is often costly to convey between willing buyers and sellers
- communication between buyers and sellers may be difficult

Second, the transfer of water can significantly affect third parties not directly involved in the transfer (such as farm workers, rural retailers and service providers). Strong opposition may be expected, especially in such institutional settings where water policy is subordinated to agricultural policy (this is the case in Israel and Jordan, where the water department is a division of the Ministry of Agriculture). However, there are policies that may encourage water reallocation by providing satisfactory compensation mechanisms, and that have been applied with some success in the Western US and Chile, albeit with considerable political wrangling. In fact, the greatest challenge for implementing water transfers in the future may lie in properly identifying the affected parties and adequately mitigating the impacts. Several mechanisms have been suggested to ameliorate the impact of or to compensate groups harmed by water transfers. These mechanisms include (Lund and Israel, 1995)::

- Taxing transfers to compensate harmed third parties
- Requiring transferors to provide additional water for environmental purposes
- Using State compensation to help economic transitions in water-selling regions
- Requiring public review and regulatory and third party approval of transfers
- Requiring prior evaluation of third party impacts of transfers, similar to an environmental report
- Requiring formal monitoring of third party impacts

The role of government is so important in many cases that it must be considered part of the system engineering. Government involvement can improve the prospects for water transfers by (Lund and Israel, 1995):

- Improving information regarding transfers and transfer impacts
- Establishing a process for managing third party impacts
- Reducing the transaction costs of arranging and implementing water transfers
- Increasing the probability that efforts between the parties to arrange a water transfer will be successful, and reducing the risks to parties from involvement with transfers

An overriding obstacle to implementing water market concepts in developing countries is the absence of the required institutions and physical infrastructure. The financial transactions and physical movement of water require government intervention to provide indisputable means to measure the water, convey the water, and monitor its movement. There must be an honest broker to hold the money and take control of the water and an enforcement agency to record and oversee these movements. And before that there must be a clear and firmly enforced water-rights system fully in place. The Palestinian Authority has none of these components. Further, water-rights markets and transfers do not produce any additional water for a country: they only reallocate water already applied productively. Frederiksen (1994) argues that for that reason water markets would be largely counterproductive where poverty alleviation is a primary objective. "Awarding water to the highest bidder would not help, and probably would undermine a country's primary social, regional development, security and environmental goals" (Frederiksen, 1994). Yaron (1995) also acknowledged the inherent risks of a pure market mechanism for water allocation within a country:

- it may lead to drastic changes and deviations from the status quo in agriculture
- it may lead to a conflict with national goals
- large scale projects imply government intervention and coordination

Yaron is in favor of an allocation-pricing policy based on a mix of quota system with market mechanism, with the latter applied only at the marginal segment of the quotas. This policy should increase the efficiency of water use over time and at the same time avoid drastic changes in allocation.

5.7.4 Potential in the Gaza Strip

The bulk of Gaza water supply is allocated to irrigation. As shown in Section 5.5 Optimizing crop mix, in 1996, 53 percent of irrigation water was allocated to citrus crops which contributed only 13percent to total agricultural income. This is an explicit example of misallocation of water. In Gaza, irrigated agriculture has become the dominant "high-volume, low-value" user. Irrigation water is provided at virtually no cost. Even though agricultural use of water has the lowest value per cubic meter, there is strong political opposition to diverting water from agriculture to other sectors. However, the purchase of water rights from a few farmers could be sufficient to provide water for thousands of urban dwellers. In Gaza, due to the extreme water scarcity, there has been an endogenous move by local citizens to develop some form of informal market. In 1996, the city of Gaza purchased water and land rights from farmers in the northern part of the Strip to ensure access to additional water of acceptable quality (Odièvres, Personal Communication, 1997). These are signs that formalization of water markets may be welcomed because it would reduce transactions costs. To help transfers, new market-driven methods for reallocation should be developed. The striking features of these market-based reallocation methods are that they are voluntary and yield economic benefits for both buyers and sellers. Providing a market for water to encourage owners of wells to sell water to municipalities would reduce excess demand in agriculture, and lead to increased efficiency in water use and to a fall in the irrigation of low value crops. In the first case it would make cultivation of certain crops unprofitable and lead to new cropping patterns which would benefit the economy. In the second case, the opportunity cost of applying water to cultivation, as opposed to selling it, would induce owners of water rights to re-allocate their water to domestic and industrial use (WRAP, 1994). The implied concept is that diverting a little from the entire irrigation sector should be easy, inexpensive, and painless. However, urban centers will try to take all their incremental needs from the immediately adjacent irrigated areas for physical and economic reasons. And if they do so, they will have substantial impact on the production of the affected farmers and the economy of the villages, creating serious social and economic consequences. Those impacts will have to be carefully evaluated, and mitigation and compensation mechanisms will need to be put in place. A particularly promising alternative would be to swap freshwater for recycled wastewater. To be able to evaluate reallocation choices and calculate the potential costs and benefits, one should be fully informed of the true social, economic, and environmental ramifications and costs of the reallocation options versus other sources.

5.8 Use of Saline Water for Crop Production

According to many experts, Gaza agriculture will become increasingly dependent on recycled sewage and other types of low grade waters which are unsuitable for drinking. Due to overabstraction, salinity of irrigation water will continue to rise, and farmers will gradually be driven out of business unless they can develop techniques to crop crops with increasingly saline waters. In addition, it is expected that more freshwater will be reallocated to urban consumption as the cost of opportunity of using freshwater in irrigation will reach critical levels. On the other hand, quantities of recycled water will grow considerably in the near future, provided plans for upgrading and expanding existing treatment plants are implemented. Treated wastewater could be used as a substitute for well water to the extent of 50 million m^3 in 2010 (see Section 6.4.1). Depending on the population and consumption per capita scenarios, wastewater production could even exceed current irrigation needs in 2010 or 2020. However, it should be noted that salinity problems could considerably limit uses of recycled water in irrigation under the current conditions. The high salinity of domestic water may place significant constraints on wastewater reuse. Indeed, water reallocation and wastewater recycling will increase the salinity of the water available for irrigation from a current average of 1000 ppm up to 1200-1500 ppm (Amir, personal communication, 1996). Therefore, wastewater recycling may be viable only in the case of imports of freshwater, unless technologies and infrastructure are developed in Gaza to use saline water in agriculture.

Water availability for irrigation could be enhanced through judicious and proper use of saline water and the recycling of drainage waters for irrigation. Waters generally classified as unsuitable for irrigation can, in fact, be used successfully to grow crops without long-term hazardous consequences to crops and soils, with the use of improved farming and management practices. Recent studies in Israel have shown that there are crops and technologies that allow agricultural production with water of up to 4000 ppm TDS (or 10 percent sea water) (De Malach and Pasternak, 1994).

Box 4 - Agriculture In A Desert Saline Environment A Case Study (De Malach and Pasternak, 1994)

At the beginning of the seventies Israel was utilizing all its known fresh water supplies. Out of 1.8 BCM of fresh water available, 1.2 were used for irrigation and the amount of fresh water still available for agriculture diminished each year due to competition with urban and industrial customers. Almost everywhere one drills in the Negev desert saline water can be found. In the Negev today fresh water is scarce but saline water is not. Energy costs today do not allow water desalination for commercial irrigation purposes, so Israel had to look after the best agricultural use of this water without any treatment.

A small demonstration farm was established to show farmers that this kind of water has at least some agricultural value. This step was important for creating a favorable atmosphere among farmers, planners and extension officers and to encourage a re-evaluation of the potential of brackish water for irrigation. Extensive research was then conducted, including crop selection, field studies of salt resistance mechanisms, management practices, selection and breeding for salt resistance. The greatest advances that have been made in the use of saline water have been due to the development of specific agromanagement practices, especially drip irrigation.

The study has shown that saline water irrigation can actually give significant economic advantages over fresh water and in some cases increase marketable yields. In almost 20 crops the yields were not significantly decreased under saline water irrigation when adequate management procedures were employed. Cotton, sugar beets, wheat and barley were the most important crops of this group. Asparagus was found to be the most resistant crop. Tomatoes, rye grass, brassicas, celery and onions follow. Among orchard species, olives, pomegranates, grapes and even pears were successful. More species are under study and the list of plants fit for salinity agriculture is increasing. Israeli farmers are starting to exploit the economic advantages of saline water commercially for tomatoes, sugar beets, grapes, pomegranates and melons.

Today crops and technologies allow agricultural production with water of up to 4000 ppm TDS (or 10 percent seawater). It is reasonable to assume that in the future, water of even higher salinity will be put in use, opening new horizons for salinity-based agriculture in deserts throughout the world.

5.9 Supply segregation

An attractive option to address the major issue of water quality for the Gaza Strip is supply segregation. High quality water could be supplied to meet potable requirements only, while the current low quality sources of supply would be used for other domestic needs. Such a system is already developing informally. Many Gazans fill jerricans at sources or wells that still provide water of good quality. The drinking water consumed at the Ministry of Planning does not come from the tap, but instead is supplied with jerricans from a standpipe located in the Beit Lahiya area, the only location in the Gaza Strip endowed with water resources of a salinity lower than 100 ppm/l. Only 2 to 4 percent of domestic water require drinking water quality. With the current consumption levels, that is 1 to 2 million m^3 per year (MOPIC, 1996). The UNRWA report analyzed the daily household water consumption for a family of eight (the average size of a Gazan family) living in the refugee camp (Table 10).

ACTIVITY	ADULTS		CHILD	TOTAL	TOTAL
	Male	Female		CHILDREN	FAMILY
Drinking	4	4	2	12	20
Cooking	2	8	-	-	10
			HIGH QUALITY DEMAND		30 liters 4 LCD
Bathing	6	10	6	36	52
Washing clothes	15	15	15	90	120
Home maintenance	10	20	-	-	30
Toilet flushing	5	10	5	30	45
Religious ablution	20	10	-	-	30
Outside use	10	10	-	-	20
		NO QUALITY REQUIREMENTS			297 liters 37 LCD
TOTAL	**72**	**87**	**28**	**168**	**327 liters 41 LCD**

Table 10 – Household Basic Water Requirements for a Family of Eight

Two hypothesis for the demand for high quality water can be considered:

- 6 lcd (low consumption), more likely for the camps
- 10 lcd (high consumption), more likely for rural villages, medium and high income districts

According to the LYSA report (1996), 60 percent of the population do not have access to potable water and should be supplied with high quality water. Total demand will therefore be in the range of 4,500 –5,500 m^3/day (or 1.6 –2.0 million m^3/year) for the entire Gaza Strip in year 2000.

High quality water could be drawn from the northern aquifer (production cost: \$0.10/ m^3) (see Section 5.1) or produced by small brackish water desalination units (production cost: \$0.50/ m^3). Therefore, as a realistic long term objective, groundwater protection should aim at managing a small portion of the dune aquifer in a sustainable manner in order to safeguard a supply of about 5 million m^3 per year of groundwater for the coming 30 years. Thus, the Gaza Strip could be self-sufficient in drinking water in the long run. The other option would be the construction of small brackish water desalination units. While the choice of the mode of production depends on economic and technical factors, the selection of an appropriate distribution system is related to the desired level of service and economic constraints. Possible distribution channels are summarized in Figure 17.

Distribution options and levels of service (LYSA, 1996):

- Tap Water (1): this system requires the construction of a second system (dual network) that becomes the drinking water system. Assuming a total length comparable to the existing network (about 1000 km), the estimated capital investment would be around US$ 45 million
- Water in Jerrican: for the user, this is the minimum service level, unfortunately borne by an increasing number of Gazan households. The main constraint for the user is the distance to the filling station. A service of distribution by truck (4) minimizes journeys of the user. The construction of filling stations can also be considered (2) and (3). A step-by-step solution could be implemented where a basic water network would feed autonomous water stations built at convenient locations. Studies in Africa and in Latin America are concordant to consider that 300 to 400 m is the maximal distance the user is ready to accept to fill its containers (Whittington, Briscoe, 1990). This system could be the skeleton of a future dual system distributing directly drinking water to users.

A survey (and possibly a pilot project) should be conducted to determine the acceptance of the different alternatives by the potential users. Examples of overestimated demand in similar projects are numerous (Whittington, 1994). Users may well prefer to buy bottled mineral water. Methods for determining potential demand – and thus optimizing the supply-demand match - are discussed in Section 7.5.

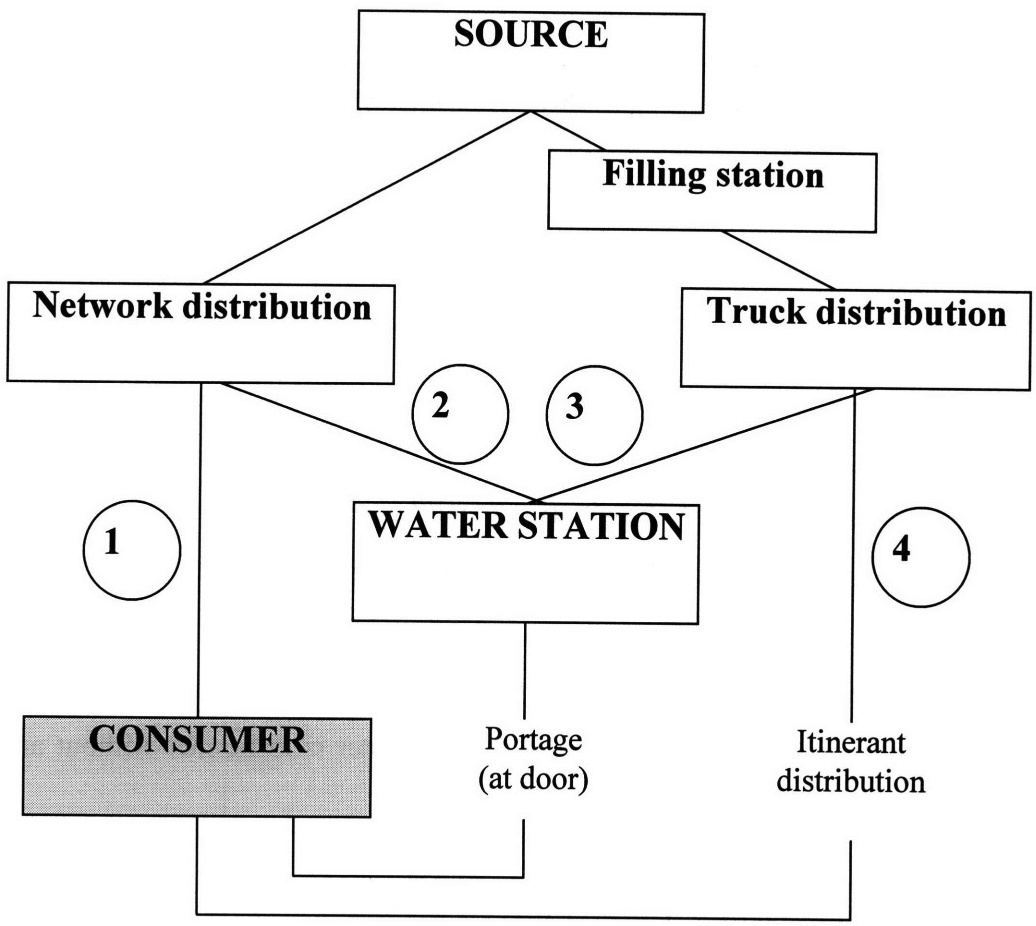

Figure 17 – Water Distribution Scheme (LYSA, 1996)

Table 11 summarizes the distribution costs of the various alternatives. It should be noted that among the short-term options, "water station fed by network" is the most cost-effective. Construction of a dual network may well be a promising alternative in the long run.

Distribution Option	Distribution Cost ($\$/m^3$)
Dual network	1.80
Distribution to door by tanker truck	2.69
Water station fed by network	1.95
Water station fed by tanker truck	2.78

Table 11 – Supply Segregation - Distribution Costs (LYSA, 1996)

A dual system could be financed and implemented according to the following incremental approach:

- The residents of the Gaza Strip collectively pay the production cost of water (whether from groundwater pumping or brackish desalination), and the additional cost of conveying water to the autonomous water stations. The current critical economic situation of the Gaza Strip makes it very unlikely to include capital costs (desalination plant, conveyance infrastructure) in the selling price. They will have to be borne by international banks or donors if the objective of supplying all communities with potable water is to be met without any further delay.

- The residents of a neighborhood served by a water station may decide whether they are willing to pay for the construction of a distribution system supplying blocks from the water station. Community organizations should be consulted on basic choices, and the details should then worked out with the future beneficiaries. Again, external support for infrastructure financing may be provided to the communities; however, O&M and renewal costs should be borne by users.

- The residents of a block served by an expanded distribution system may then decide whether they want to pay for on-lot water connections.

- Households may then decide on the quantity and the quality (dual system) of water they want to pay for.

Chapter 6

Options: New Water

This chapter deals with water development policies, which can be defined as actions affecting the increase of quantities of water available for distribution and use.

6.1 Introduction

Even with measures to contain the growth in demand and to improve the efficiency of existing systems, new water supplies will be needed for the Gaza Strip. The new sources of supply currently being considered have higher financial and environmental costs than those developed earlier. The question is to assess whether these alternatives are economically efficient and feasible, and how and when they should be implemented. Various alternatives have already been suggested by government agencies and international consultants and donors to solve the water crisis in Gaza, including:

- desalination of water
- aquifer recharge
- conveyance of fresh water via pipeline from the Sea of Galilee (extension of the Israeli National Water Carrier) or the West Bank mountain aquifers
- inter-regional water conveyance (from Turkey, Egypt or Lebanon)
- wastewater recycling and agricultural reuse
- virtual water
- weather modification

6.2 Surface Water

6.2.1 Recharge with storm water

In Israel, underground water recharge is an integral part of the country's water supply system. Part of the artificial recharge is connected with flood water utilization and wastewater reclamation. Recharge operations replenish over-exploited aquifers, thereby preventing seawater intrusion ad providing temporary storage. Projected recharge rates in Israel are 200 million m^3 through about 150 recharge wells and spreading grounds by the year 2000 (Issac/Shuval, 1993).

Within the Gaza Strip, precipitation collected as storm water is potentially a source of water which could be utilized. This is especially true of the huge flows which are experienced in the wadis following heavy winter rains and that discharge unused into the sea, or into open areas where they partially evaporate. Wadi Gaza which has a catchment area of around 3000 km2 has the highest discharge. It was estimated that during the flood events of November and December 1994 around 100 million m^3 of storm water flowed down Wadi Gaza to the sea in a period of ten days. This is almost equal to the annual water demand of the Gaza Strip. The Wadi Gaza arguably could provide 20 to 30 million m^3 of water per year (IWACO, 1994). However, Israel impounds this water before it even enters Gaza. Utilization of the floodwaters within Israel, by either damming the wadi or pumping the water to side reservoirs has caused infiltration from storm water to dry up. Negotiation with Israel is necessary to determine the future utilization of the Gaza stream floodwaters. Wadi Selqa, with a catchment area of only tens of km2 could also be a source. This wadi has no direct outlet to the sea, but ends in a depression on the inland side of the dunes at Deir el Balah. Hundreds of dunums are flooded here seasonally. This water mainly evaporates. (IWACO, 1994)

From a rough water balance calculation for the recharge pools in the dunes at Beit Lahia, it is calculated that the surface infiltration rate at that specific location is around 11 cm per day (IWACO, 1995). Comparing this with the evaporation rate (between 2 and 7 mm/day), indicates that only between 2 and 6percent of the flow is lost through evaporation. Using this infiltration rate, an area of 0.25 km2 would be needed to recharge 10 million m^3 per year. Recharge by infiltration requires considerable land with not only a suitable aquifer but also soil conditions - the dunes appear to be the most suitable - and that could be a major constraint. Acquisition of appropriate land should not interfere with land use planning allocations for higher priority economic development. A rapid estimate indicates that, assuming that recharged water is valued at \$0.50/ m^3 - approximately the shadow price of water in 2000 -, and assuming the above infiltration rates, income per m^3 would amount to approximately \$20/year. This value compares unfavorably to industrial or housing uses, but compares favorably to agricultural uses - high-value crop such as strawberry yields incomes of less than \$3 per m^3. Perhaps land should be found that otherwise would be left abandoned. Recharge ponds may also be developed for recreational uses, such as swimming or wetland, forest or other aesthetic settings in public areas. Other recharge techniques such as infiltration wells are much less land-intensive but may be problematic to operate and maintain. With respect to the Gaza Strip there is an absence of hydrogeological and geochemical data and testing will be required to establish the characteristics of potential sites.

In an attempt to enhance water resources in the Gaza Strip and improve water quality, a large pool has been constructed near Gaza City to collect storm runoff and permit artificial recharge to the aquifer. The project is estimated to inject some 1.5 million m^3 per annum into the aquifer. Unfortunately, the project has not been completed yet and sewage is flowing into the pool, creating pollution problems in the area (WRAP, 1994). The USAID-funded Gaza stormwater project, launched in early 1996 and led by Metcalf&Eddy International, will rehabilitate the storm water pool.

6.2.2 Recharge with treated wastewater

If a reuse system is in operation there will be times of the year when more water is required than others. The conditions within the Gaza Strip is that there is a paucity of storage space in which to hold the treated water. The aquifer could then be utilized by recharging excess quantities of wastewater.

The quality of the treated effluent is an important constraint when considering either future potable use or agricultural use. Without the correct hydrogeological conditions then the recharge of the aquifer will be unsuccessful. If karstic conditions exist - widely fissured strata that promote preferential flow - the transmission of pathogens to the groundwater table may be enhanced or it may allow the rapid flow of effluent to a well used for potable supply (IWACO, 1994). It is also important to select a site where the depth to the water table is sufficient to allow for further purification. A good example is the discharge of anaerobic pond effluent which may require 40 m depth to the water table to allow for sufficient nitrogen removal (Montgomery, 1988). The geochemistry of the aquifer is also an important issue, especially if the infiltrating flow could come into contact with water-soluble minerals. Another risk could be recharging anoxic effluent through an aquifer with iron deposits, which would then become soluble and then precipitate at other locations causing blocking.

Figure 18 identifies potential locations for recharge of the aquifer. It includes sandy areas with a high recharge rate, as well as coastal areas where sea water intrusion is expected to take place.

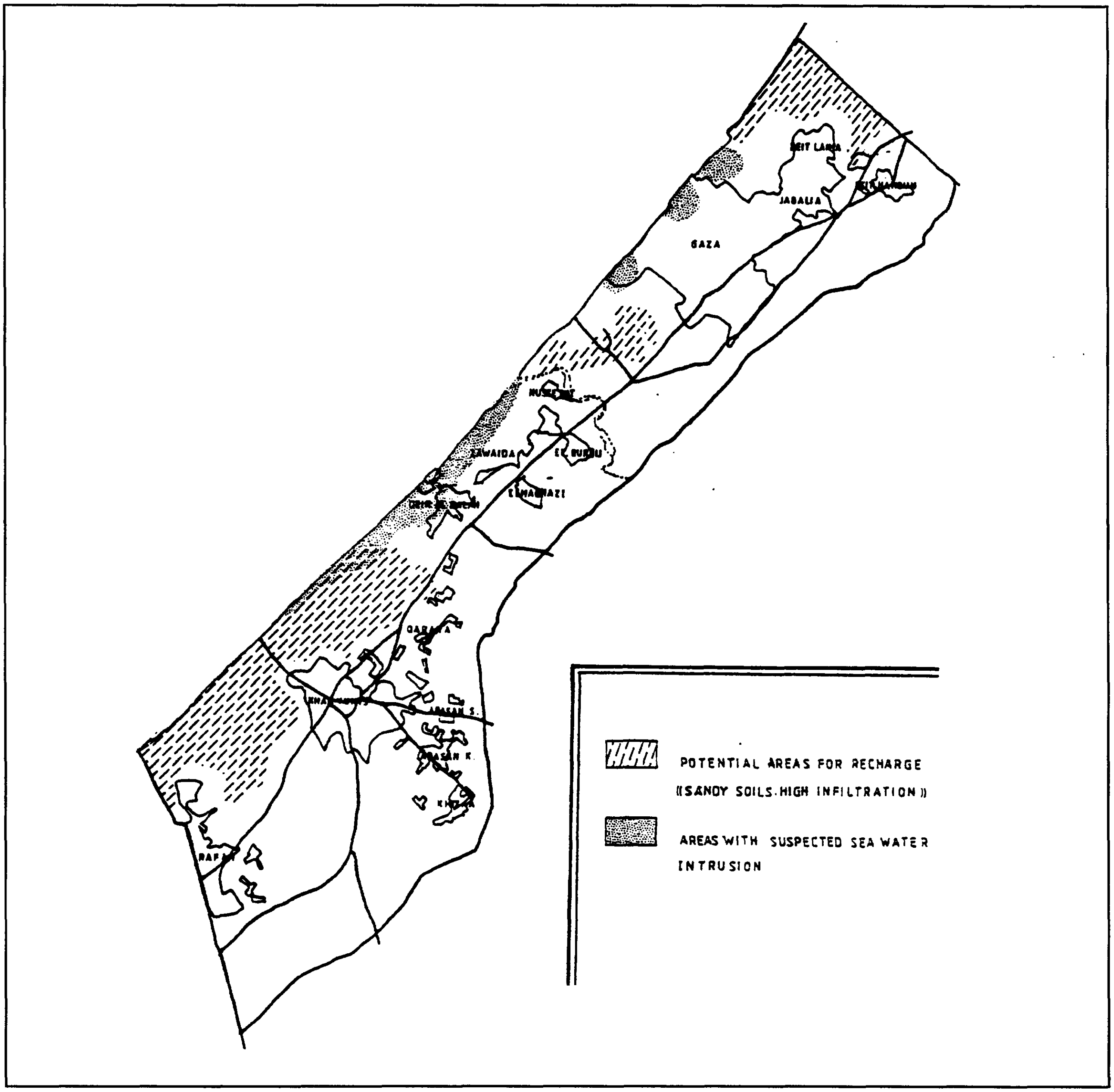

Figure 18 - Potential Recharge Areas (IWACO, 1994)

6.2.3 Rainwater harvesting

Rainwater harvesting at the household and small community level has always been and remains a major source of water for domestic purposes in rural areas, as well as in major cities. People collect rainwater falling on roofs or rock catchments and store it in cisterns, to meet part of household water needs. 50,000 households in the West Bank already harvest rainwater for household purposes, implying a total of 5 million m^3 per year (Shabbah and Issac, 1995). The present volume of water collected in this way in the Gaza Strip as well as the investments needed to increase rainwater harvesting are not known.

6.3 Water imports (inter-regional water trading)

6.3.1 Introduction

There is a certain fascination with the idea of transferring water over large distances from wet to dry regions. The Romans built an extensive network of aqueducts and canals to supply their cities and military outposts. The California aqueduct brings water over hundreds of kilometers to arid southern California, and the Israeli National Water Carrier channels water from the Sea of Galilee in the North to the coastal regions and into the South. History shows that large-scale water supply networks are advantageous. They make economic sense, just as electrical networks, oil pipelines and telephone connections make sense. Water supply networks can also be connected across national borders to balance supply and demand over very large areas and manage networks in a flexible manner (Kuffner, 1993). The International Conference on Water and the Environment in Dublin (1992) stated that “water has an economic value in all its competing uses and should be recognized as an economic good”. This is a clear departure from previous declarations stressing the “public good” nature of water. If water is considered to be an economic good, it could also be traded like other goods.

Several import and trading options have already been proposed to supply water to the Gaza Strip (and the other water-deficit countries in the region) (see Figure 19).

- Transfer of water from Israel via the Israeli National Water Carrier (INWC). The Oslo II agreement calls for the construction of a pipeline connecting the Gaza Strip to the INWC to transfer the agreed upon quantity of 5 million m^3/year.
- Water transfer from the West Bank. The costs of piping water from the West Bank, from high elevations to sea level, would certainly be lower than estimates for seawater desalination in Gaza.
- Diverting the Litani in Lebanon into the Sea of Galilee, from where it could go to Gaza via the INWC.
- Extending the Al-Arish pipeline from the Nile to Gaza
- A more ambitious project is the Peace Canal Project which proposes to bring water from the Turkish Ataturk Dam Reservoir through Syria to Israel

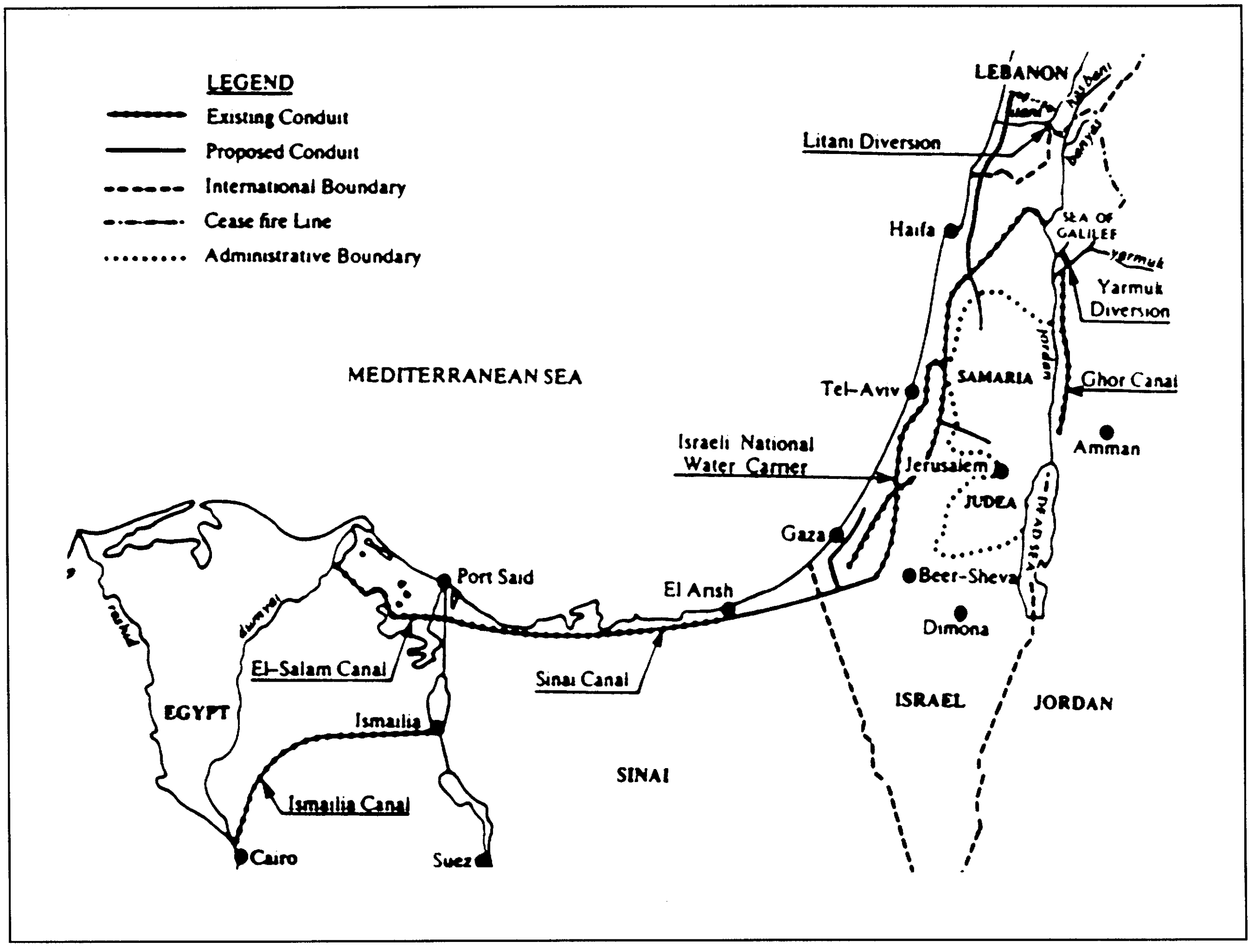

Figure 19 - Water Transfer Options (Wolf, 1995)

All options are technically feasible. Recent estimates show that water cost would be significantly lower than options such as desalination. However, it is difficult to collaborate on water issues and reach international agreements over water. Water's unique status as a resource has made it a frequent object of international controversy and conflict. Neighboring states that are otherwise cordially cooperative like the USA and Canada have found it difficult to achieve mutually acceptable arrangements to regulate their transboundary surface waters. Even states within a single federal union have engaged in bitter political and legal struggles over the waters they share. In the Middle East, the shortage of water impacts relations between states and is exacerbated by the background of religious, national, ideological, economic and political tensions. Politics can be watched and evaluated when agreements are signed to share water resources (e.g. the agreement between Sudan and Egypt regarding the use of the Nile River, the Israel-Jordan Peace Treaty and the sharing of Jordan River waters), when complaints are lodged with the UN (e.g. regarding development of the Euphrates by Turkey), in strategic threats to deny access to water resources (e.g. Turkey and Syria) or in the event of a military action (e.g. Syria's attempt to divert the Jordan River tributaries and the subsequent Israeli strike on Syrian waterworks in 1964) (Medzini, 1996).

Under certain conditions, water trade among potential users may increase regional welfare and be preferred over cases where individual entities maximize welfare subject to in-country water resources. In Gaza, the obvious associated benefits would be the use of purchased water to avoid higher cost of developing new sources, and the possibility to trade low-quality water (recycled water) for higher quality water (groundwater). But economic efficiency is not a sufficient condition for cooperation, especially when it is related to water. One possible problem associated with this kind of international water transfer is at the engineering level, that is, hardware complications in moving huge quantities of water between regions. Another problem that may add to the difficulty in dealing with international water transfer is associated with the special nature of water as a commodity. International water transfer is influenced by ideological-political considerations that may affect potential arrangements in the region. Such considerations are hard to account for in a quantitative modeling framework. A procedure is needed which incorporates political and ideological considerations into the decision-making process of the potential participants.(Dinar and Wolf, 1994).

Very few examples of inter-regional transfers can be found in the world. Several factors may account for the negligible amounts of water that have been traded between countries:

- Water rights are often poorly defined
- Water transfers can have high transaction costs
- There are uncertainties regarding transfer policies
- Absence of a recognized regional institution that could oversee physical and financial transfers
- Communication between buyers and sellers may be difficult
- Potential seller/buyer experiences/does not experience water scarcity
- Potential seller/buyer does not/ does have easy access to alternative fresh water sources or substitutes for water
- Economic benefits are not significantly greater that the transactions costs, including political costs
- External and internal politics dominate
- Buyer and seller have significantly different strategic power
- The water supply is shared by more than a region or state
- The seller has an advantageous riparian position in the drainage basin

The parties involved in the region's confrontation over water invoke a variety of legal principles to establish their claims: first-in-use, first-in-right, customary or equitable utilization, absolute sovereignty, beneficial use, basic justice and fairness, good neighborliness, prior use, etc. In making claims, each party is selective, choosing the legal principles that best buttress its own claims (Naff, 1991). The extent of water scarcity in the region is an important factor in the designing of water distribution laws. In areas of the world where water is plentiful, water is usually allocated according to the riparian rights doctrine, which states that anyone who possesses land next to a flowing river or stream may take its water as long as enough is left for downstream users. In the Middle East (and in the Western United States), where potentially productive lands are located far away from water sources, the doctrine of appropriative water rights emerged. The doctrine of appropriative water rights, or prior appropriation, permits diversions to and allocated quotas among specified parties. The quotas are allocated on a first-come, first-serve basis and are subject to the "use or loose it" or “first in time is first in right” rule. The amount of water initially used determines the size of a user's quota, and there are severe restrictions on trading in water rights once they are assigned (Howitt, 1995).

Perhaps the most important implication of water transfer planning is the need to increase integration and cooperation among countries in the region. This necessary coordination of planning and operations between functionally diverse national water agencies will imply potentially protracted, and probably controversial, negotiations, at least for long-term transfer arrangements.

6.3.2 Imports from Israel

From a purely technical standpoint, importation of water from Israel is the most attractive option. Water trading with Israel would require the construction of a 5 km pipeline connected to the Israeli National Water Carrier which runs parallel to the Gaza Strip. In addition, the costs of piping water from the West Bank, from high elevations to sea level, would certainly be lower than estimates for seawater desalination in Gaza.

The Harvard Middle East Water Project argued that both Palestinians and Israelis would benefit from a system of voluntary trade in water permits - short-term licences to use each others’ water. In addition, this system could become a mechanism for flexibly adjusting water allocations to the benefit of all parties - thereby avoiding the potentially destabilizing effect of a fixed water quantity arrangement in a peace agreement (Fisher et al., 1996). At the heart of the proposed approach is the assumption that, from an economic standpoint, issues of water ownership rights and water usage are analytically separate. Water ownership is thus a property right entitling the owner to the economic value of the water, regardless of who uses the water. By translating the value of water ownership into money terms, water trade can take place before a final settlement on property rights is settled. Hence, the dispute over water ownership could be translated into a dispute over the proceeds of the sales of water. The Harvard study showed that the water in dispute is currently worth $110 million per year, and will be worth no more than $500 million per year even by 2020. These values are very small compared to the economy of the region and, perhaps more to the point, they are small relative to the cost of fighter planes. The economic gains from trade were illustrated using the total amount of Mountain Aquifer water to be allocated to the Palestinians under the Oslo II agreement (see Section 3.10).

Assuming that desalination cost at Gaza would be about $0.80/ m^3$, the net economic benefit from trade in 2010 would be more than $61 million per year. The Palestinian entity would receive the largest benefit ($51.5 million per year), partly through its ability to purchase water at costs considerably lower than the cost of desalination at Gaza associated with the case of no trade and partly through increased water consumption.

Using the water allocation model developed for the project, a range of shadow prices of water at Gaza South was calculated assuming a medium scenario for population growth and demand (see Section 4.1). They are indicative of the real price that would be charged by Israel for water sales to Gaza. The current price of water sold by Mekorot - the Israeli national water company -to the villages in the south of the Strip stands at $0.46/ m^3$.

Gaza South	2010	2020
Shadow price of water (1990 US$/ m^3)	0.47 - 0.58	0.69 - 0.77

Table 12 - Shadow Price of Water in Gaza (base 1990) (Fisher et al., 1996)

An awkward outcome of the proposed approach is the existence of an inverse relationship between the benefits from trade for the Palestinians and the quantity of water allocated to them under a final settlement. In other words, benefits from trade would reflect an imbalance between the quantities allocated to Israel and the Palestinians.

Trade with the Palestinians will mean less water for Israel. Two issues stem from this inescapable fact. First, for trade to happen, the economic benefits to Israel will have to exceed all transactions costs, including the political costs of reducing water use, particularly in the agricultural sector. Many agricultural and water experts in Israel have argued that the region's water crisis was artificially created by the huge subsidies on water supplied to Israeli farmers (around $200 million per year), and that "It would be better to hand the farmers cash than to continue to subsidize water". (Jerusalem Post 01/15/97). However, cutting entitlements is easier said than done. In Israel and the neighboring states agricultural interests are a well-entrenched and powerful lobby. The issue here is that water trading entails diffuse benefits but concentrated costs. Second, Israel will need sufficient guarantees that the sale of part of its water will not be considered as an implicit relinquishment of property rights. In absence of a fully defined and enforceable property rights, the probabilities of trade are slim, regardless of the economic benefits. Israel is reluctant to yield tangible water assets - even temporarily in the framework of a voluntary trade agreement - unless it is given clear political and economic incentives to do so, along with solid guarantees of equivalent water supplies either by importation or desalination. There are compelling examples in many parts of the world, notably in the American West, that, in the presence of uncertainties regarding transfer policies, transaction costs, and property rights, trade will not occur, regardless of the potential gains from trade. The fact that California had much less water transfer activity than most of the other Western states cannot be attributed to the lack of profitable opportunities for trade. For example, Vaux and Howitt (1984) showed that in 1980 some 2500 million m^3 could have been profitably traded from agricultural regions to the state's major urban areas. This study showed that buyers and sellers would have jointly benefited by $156 million by 1995. The explanation for the lack of transfer activity appears to lie with poorly defined property rights and a reluctance to change water institutions.

6.3.3 Imports from the West Bank

Israel's utilization of the mountain aquifer's entire safe yield (Figure 20) is disputed by the Palestinians of the West Bank. The water supply potential of the aquifers underlying the West Bank has been estimated at about 630-640 million m^3/yr. Out of this amount about 110 million m^3/yr are consumed by the 1.2 million West Bank Palestinians, 50-65 million m^3/yr by the 140,000 Israeli settlers, while the remainder (413 million m^3/yr) flows to Israel where it is fully utilized, and in some years over-utilized (Shuval, 1996).

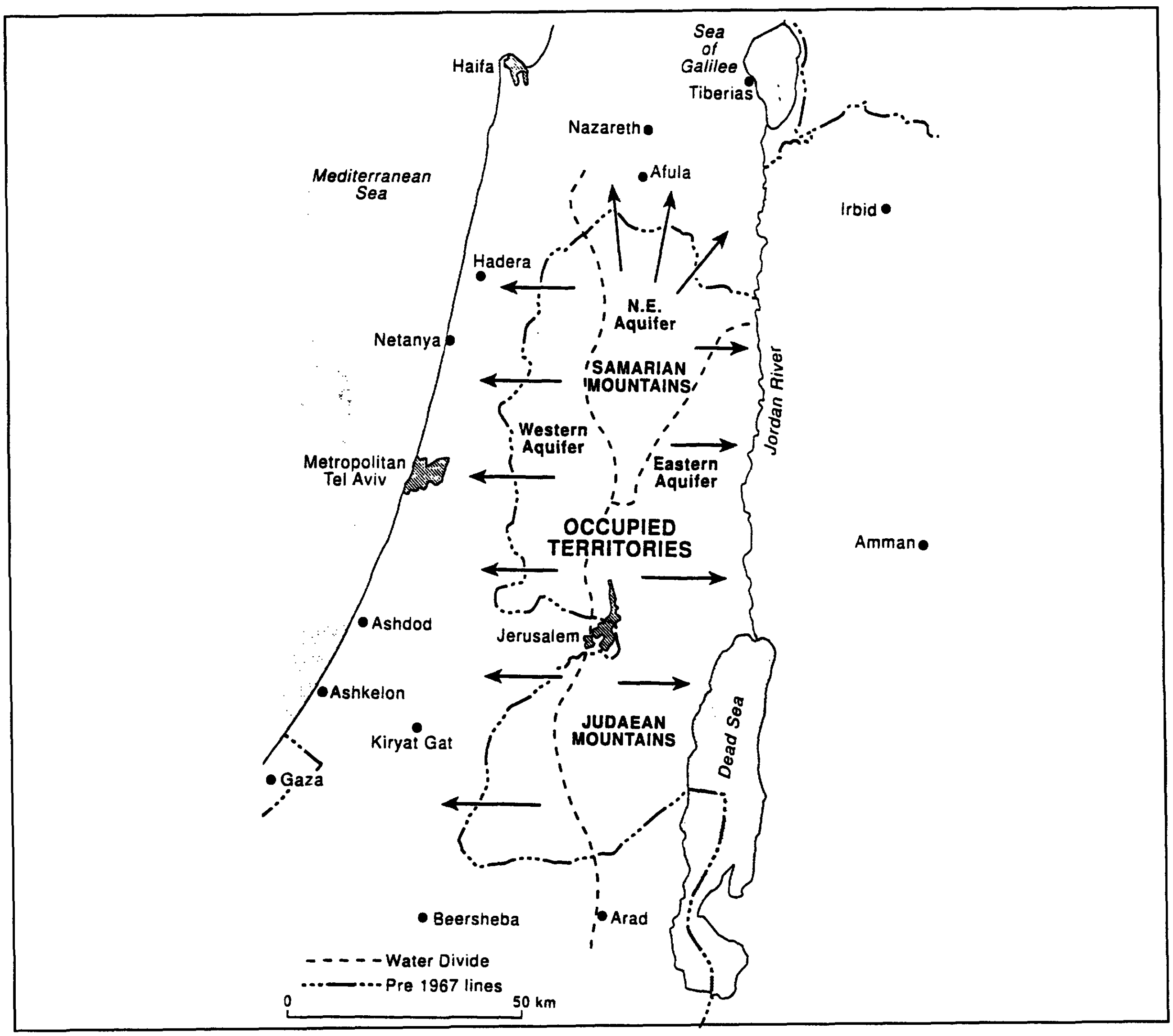

Figure 20 - Aquifers Underlying Israel and the West Bank (Shuval, 1996)

To protect its water supplies, Israel has restricted the right of the Palestinian residents of the West Bank to drill into the underlying aquifer. Stringent measures have been enforced to control water use there (Hillel, 1993). Clearly, the Israelis are concerned that the drawing of water from the aquifer in the West Bank is likely to reduce the water yield of wells in Israel by the principle of connecting vessels. In the words of Meir Ben Meir, a former water commissioner: "If the demand is for drinking water, we must say yes... But we are not going to stop irrigating our preexisting orchards so they can plant new ones" (Hillel, 1994). Israel is also concerned that population and industrial growth in the West Bank may lead to the percolation of sewage and waste into the aquifer.

These concerns were reflected in the Oslo II agreements which placed a clear emphasis on the formulation of policies aimed at the protection of groundwater resources. The additional quantities made available to the Palestinians were restricted to the Eastern Aquifer, thus safeguarding Israel's current use of the Western Aquifer. However, the taping of additional water from the Eastern Aquifer - which is by definition of international law replenished and owned by Palestinians - is currently difficult and may not be economically feasible, considering the depth of the Eastern Aquifer and its complicated topography (Issac, 1996).

The Israeli Ministry of Agriculture, in a 1990 advertisement dealing with the country's water problem, stated the following:

> Excessive pumping or uncontrolled sewage and waste disposal in Judea and Samaria are liable to cause serious depletion, salination and pollution of the aquifers. Relinquishing the western slopes of the Judean and Samarian hills will create a situation in which the fate of the national water supply could be determined by the actions of whatever Arab authority controlled the evacuated areas after withdrawal. Given the present critical scarcity of water in Israel, even with all the available sources of supply at her disposal, withdrawal and the relinquishing of control of a substantial portion of these sources could leave the country in a potentially desperate plight (Raphael Eitan, Minister of Agriculture, Jerusalem Post, 1990)

Many Israeli government officials or policy-makers believe that even after the Palestinians are granted autonomy or sovereignty, Israel should retain control over the water resources of the

West Bank. They claim that if there is a major unregulated increase in pumping from the aquifer underlying the West Bank, Israel's current utilization could be reduced by some 300-400 million m^3/year. There is a fairly broad consensus in the current Netanyahu government that Israel should annex hydrostrategic areas - the Western slopes of the Samarian hills - and that Israel should be able to exercise its veto power on water projects in areas to be handed over to the Palestinians.

The contention between the Palestinians and the Israelis regarding the waters of the mountain aquifer is a classical clash between two principles: sovereignty over the source of water (claimed by the Palestinians) versus the right of prior use and the natural course of the water (claimed by the Israelis) (Shuval, 1996):

- The Palestinians claim that the flow of the Mountain Aquifer that is derived from rainfall over the West bank, 80-90 per cent of which is currently extracted from deep wells mainly within Israel, should be allocated for their use
- Israel claims that it has legitimate historical riparian rights to the Mountain Aquifer, based on the principle of prior use, major portions of which flow naturally into its territory and which has been developed at great expense and fully utilized over a period of time going back some 60 years

International water law may possibly contribute to the resolution of these seemingly irreconcilable claims and counter claims of the parties. Indeed, Israel and the Palestinians will be expected to negotiate a settlement based on the assumption that they share common water resources and that the principles of international law should apply.

Geneva Convention (1949)

The Palestinians claim that any water extraction within the West Bank for Israeli civilian settlements is in violation of the Geneva Convention concerning the rights and obligations of what is defined as a "belligerent occupier". The Geneva Convention prohibits the "belligerent occupier" from using natural resources, including water, for its own benefit. In this case Israel will not be able to claim prior historic use since all of these wells were drilled by Israel after the 1967 occupation of the West Bank (Shuval, 1996). The quantities that may be relinquished to the Palestinians would be around 50-60 million m^3/year.

Helsinki Rules (1966)

One of the best known examples of international law of international water resources was the Helsinki Rules on the Uses of the Waters of International Rivers, formulated by the International Law Association and adopted in 1966. The Helsinki Rules promote the concept of restricted sovereignty through adoption of a rule of "equitable utilization". They propose that water disputes be settled by negotiations (Dellapenna, 1995)

Helsinki Rules, Article VII

> Each basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin.

International Law Commission Rules (1991)

The International Law Commission, an organ of the United Nations, embraced both the principle of equitable apportionment and the obligation not to cause appreciable harm to other States in its Draft Articles submitted to the General Assembly in 1991 (Khassawneh, 1995).

The three main obligations in the draft articles are:

- Art. 5 the duty to effect the equitable and reasonable utilization of the watercourse
- Art. 6 the obligation not to cause appreciable harm
- Art. 8 the general obligation to cooperate in the attainment of optimal utilization and adequate protection of international watercourses

Article 7 attempts to appreciate the strength of the absolute sovereignty doctrine vis-à-vis natural and historic rights by providing a factor-analysis approach (Caponera, 1993):

Box 5 - Article 7 : Factors relevant to equitable and reasonable utilization

Utilization of an international watercourse in an equitable and reasonable manner within the meaning of article 5 requires taking into account all relevant factors and circumstances, including:

a? geographic, hydrographic, hydrological, climatic and other factors of a natural character
b? the social and economic needs of the watercourse States concerned
c? the effects of the use or uses of an international watercourse in one watercourse State on other watercourse States
d? existing and potential uses of the international watercourse
e? conservation, protection, development and economy of use of the water resources of the international watercourse and the cost of measures taken to that effect
f? the availability of alternatives, of corresponding value, to a particular planned or existing use

The Bellagio Draft Treaty and the Seoul Rules on Groundwater (1989 and 1991))

While there is far less experience regarding disputes over aquifer management, Helsinki and ILC Rules would no doubt be applied by analogy. A gathering of experts on the law of international water confirmed this conclusion in meetings at Bellagio, Italy, and Seoul, where they drafted a model treaty to assure the equitable utilization and management of shared groundwater basins.

Of these obligations, the duty not to cause appreciable harm appears easiest to understand and prove, although the term "appreciable" infers the definition of a threshold against which actions and damages can be objectively measured. Defining reasonable and equitable utilization is more difficult. To establish that a state has exceeded its equitable share would require the adoption of a yardstick and the balancing of all relevant factors and circumstances in all relevant states (Khassawneh, 1995).. To complicate the matter even further, the relationship between the obligations of equitable utilization and the prevention of appreciable harm is also unclear. The established position of the ILC is that priority should be given to the prevention of appreciable harm in a case where the principles conflicted. Support for prioritizing equitable utilization is likely to come from countries which, like Turkey or the Palestinian Entity, are keen to develop their water resources. Downstream riparians such as Israel are likely to call for a prevailing duty not to cause appreciable harm (Khassawneh, 1995).

Informal Israeli-Palestinian tracks on water currently underway, in which Palestinians have been participating in official capacities, have been confined at Israel's insistence to the economics of water management and joint management of the common groundwater sources alone (Elmusa, 1995).. None of the discussions have addressed the question of water allocation. However, an agreement over sharing the water resources is essential to any peace agreement between Israelis and Palestinians. Such an agreement will perhaps prove to be one of the most difficult aspects of the entire negotiating process, yet, if done properly, it could contribute to a lasting peace between the parties. If the negotiation is based on the principles enunciated in the Helsinki and the ILC rules - equitable sharing and prevention of harm to the resource - the scarcity of the resource will render impossible a simple apportionment of the existing resource, and the parties will have no other alternative than to consider regional water management (Elmusa, 1995).

In the recent years, several scholars have proposed different schemes regarding the sharing of the water in dispute:

Shuval Proposal

Shuval (1996) proposed a possible approach that would satisfy the minimal human needs of the parties and would satisfy the criterion of a "reasonable and equitable share" as formulated under the Helsinki Rules. The proposal is based on a Minimum Water Requirement (MWR) of 125 m^3 per capita per year, including 100 m^3 for domestic, urban and industrial uses, and a symbolic allocation of 25 m^3/capita/year for minimal growing of fresh vegetables. The MWR does not include any other direct allocation of fresh water for agriculture, but assumes that about 65 per cent of domestic/urban/industrial water can be made available to agriculture through recycling. Thus, the total allocation of water could reach 190 m^3/cap/year; 125 m^3/cap/yr from fresh water sources and 65 m^3/cap/yr from recycled water.

Table 13 shows that both Palestinians and Jordanians will not meet the MWR in 2025.

	Population (millions)		Water resources potential (million m^3/yr)	Water availability		Total MWR in 2025 (million m^3/yr)	Excess/ deficit (million m^3/yr)
	1995	2025		1995	2025		
Israel	5	10	1,500[1)]	300	150	1,250	+ 250
Jordan	3	10	880	250	90	1,250	- 370
West Bank	1.3	2.8	155[2)]	120	55	350	- 195
Gaza Strip	0.9	2.2	45	50	20	275	- 230

Table 13 - Minimum Water Requirements and Water Resources Potential (Shuval, 1996)

1) May be reduced (water transferred to Jordan (peacer treaty) and to the Palestinians)
2) Current allocation (Oslo II interim agreement)

Applying the same methodology, Syria would have an excess of 11,750 million m^3/year, Lebanon 8,460 million m^3/year and Turkey 239,600 million m^3/year. Shuval proposed that these countries contribute to cover the deficit of the Jordanians and the Palestinians. If Turkey agreed to contribute all the water needed, it would represent only a reduction of 0.3 percent of its excess resources (resp. 10 percent for Lebanon and 6.8 percent for Syria)

Moore Proposal (1994)

Building upon Article 7 of the ILC Rules (see above), Moore (1994) proposed that sharing of the disputed water be based upon a mix of equity standards: equity utilization, recharge area, natural flow, and population. He obtained the following results (Table 14):

	Alternative 1 Existing utilization	Alternative 2 Recharge Area	Alternative 3 Natural Flow	Alternative 4 Population	Combination
Israeli Share	83	5	63	71	63-71
Palestinian Share	17	95	37	29	29-37

Table 14 - Alternative Equity Standards (Moore, 1994)

According to the Moore proposal, the Palestinians would receive between 29 and 37 percent of the Mountain Aquifer, or 182 to 239 million m^3/year (current utilization: 110 million m^3/year). About 50 million m^3/year could be earmarked for the Gaza Strip.

Issac and Kubursi (1996) proposed that Israel instigate some confidence building measures such as immediately providing Gaza with 50 million m^3/year through the National Water Carrier. According to the authors, such a move would serve as a practical recognition of the Palestinians' riparian rights.

6.3.4 Imports from Egypt

The idea of the El-Salam Canal project (see Figure 21) was launched by Egyptian President Sadat following his declaration in Haifa (1979) that he would transfer Nile water to the Israeli

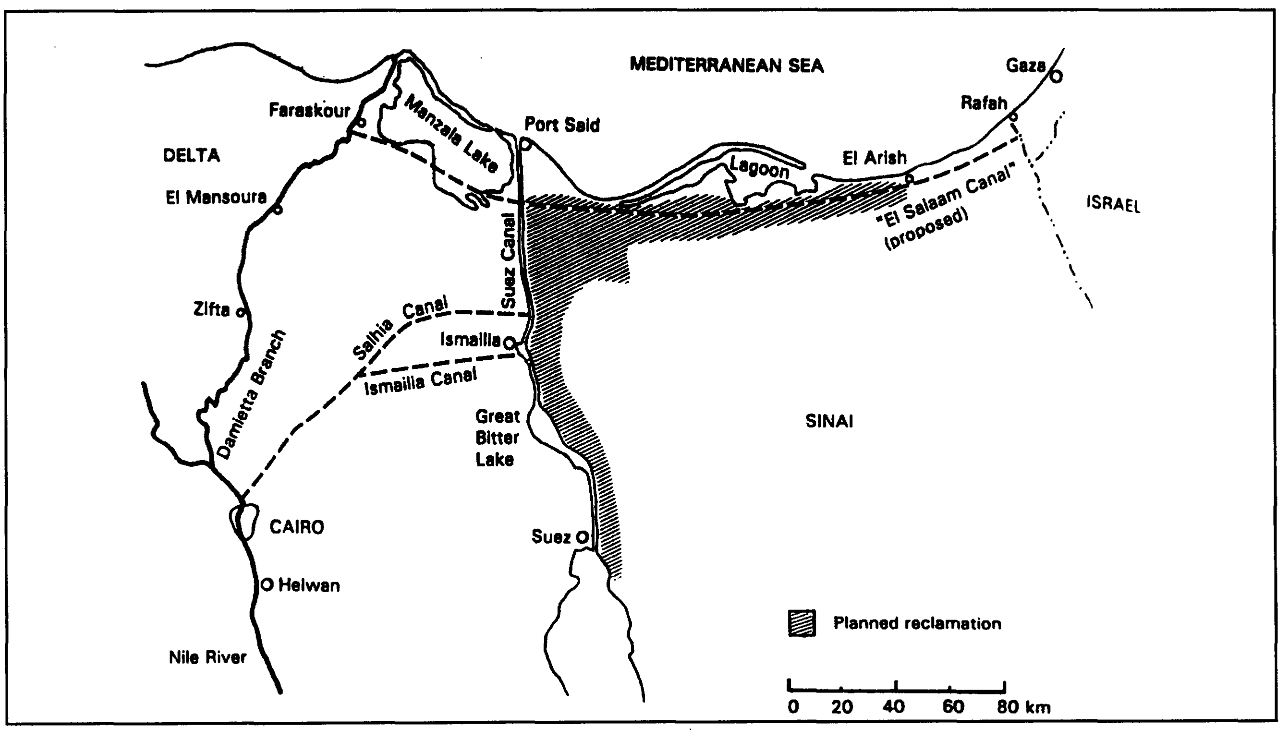

Figure 21 - Nile to Gaza Transfer (Hillel, 1994)

Negev, Gaza and Jerusalem. The project stemmed from a study carried out by Elisha Kally who contended that Israel's water problems could be solved, and for a long period of time, by using 1percent of the Nile water (i.e. 800 million m^3 annually). Kally believed that the Ismailia Canal that extends from Cairo to the Suez Canal could be enlarged to produce 30 m^3/sec. The water would then be carried in pipes under the Suez Canal near Ismailia to the northwest in a concrete canal until it reached Al Arish, and then from there to Khan Yunis (Gaza Strip). In Khan Yunis the water would be divided into two branches. The first would flow towards the Gaza sector and the second towards the Western Negev. Sadat viewed Israel's supply with a part of Egypt's share of the Nile water as an incentive conditional to the resolution of the West Bank and Jerusalem issues. In a letter to Menachem Begin, Israel Prime Minister then, Sadat wrote:

> As we embark on the comprehensive resolution of the Palestine issue, we shall make these waters a contribution from the Egyptian people and in the name of the hundred millions of Muslims, a monument to the peace accord. The Nile waters will become Zamzam[2] wells to all believers. These waters will be an evidence that we are promoters of peace, life and prosperity. (Anwar Al Sadat, 1979)

Sadat's declarations made severe repercussions in Egypt and the Nile riparian countries, particularly Sudan and Ethiopia. Ethiopia declared its opposition to the project. Sadat retaliated by stating that Egypt would declare war if its share of the Nile water was threatened. Egypt's foreign minister, Boutros Boutros Ghali, said "the next war in our region will be over the waters of the Nile, not politics". Ethiopia, which controls more than 86percent of Nile water flowing into Egypt, is increasingly jeopardizing Egypt's water security with new water projects (Waterbury as cited by Lowi, 1990).

The following points were of particular concern in Egypt:

- The legal aspects pertaining to the project in the sense of whether Egypt has the right to take an unilateral decision to divert the Nile water to any area outside her borders.
- The fear that even if the sale to Gaza (or Israel) would be considered as a temporary measure, that Gaza (or Israel) would not surrender to the logic of returning the Nile water after a while, should the water become more valuable to Egypt in the future.

[2] Zamzam is the well that supplies the Muslim holy shrine Ka'aba at Mecca with water.

In Israel, responses to the Sadat proposal were mixed at best, with then Agricultural Minister Ariel Sharon voicing the common concern that "I would hate to be in a situation in which the Egyptians could close our taps whenever they wished". However, Israel would view favorably (and probably support) a transfer of Nile water to Gaza rather than the alternative of increased groundwater exploitation from the shared aquifers. On the other hand, the Egyptians may be reluctant to supply Gaza, as it may be considered as an implicit endorsement of the current water apportionment between the peoples of the region.

Since the Sadat proposal, Egypt's own water prospects have deteriorated as the water surpluses enjoyed in the 1970s have dwindled. Egypt may eventually face water shortages as its population continues to grow and if its upstream coriparians appropriate significant quantities of water. However, the Nile to Gaza transfer scheme could be revived. The amount of water needed in the Gaza Strip, estimated to be 150 million m^3/year in 2010, is not significant when compared to Egypt's water budget - less than 0.25 percent of it.

Technically, supplying Gaza from the Nile would be quite straightforward, as it would merely require the extension (and upgrade) of the pipeline that reaches to Al-Arish City, 40 km away from the Egypt-Gaza Strip border. Recent costs (Kally, 1994) of Nile Water conveyed to the Gaza Strip are between $ 0.20 and $ 0.82 / m^3, depending on discount rate and water volume. For 50 million m^3 /year, at 12 percent discount rate, the conveyance cost Nile-Gaza results in $ 0.74 / m^3 by pipeline. In this route, a canal system can replace the pipeline economically and reduce the conveyance cost to about a half ($ 0.38 / m^3). Additional significant cost decrease can be achieved here if the project is combined with the Egyptian "El Salaam" project ($ 0.21 / m^3 in the proportional cost sharing). However, there are serious concerns regarding the quality of the Nile water downstream of Cairo. The water is saline and so contaminated that a very high incidence of waterborne diseases - notably schistomasis - has recently been reported in the Lower Delta (New York Times, 03/24/1997). Costly water treatment would be required.

Economically, the project may be viable even for water-short Egypt. Indeed, Egypt is currently importing virtual water (see Section 6.6) at a cost of \$0.10 per m^3 (Allan, 1996). Provided grain prices do not change considerably in the future, the following arrangement may be envisaged. Egypt would purchase water (as foodgrain) on the world market, at a cost of \$0.10/ m^3, and sell the same amount to Gaza, at a price higher than \$0.10/ m^3 (not included transportation, treatment, and other transaction costs).

Dinar and Wolf (1994) have used a particular cooperative arrangement of water conservation and transfer in Southern California to develop a general regional water trade model. Under the agreement, the Metropolitan Water District pays the Imperial Irrigation District to finance water conservation projects over a period of time. In exchange, the Metropolitan Water District receives the water saved by the conservation projects. The water transferred for urban uses is water that was previously lost through conveyance leakage, and it does not alter the amount of water available to farmers for irrigation. Dinar and Wolf (1994) subsequently applied the water trade model previously developed to a simplified case study that includes the scenario of trading Nile water for irrigation technology between Egypt and Israel. The annual economic outcome to the region (in terms of incremental welfare) was \$126.5 million and \$8.00 million for the full regional cooperation and for the partial cooperation (Gaza Strip only). Fishelson (1994) estimated that the cost of saving one cubic meter of water by converting to sprinkling or drip irrigation, depending upon the suitability of crops, is only \$0.10/ m^3. Fishelson proposed that the sprinklers and drip irrigation equipment would be provided to Egyptian farmers by Israel free of charge. In return, Egypt would transfer to Israel half of the water saved by the farmers through the adoption of modern irrigation technologies. Out of this sum, Israel would take for its own use 60 percent, and the remaining 40 percent would be shared by Gaza and the West Bank. According to Fishelson, the costs of water on the border between Israel and Egypt, in the Gaza Strip, would be about \$0.40/ m^3, considering capital and O&M costs of the conveyance system from Egypt to Israel.

6.3.5 Imports from Lebanon

> To provide water for their increased population, the Palestinians would negotiate with Lebanon for the annual diversion of 400 million m^3 from the Litani River which presently flows unused to the sea. The water would be carried by a tunnel from the "knee" of the Litani, below Beaufort, for nine kilometers into Israel and Israel would transfer the same amount to the Palestinians from the National Water Carrier. The Lebanese would likely agree to such a plan because it would be part of an overall settlement that would rid them of the Palestinian refugees. Noting the proposal by Yossi Beilin to transfer to the Gaza Strip part of the Halutza Sands in the western Negev - to compensate for the parts of the West Bank that would be annexed to Israel in a final settlement , Weitz says this area could be made as productive as Gush Katif - "the spearhead of modern Israeli agriculture" - if water from the Litani were available (Jerusalem Post, 03/09/1997).

This statement by Ra'anan Weitz, the former Director of the Jewish Agency Settlement Department, reflects the interest that Israel has expressed for a long time for the Litani River. Israel's pursuit of the Litani waters can be traced back to 1919, when Chaim Weizmann, Chairman of the Zionist Organization who would eventually become the first president of Israel, addressed a letter to the British Prime Minister Lloyd George concerning the Zionist territorial demands. Weizmann argued that "the valley of the Litani for a distance of 25 miles above the bend" of the river to be important to the future of the national home promised to the Jewish people by the Balfour Declaration of November 1917 (Wolf, 1995). These and subsequent requests were turned down when the British, acceding to French demands, agreed to set the border between Mandate Palestine and Lebanon so as to include the entire length of the Litani River within Lebanon (Sykes-Picot Agreement, 1919). 1954, Israel put forward a plan for developing and exploiting the waters of Rivers Jordan and Litani. This plan was devised by the engineer John Cotton and it envisaged diverting 400 million m^3 of the Litani water to Israel. In 1967, Israel still expressed its interest, however indirect, in the Litani waters. The Israeli Prime Minister Levi Eshkol is quoted as having expressed his concern at seeing half a billion cubic meters of Litani waters flowing wastefully into the sea instead of being exploited by the people of the area (Wolf, 1995). Some claim that it is from this perspective that the Israeli occupation of South Lebanon should be seen. Some Israeli officials have stated that the water shortage in Jordan and the Palestinians territories could be solved by tapping a share of the Litani River. On May 11, 1991, Israel declared officially that it would not withdraw from Lebanon without assurances of its share of the Litani. Lebanon claim that Israel has already built a diversion of the Litani to the Jordan River; however, this assertion has been categorically denied by Israel.

It would be technically feasible to divert part of the Litani River into the Sea of Galilee, from where it could go to Gaza via the Israeli National Water Carrier. The construction of a 8 km long tunnel from the "knee" of the Litani to the River Brivit - which flows to the Sea of Galilee - would secure the flow of 400 million m^3 of the Litani waters into Israel. The Litani waters would be especially suitable for domestic and industrial uses because of their purity and very low salinity (less than 20 ppm). It should be noted that the facilities needed for such a system could be constructed within a period of two years. Kally (1994) estimated that the costs of conveyance of Litani water to Gaza would range from \$0.25/ m^3 to \$0.35/ m^3, depending on the quantities transferred and the discount rate.

However, a major part of the Litani waters are currently diverted to a hydropower plant located in the coastal plain - 450 million m^3/year out of a total long-term average discharge of 700 million m^3/year - thus significantly reducing the quantities potentially transferable to the Sea of Galilee. Two alternatives could therefore be envisaged:

- Reduce the hydropower plant output, if trading yields more benefits than using water for electricity production
- Build a coastal carrier that would be fed by both ex-hydropower plant waters and the Litani River before it discharges into the Mediterranean Sea. This coastal carrier would then run southwards, supplying South Lebanon cities and irrigation fields, and on to Israel and Gaza via the existing Israeli National Carrier. This option would carry the double advantage of maintaining the hydropower plant output and benefiting underdeveloped South Lebanon.

Diverting the Litani would not be without consequences for the population in Southern Lebanon. In the early 1970s, the Shiite community of Southern Lebanon staged violent protests against a plan to divert the Litani to supply the city of Beirut. Irrigation water holds the promise of raising the standard of living of the impoverished Shiite population, thus bringing economic and political stability to Lebanon (Hillel, 1993). Diverting the Litani is also predicated on peace with neighboring Israel. The present social and political situation makes it unlikely that the Litani option will materialize in the near future.

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6.3.6 Imports from Turkey

One of Turkey's responses to international challenges triggered by the construction of major water projects on the Upper Euphrates has been to offer piped water to the affected countries from alternative sources, guaranteeing the supply of drinking water in their main cities. The project consists basically of piping water from two Turkish rivers (the Ceyhan and Seyhan) to the Arab countries to the south. It is proposed that the "Western Pipeline" should run across Syria and Jordan to Mecca, carrying 3.5 million m^3 of water daily. Its main objective is to supply drinking water to Damascus, Amman, and possibly the West Bank and Gaza. It is the search for a multilateral agreement which has suggested the name of "peace pipeline", although this should not disguise the fact that it also offers Turkey new strategic possibilities (del Rio Luelmo, 1996). The main obstacles to the peace pipeline are political rather than economic. The balance of power in the region could easily be disturbed by the high level of dependence on Turkey. Some of the potential recipient countries do not trust Syria, which will be crossed by the pipeline and therefore could exercise a high degree of control over the flow of water. There is also a complete lack of agreement in several matters relating to the use of water in the region. The potential for disagreements has already been seen in the dispute over the water of the Euphrates when Atatürk Dam was being filled in 1990. (del Rio Luelmo, 1996). The present political situation does not inspire confidence that the project will be realized. A further worsening in the Kurdish conflict, including the occupation of north Iraq, has hardened Turkey's attitude to the water issue, especially towards Syria. Yet the idea is not dead: Turkish Prime Minister Tansu Ciller appeared to revive it publicly during her visit to Washington in October 1993 (Hillel, 1993)

6.3.7 Summary

Table 15 summarizes the water transfer potential of the alternatives discussed in this section.

Million m³/year	1990	2000	2010	2020
Intra-regional water imports				
From Israel, West Bank, Jordan [1]	5	50-150 [2]	50-150 [2]	50-150 [2]
Inter-regional water imports [3]				
Nile-Gaza canal (Egypt)			100-200?	100-200?
Litani diversion (Lebanon)			100 [4]-500 [5]	100 [4]-500 [5]
Mini Peace pipeline (Turkey)			500-1000?	500-1000?
Total potential	**5**	**50-150?**	**?**	**?**

Table 15 - Water Transfer Potential

1) Via INWC (Israeli National Water Carrier)
2) Depends on outcome of negotiations between Israel and the Palestinian
3) Figures represent total quantities shipped to the region. Gaza would be allocated a fraction of these quantities
4) Litani diverted into the Sea of Galilee. Awali hydropower plant output maintained.
5) Coastal Carrier

The potential for the Gaza Strip is huge, but limited due to competing use by several other countries and entities. Importation of water from the Israeli National Water Carrier is needed for Gaza on a short-term basis (purchase from Mekorot, the Israeli utility, current price \$ 0.65 / m^3, but subject to negotiation), before new capacity investments are completed. On a long-term basis, importation of water from Turkey, Lebanon or Egypt should be compared to other possible alternatives, including regional water trading, both in terms of relative cost and management/political issues.

Table 16 provides cost estimates for the different options, calculated by Kally (1994). These costs are conveyance only and do not include storing and treatment which may cost more than $ 0.30 / m^3.

Project	Distance	cost/ m^3 A	cost/ m^3 B	cost/ m^3 C	cost/ m^3 D
Nile-Gaza (pipeline)	390 km	0.38	0.59	0.33	0.45
Nile-Gaza (canal)	390 km	0.19	0.29	0.17	0.22
Litani-INWC-Gaza	150 km	0.27	0.35	0.25	0.30
Euphrates-INWC-Gaza	550 km	0.68	0.91	0.60	0.79

A : 100 million m^3/year, discount rate: 6 percent
B : 100 million m^3/year, discount rate: 12 percent
C : 200 million m^3/year, discount rate: 6 percent
D : 200 million m^3/year, discount rate: 12 percent

Table 16 - Conveyance Costs to Gaza (Kally, 1994)

6.4 Wastewater recycling and reuse

6.4.1 Introduction

Efficient wastewater collection and treatment and reuse are of major importance to the cities and the agricultural sector of the Gaza Strip. Advantages of wastewater recycling and reuse are threefold. First, it provides an additional water supply for irrigation, thereby freeing groundwater for other uses, notably drinking water. Second, wastewater reuse yields benefits that can be reinvested in the development of sanitation systems. Third, construction of sewer and treatment systems contributes to the protection of surface and groundwater reserves, and reduces health hazards in cities.

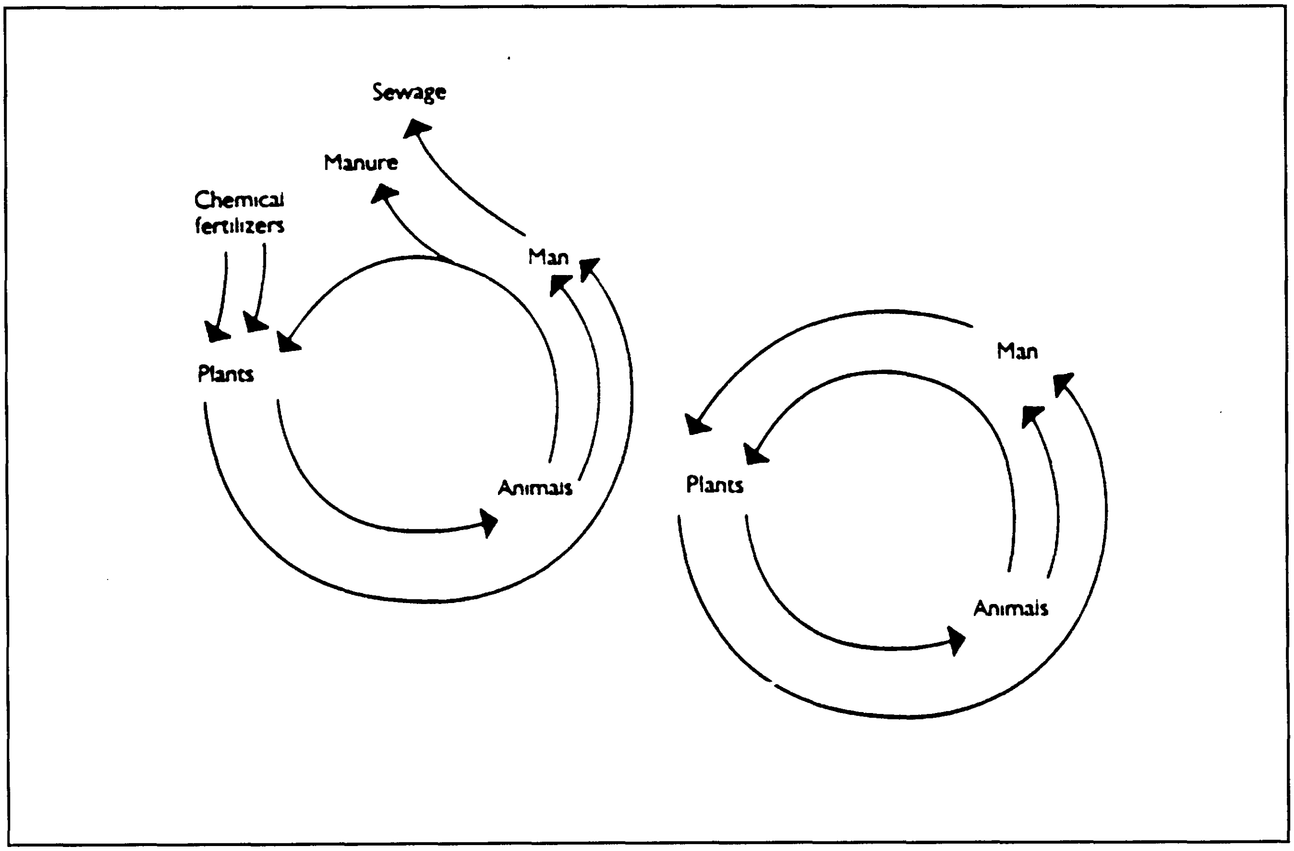


Figure 22 - Evolution of the Food Growing Cycle (UNDP, 1996)

Wastewater recycling can also contribute to the development of urban agriculture. Urban agriculture plays a significant role to the socio-economic development of towns and cities throughout the world. In several economies, particularly developing ones, it is one of the largest urban productive industries, and a prime generator of jobs. The development of urban agriculture can enable ashift from the open (unsustainable) loop to the closed (sustainable) loop (Figure 22). A complete or sustainable design for a city would be a closed loop, with all the wastes of one process used as input of another process. Simply put, cities can feed themselves (UNDP, 1996).

According to many experts, Gaza agriculture will become increasingly dependent on recycled sewage and other types of low grade waters which are unsuitable for drinking: the high cost of new water supplies will render the agricultural sector unprofitable, unless irrigation water is massively subsidized. Treated wastewater could be used as a substitute for well water to the extent of 60 million m^3 in 2010 (see Figure 23).

Figure 23 reflects the agricultural demand and the wastewater quantities that can be reclaimed, assuming that they equal 65 percent of domestic consumption (Figure 23). The chart shows that there is considerable scope for wastewater recycling and reuse in Gaza. Depending on the population and consumption per capita scenarios, wastewater production could exceed current irrigation needs in 2010 or 2020. The excess of reclaimed water could be either exported to the Negev or used to expand the irrigated area in the Gaza Strip.

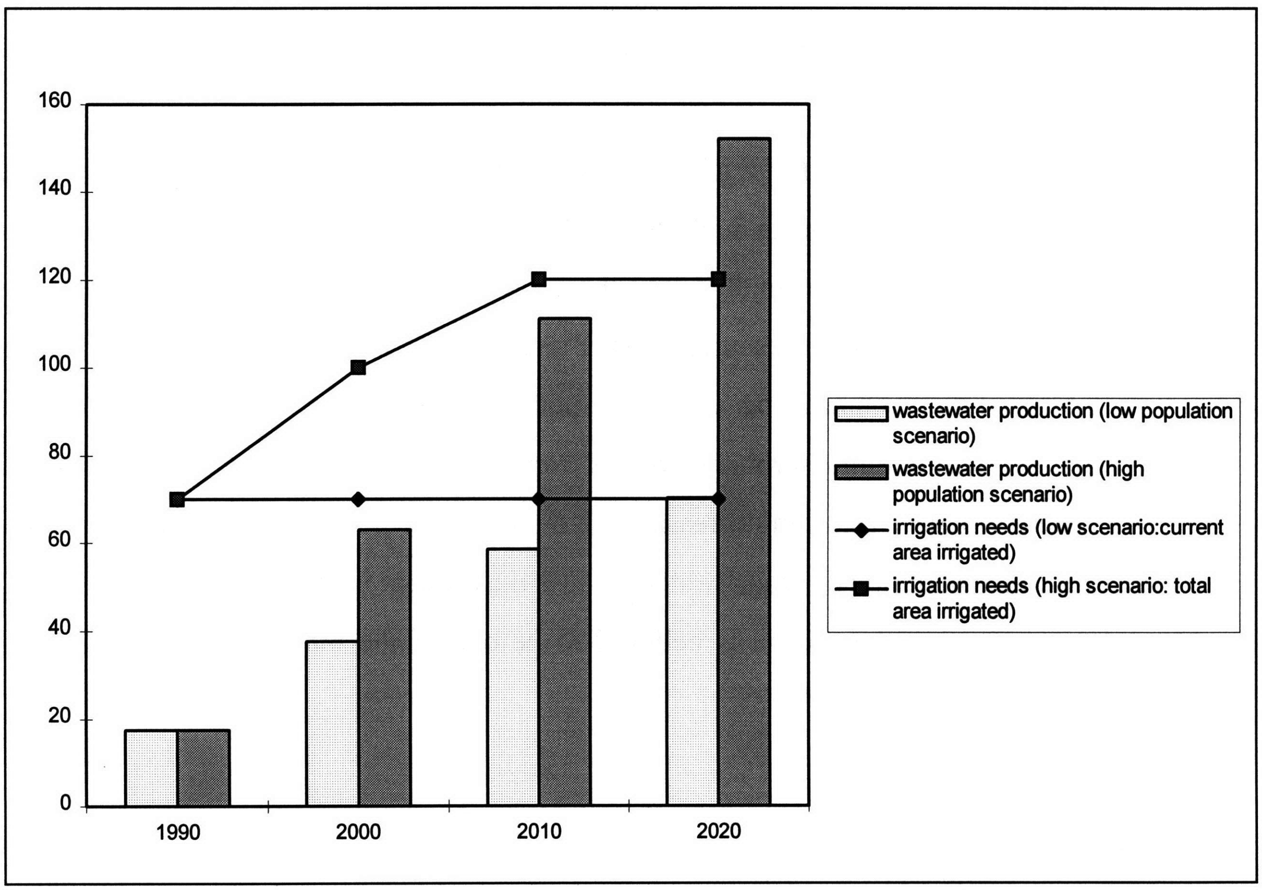


Figure 23 - Wastewater Production vs. Irrigation Needs (million m^3/year)

According to simulations of the Harvard Middle East Water Project model, the provision of additional recycling facilities in Gaza would be very beneficial (Fisher et al., 1995). In particular, it appears that it will be profitable to build recycling plants in Gaza with the recycled water sold to Israel for use in the Negev. The benefits from such facilities are $ 24.6 million per year by 2010, assuming household/industrial effluent charges of $ 0.30 per m^3 and recycling costs taken as an additional $ 0.10 above this. These findings suggest that Israel has an interest in assisting the Palestinian Authority to construct collection and recycling facilities in Gaza. One may point out the fact that such a system will not solve the water issue for Gaza, if recycled water is exported to the Negev. However, the model shows that benefits are maximized in this way because water is more valuable in the Negev than in the Gaza Strip. In addition, the effects on the price of water to agriculture (which uses the recycled water) are great. In the Palestinian entity, the institution of recycling lowers the price to agriculture in most districts to about $ 0.12 / m^3 -- a reduction in many districts of nearly $ 0.50 / m^3 (Fisher et al., 1995).

Water reuse is considered a priority issue in the Gaza Strip for a number of reasons. Firstly, the fresh groundwater resources are being depleted rapidly; more freshwater is consumed every year than is added to the resources. Secondly, current wastewater disposal practices form a serious pollution threat to the groundwater resources. Water reuse is not a new concept in the Gaza Strip. It has been estimated that around 30 per cent of the potable water is reused (MOPIC, 1996). This water recharges the aquifer either through leakages from the distribution system or infiltration of wastewater. These practices assist in decreasing the deficit in the fresh water balance, but at the same time they cause pollution of groundwater because the effluent is of poor quality. Promoting the first whilst mitigating the second is believed to be one of the major challenges in water management in Gaza (MOPIC, 1996).

6.4.2 Issues and constraints

Potential scheme locations

In Figure 24 potential areas for agricultural irrigation with recycled water are indicated. It includes areas where one type of crop is cultivated over an area of 500 dumams or more. This also includes citrus areas in Beit Hanoun and south of Gaza City, where an unsuccessful start was made with implementing the infrastructure for agricultural reuse.

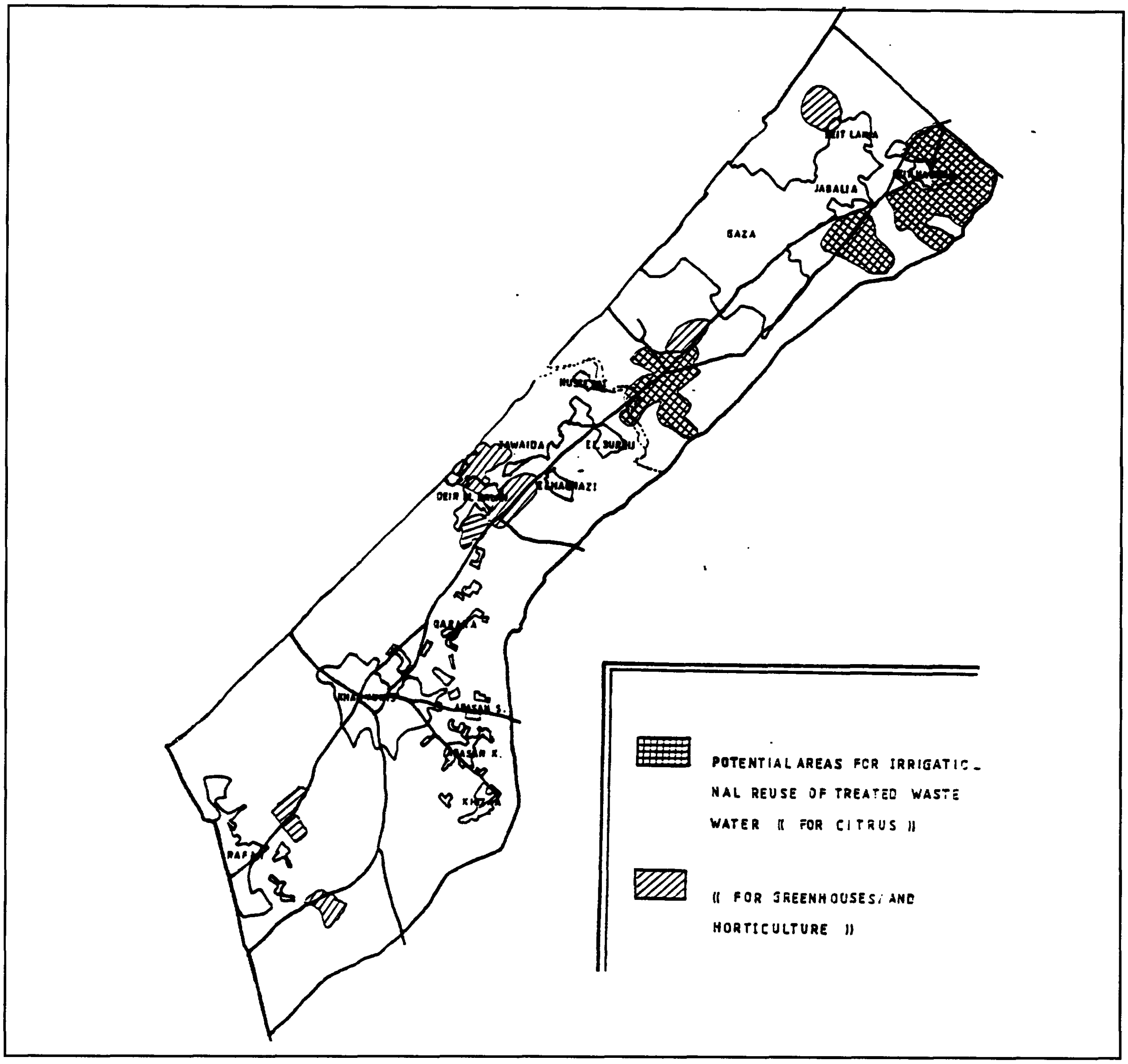


Figure 24 - Potential Areas for Irrigation with Wastewater (IWACO, 1995)

Infrastructure

The infrastructure needed to collect and treat the sewage in the Gaza Strip is still very poor and inefficient, and a lot of investment is needed. Approximately 3 households out of 4 are not connected to a buried sewerage system. Not connected households discharge wastewater into infiltration wells, and more or less water-tight cesspit-tanks and gutters. The massive infiltration of non treated wastewater contributed to the groundwater deterioration and poses significant risks to public health. Wastewater treatment plants (aerated ponds) are undersized and inefficient. They had been originally designed to treat water for reuse, but due to their current bad performance no reuse is possible. Rehabilitation work is currently ongoing. Metcalf & Eddy International is currently implementing a $23 million USAID-funded program to upgrade the wastewater infrastructure in Greater Gaza City.

Costs

Conventional sewerage is expensive. Construction of domestic sewage collection systems and treatment facilities amount to a per capita investment in the order of respectively US$ 300 and US$ 200 in the Gaza Strip (IWACO, 1995). Hence, total cost for implementation of sewage schemes in the urban areas and refugees camps of the Gaza Strip amounts to US$ 450 million for the year 1995. Less expensive solutions are needed, such as simplified sewerage and other intermediate cost collection systems.

The principal costs of reuse schemes are the costs of storage, conveyance, distribution system, and on-farm costs. Costs will depend upon the location of the wastewater treatment plant, on whether or not a reservoir is planned and its size, and the size of the irrigated area. Within the Gaza Strip the allocation of land is haphazard and often divided into small holdings with some farmers owing different portions of land over scattered areas. This would make it more costly to convey, distribute and supply wastewater for agricultural reuse to many different locations. If the area is irrigated with drip or sprinkler irrigation systems, the investment costs including pumps will be around $400 per dunam (IWACO, 1995). For the entire Gaza Strip, cost would be 56,000 dunums x 400 = $22.4 million.

Willingness-to-pay

Currently, sewage fees are not charged efficiently to recover the cost of the network. Municipalities estimate the household willingness to pay at about $11 per household per month, or on average $18 per capita per year (LYSA, 1995). Assuming a wastewater production of about 50 l/c/d, this translates into a willingness to pay of less than $1/ m^3. Households are likely to pay for immediate benefits but they are less willing to pay for major externalities, such as improved environment and better public health.

Salinity problems

The main source for reuse in agriculture is domestic wastewater. An issue of particular importance for the Gaza Strip is the relatively high salinity of the potable water and consequently the high salinity of the domestic wastewater. It has been shown that the salinity of wastewater is about 200 mg/l higher than the original potable water (Amir, personal communication, 1996). Thus, assuming an average salinity of 800 ppm for domestic water, recycled water salinity may exceed 1000 ppm. This could pose major restrictions to reuse for crop production. Wastewater recycling may be viable only in the case of imports of freshwater, unless technologies and infrastructure are developed in Gaza to use saline water in agriculture (see Section 5.8).

Environmental and public health problems

Increasing use of treated wastewater in irrigation, and a high level of use of chemicals in agriculture brings the focus to environmental problems and the protection of freshwater resources. This nutrient-rich water should be used efficiently, in accordance with environmental and health standards. There is little doubt that health risks exist when treated wastewater is used for the irrigation of agricultural crops but these are known and can be assessed (PECDAR, 1994). The objective is then to minimize this risk both for the workers involved and for the consumer of the end product. Strict restrictions on the use of treated wastewater in irrigation need to be declared; the issue of gradual contamination of groundwater by chemicals needs to be discussed; problems of enforcement of the regulations will need to be solved.

Storage and aquaculture

Since wastewater is generated by the community 365 days a year and the irrigation season in most areas is limited to a number a months per year, a suitable solution is the large interseasonal storage reservoirs pioneered in Israel. These reservoirs are designed to store up to ten months of wastewater flow until the irrigation season, and may also be designed to catch surface runoff. Studies indicate that wastewater quality improves considerably in such reservoirs. Another solution is to develop aquaculture in the final maturation ponds or additional storage reservoirs. For fish farming, tilapias and the common carp are suitable for wastewater-fed breeding. Mean annual yield of polyculture fish ponds is about 3-5 tons/ha/year (PECDAR, 1994).

Public acceptance

Reuse of wastewater may also be constrained by socio-cultural barriers. However, acceptance of wastewater reuse should be promoted by increasing farmers' awareness and implementing successful demonstration projects. Farmer reluctance of the farmer to utilize recycled water can be expected especially in the Northern part of the Strip where groundwater quality is still relatively good. A limited survey conducted by the author in the Southern part - where aquifer salinization is a major problem - showed that wastewater would be fairly well accepted because of the lack of alternatives. Untreated wastewater is utilized in Nablus, Hebron and elsewhere for irrigation even of fresh vegetables so religious and cultural attitudes are not thought to represent a major constraint. However, local consumers and potential importers can be reluctant to purchase products which are irrigated with treated domestic wastewater. The EU recently passed legislation prohibiting the importation of vegetables irrigated with wastewater.

6.4.3 Selection of a wastewater treatment technology for Gaza

Wastewater treatment and reuse requires provision of the correct treatment process, together with reliable consistent operation. The fact that proper treatment was not provided was one of the reasons for the failure of an agricultural reuse project south of Gaza City. The lack of management skills also contributed to the failure of the project (IWACO, 1995). A variety of personnel with different skills is necessary to design, operate, maintain and to monitor the systems. Such skills demand a sound human resource development program and assistance over a long time frame in order to build real capacity. The technology utilized in a project can also be an important constraint, especially when human resources are not available for the management of a certain type of plant. It would then be prudent to select a technology that does not require sophisticated skills that may not be available in the Gaza Strip in the short and medium term.

A large number of technically feasible wastewater treatment technologies are currently available. Ten representative systems, arranged roughly from the simplest to the most complex (primary to tertiary treatment), are selected to show the wide range of treatment capabilities and costs (see Table 17). All ten systems are proven technologies in full-scale operation in the United States. The ten wastewater treatment systems can be grouped in the following categories:

- Primary treatment (e.g. stabilization ponds (see box))
- Chemically-Enhanced Primary Treatment (CEPT)
- Primary+biological treatment (e.g. activated sludge)
- Secondary treatment (e.g. nutrient removal)
- Tertiary treatment (e.g. high lime, granular activated carbon, reverse osmosis)

Performance and Costs

Table 17 is based on two surveys of over 100 US publicly owned treatment works undertaken in 1990 and 1991 (Murcott and Harleman, 1992) and also on technical literature (National Research Council, 1993). Performance is expressed as average performance removal for TSS (total suspended solids), BOD_5 (biological oxygen demand), TP (total phosphorus), and TN (total nitrogen). Costs are expressed as capital cost, operation and maintenance (O&M) costs, and total cost. All costs are annualized costs. Assumptions include an 8 percent discount rate for a 75,000 m^3/day facility with a design period of 20 years. Land costs are not included.

	TSS	*BOD_5*	*TP*	*TN*	*Capital cost $/m^3*	*O&M cost $/m^3*	*Total Cost $/m^3*
Primary (1)	55	30	38	15	0.06-0.08	0.05-0.06	0.12-0.15
Low-dose CEPT (2a)	71	55	63	37	0.08-0.11	0.06-0.07	0.15-0.18
High-dose CEPT (2b)	92	78	93	40	0.11	0.07-0.09	0.17-0.20
Biological (3)	93	92	38	31	0.16-0.19	0.08-0.11	0.25-0.30
Conventional Primary + Biological (4)	93	95	87	31	0.20-0.23	0.09-0.12	0.29-0.35
Nutrient removal (NR) (5)	94	94	81	91	0.20-0.23	0.13-0.15	0.33-0.38
NR + Filtration (6)	98	98	88	94	0.24-0.30	0.15-0.17	0.38-0.48
NR + High Lime (HL) + Filtration (7)	99	99	99	94	0.34-0.45	0.29-0.34	0.63-0.79
NR + Filt. + Granular Activated Carbon (GAC) (8)	99	99	94	96	0.30-0.38	0.22-0.25	0.53-0.63
NR + HL + Fil. + GAC (9)	99	99	99	96	0.40-0.48	0.36-0.44	0.75-0.91
NR + HL + Fil. + GAC + Reverse Osmosis (10)	100	100	100	97	0.53-0.60	0.66-0.79	1.19-1.45

Table 17 - Performance and Costs of Wastewater Treatment Technologies

Technologies 6 to 10 (tertiary treatment) may not be considered for application to irrigation in the Gaza Strip due to their high nutrient removal and, first and foremost, their excessive cost..Technologies 9 and 10 are the only potable reuse alternatives, and might be considered at a later stage for domestic consumption, provided they become economically viable and socially acceptable.

It is often assumed that low-tech low cost solutions such as stabilization ponds require too much land in order to create an alternative for large cities. This is not entirely true. The conventional active sludge and trickling filter process requires around 0.2-0.3 m2/person. For comparison, facultative aeration lagoons require 0.3-0.4 m2/person, oxidation ponds 1.0-2.0 m2/person; and stabilization ponds 2.5-3.0 m2/person. For the Gaza Strip, the total pool area required for stabilization ponds would be 300 ha for a population of 1 million (or 1 percent of the total area of the Gaza Strip). Although this technology would probably be the most cost-effective and easiest the operate and maintain, the land requirements may be excessive in view of the scarcity of land resources in the Gaza Strip

Box 6 - Stabilization Ponds (Shuval, 1990)

Stabilization ponds are suitable for many situations in developing countries: they cost little to use, require little or no mechanical equipment, and are robust and easy to operate. What is most important, they provide an exceptionally high degree of pathogen removal, better than that achieved by most conventional wastewater treatment processes.

Stabilization ponds are simple, natural waste treatment systems consisting of large open earthen lagoons or ponds, usually 1.5 to 2 meters deep. Typically, they hold the sewage flow for 20-25 days. Although many factors -- for example, wastewater quantity and quality, climatic conditions, and the degree of treatment required -- must be taken into account in the actual design of stabilization ponds, the pond area required for warm countries is about 3 m2 per person; that is, 30 ha for a city with a population of 100,000 connected to the sewerage system. Ponds are particularly attractive for developing countries because they cost little to maintain and are robust and fail-safe. When operating, land costs and capitalization are combined, ponds cost about 6-8 times less than conventional plants. However, they should never be considered as a cheap substitute. In reality they are superior to conventional methods of treatment in all respects. They produce a biologically stable, odorless, nuisance-free effluent and rich in nutrients of value to agriculture. Stabilization ponds should be the system of choice for wastewater irrigation in warm climates, especially if land is available at a reasonable price. Effluent from stabilization ponds has been used successfully for drip irrigation in Israel and Portugal. Recently developed bubbler irrigation has eliminated clogging altogether because the equipment has larger orifices.

Chemically Enhanced Primary Treatment (CEPT) appears to be an appropriate technology to treat Gaza wastewater before its reuse in the irrigation of agricultural land. Not only are tertiary treatment levels prohibitively expensive (3-5 times the cost of CEPT), especially in cash-strapped Palestinian entity, but they remove higher levels of beneficial substance. CEPT removed only one-third of the organic matter and nutrients, allowing the remaining two-thirds to be available as fertilizer in lieu of expensive artificial fertilizers (Murcott and Harleman, 1996). In addition, considering the fact that in the Gaza Strip irrigation consists of dripping systems, tertiary treatment and probably disinfection are not necessary. Indeed, risk of infection for farmers and crops consumers typically exists when water is sprayed or sprinkled (Harleman, personal communication, 1996]. CEPT is usually accomplished by requiring minimal additional construction to conventional primary treatment plants. Therefore, little capital cost is required to convert a primary treatment plant to a chemically enhanced primary treatment plant (Murcott and Harleman, 1996). In addition, the construction of single-stage CEPT in Gaza will not close future options for upgrading them to a higher level of treatment, should effluent objectives change.

Box 7 - Chemically enhanced wastewater treatment for agricultural irrigation in Mexico City (Murcott and Harleman, 1996)

Mexico City's wastewater has not received treatment, but instead has been routed through drainage canals to agricultural districts, for use as a resource in the irrigation of farmland. However, while this wastewater reuse scheme improved crop productivity and the local economy, it has also been accompanied by a serious public health problem, namely infections with helminth eggs. The government has stated its goal: "the disinfection of wastewater with the object of eliminating pathogens" using a treatment technology that "should remove as little of the organic material and nutrients as possible in order that the treated wastewater can be used as fertilizer in agricultural production.

At projected flows of 85 m^3/s, this will be the largest urban wastewater infrastructure project in the world. Three huge wastewater plants and a number of smaller ones are planned; in addition, sludge drying beds are planned on 500 hectares.

Because the treated wastewater will be used in agricultural irrigation, its ideal characteristics would be an effluent: (1) low in pathogens (2) high in organic content (3) high in nutrient content (nitrogen and phosphorus) (4) low in toxic substances (heavy metals and organics) (5) low in salinity

Several wastewater treatment technologies have been considered to achieve the Mexican government's objectives. The most promising was chemically enhanced primary treatment (CEPT). CEPT is an appropriate wastewater treatment technology preceding reuse in irrigation, because it achieves the desired compromise between public health protection (i.e. high helminth eggs removal) and fertilizing ability (i.e. relatively low organic and nutrient removal). CEPT may be used in a single-stage process or as the first stage of a two-stage CEPT + biological process, depending on the treatment objectives. In the CEPT process, the dosage and type of coagulants can be optimized to achieve high total suspended solids (TSS) removal and, at the same time, low removal of organic material, measured as BOD or COD. The soluble organic material in the CEPT effluent provides a natural fertilizer, therefore minimizing or eliminating the need for costly petrochemical fertilizers.

The construction of single-stage CEPT plants would not close future options for upgrading them to a higher level of treatment, should effluent objectives change. In addition, CEPT allows for effective disinfection using either chlorination or UV disinfection.

That CEPT is a simple and inexpensive treatment method makes it particularly attractive for areas such as Mexico City and elsewhere coping with water resource scarcity, demographic stress, and agricultural and food supply demands . This technology would be particularly suitable for the Gaza Strip.

6.5 Desalination

6.5.1 Brackish Water Desalination

As discussed in Section 3.1.2, the salinity of the water pumped into the network is gradually increasing. In some locations, well water has already reached chloride concentrations above 1500 ppm, rendering it unfit for human consumption. This has led the Palestinian Water Authority to consider the option of brackish water desalination as a temporary measure. Brackish water desalination units would treat water from wells currently operated but whose chemical quality is deteriorated. For instance, the Municipality of Deir Al-Balah in Gaza now has a pilot reverse osmosis desalination plant to potentially partially satisfy its needs. The plant has the capacity to desalinate 45 m^3 of brackish water per hour. Brackish water with salinity of 3250 ppm is pumped from a well to the plant where salinity is reduced to 200 ppm (Frenkel et al., 1995). Unfortunately, operation of the plant has been frequently discontinued due to frequent border closures and difficulties in importing chemicals and spare parts.

A brackish water desalination plant has also been considered to supply high quality water to the proposed Gaza Industrial Estate (GIE) (World Bank, 1996). The proposed GIE would result in the employment of up to 22,000 persons in some 250 industrial firms at a site on the border with

Israel, about 5 km south of the center of Gaza City. It has been proposed is to drill 120 meter-deep into the brackish water aquifer, and provide about 800 m^3/day of potable water through the use of reverse osmosis. Reject waters (brine), which would amount to 200 m^3/day would be trucked initially and piped eventually for disposal in the Mediterranean through a dedicated ocean outfall.

Interestingly, although it had been recognized that while the potential for cross contamination of the freshwater upper aquifer and the deeper brackish water exists, this alternative has been preferred to the purchase of water from Mekorot. The cost of water produced has been estimated at \$0.40/ m^3 In January, 1997, Metcalf & Eddy International has been awarded a \$6 million contract by the US Agency for International Development (USAID) to provide design, construction management, operation and maintenance for potable and brackish water.

However, desalination of brackish groundwater does not ameliorate the crisis caused by overexploitation of groundwater, because it leads to further lowering of the groundwater table and enhances salinization. This environmental cost must be added to the cost of brackish water desalination, offsetting some of the cost benefits over seawater desalination or other alternatives. Extensive hydrogeologic studies should be carried out in order to determine the maximum sustainable yield from the confined brackish aquifer.

The costs of desalinating brackish water using reverse osmosis (RO) have dropped from about \$ 1.30 in the 1960s to \$ 0.40 - \$ 0.60 per m^3 today. According to industry experts, the costs of membrane processes should continue to decrease in line with improved membrane plant performance and improved economics associated with larger scale production of membranes. There do not seem to be any newly developing desalination technologies that will produce major reduction in overall water treatment costs. On the basis of available data, reverse osmosis (RO) of brackish water of a quality of 2000-4000 mg/l with a reduction ratio of 1:2 or 1:3 removing pollutants, sodium and nitrates to a potable level should cost approximately \$0.40-0.60 / m^3 (not including the price of pumping and piping to the nearest network) (Frenkel et al., 1995). In the Gaza Strip the salinity of brackish groundwater may increase over time because of saltwater intrusion. This could significantly increase desalination costs. It is therefore important to determine the sustained yield and long-term quality of brackish water aquifers.

6.5.2 Seawater Desalination

Desalinating seawater - using either distillation or reverse osmosis (RO) - can be from three to as much as seven times more expensive than brackish water desalination. Distillation costs are high, regardless of the salt content, due to the large amounts of energy required to vaporize water. However, seawater desalination costs have decreased markedly in the last few decades. For example, typical distillation costs in the 1940s and 1950s ranged from \$ 4 to \$ 5 per m^3. By the early 1960s distillation costs had dropped to about \$ 1.40-2.30 per m^3 (Office of Technology Assessment, 1988). Recent costs analyses indicate that distillation and seawater reverse osmosis now have comparable costs of approximately \$ 0.80 to \$ 1.00 per m^3 under near-optimum conditions. These latter costs can increase if the desalination equipment is not operated efficiently. One should mention that Israel Desalination Corps (IDE) has informed clients that "they could go down to \$ 0.65-0.70 / m^3 (ex-plant) for a large-scale project based on the successful completion of their R&D program". However, there is no evidence available to substantiate their cost projections. Dual-purpose plants (for power production and desalination) can lead to distillation cost reductions of 20 to 30 percent compared to the overall cost of separate power and desalination plants. In these plants the exhaust steam from the power plant is reused to provide the energy for desalination, thus reducing fuel consumption.

It is thought unlikely that solar energy from thermal collectors will play a significant part in the short-term application of desalination because of collection costs and overnight energy storage requirements. Fuel cost increases could alter this position in the long-term, coupled with further development in the use of solar ponds. In a study carried out in 1994 by Mekorot Water Co (Israel), a solar pond powered hybrid (distillation/reverse osmosis) system was found to have a considerable potential to be cost effective if favorable site conditions exist. It was also concluded that only for very low specific solar field cost and/or high commercial electricity prices would the fully solar options be more cost competitive than the partial solar options (Glueckstern, 1995).

Extensive consideration is currently being given to the question of large-scale desalination in the coastal region, including schemes that would derive hydropower from Mediterranean Sea - Dead Sea or Red Sea - Dead Sea canals. The inter-sea canal project seeks to capitalize on this 400 meter differential to produce water and electricity. It is estimated that a canal connecting either the Mediterranean or Red Sea to the Dead Sea could significantly improve energy production and could supplement water resources by as much as 600-800 million m^3 of desalinated water annually. According to a preliminary study by the Israel Ministry of Energy and Infrastructure, the Gaza-Dead Sea alignment appears to be the most cost-efficient and possibly to most expedient of all alternatives to implement. Estimated required investment comes to \$3.5 billion, and the cost of desalinated water would be as low as \$0.40/ m^3 (discount rate: 5 percent) (Government of Israel, 1995).

In addition to financial constraints due to high capital and operation costs, seawater desalination in Gaza would be problematic for a number of reasons:

- There are no indigenous sources of energy in the Gaza Strip. All the electricity is imported from Israel. A \$100 M large combined cycle power has been proposed for Gaza that would ultimately provide power for much of the area. However, this power would not be available over the short term.

- Gaza - which has virtually no industrial base - will lack the technical and organizational ability to implement and operate a desalination project. Its management will require major investments in human, technical, and organizational resources at the national level.

- Excessive reliance on large-scale desalination may render a country particularly vulnerable to terrorist attacks or acts of war; a clear illustration of those risks was provided by the destruction of several plants in Saudi Arabia and Kuwait during the Gulf War.

6.5.3 Selection of an appropriate technology

Selection of the most appropriate technology depends on many site-specific factors including the concentration of organic and inorganic material in the feed water, the desired quality of the treated water, the level of pretreatment that may be required prior to desalination, the availability of energy and ease with which waste concentrates can be disposed (Office of Technology Assessment, 1988). However, cost remains the primary factor in selecting a particular desalination technique.

Type of water	Brackish water	Brackish water	Seawater	Brines
Salinity (ppm)	0-3,000	3,000-10,000	35,000	higher salinity
Distillation	t	s	P	P
Electrodialysis	P	s	t	P
Reverse osmosis	P	P	P	s
Ion exchange	P			

P: primary application,   t: technically possible, but not economic
s: secondary application

Table 18 - Desalination techniques and typical applications (Office of Technology Assessment, 1988)

Figure 25 illustrates the cost breakdown of reverse osmosis systems for brackish (2,500-6,000 ppm TDS) and sea water (40,000 ppm TDS).

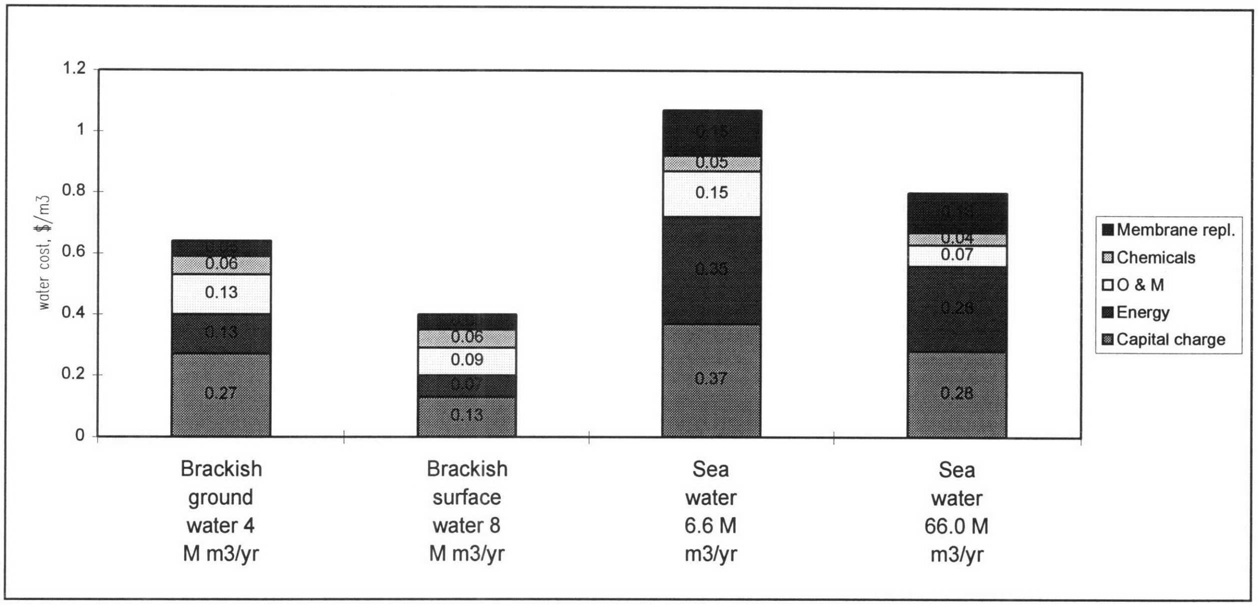


Figure 25 - Cost estimates of Large RO Systems (Glueckstern, 1991)

6.6 Virtual Water

While issues of local and inter-regional water marketing and trading are still the subject of considerable debate, increasing quantities of water are indirectly traded in the region and the rest of the Middle East. Virtual water, that is the water contained in food imports or exports - not only the actual water content but also the quantities used to grow the crop - is now a significant contribution to the water budgets of most countries of the region. This fact is typically overlooked in most water planning exercises. However, the quantities of water at stake are huge. For instance, because 1000 tons of water are needed to grow 1 ton of wheat, the decision to import one ton of wheat - instead of growing it at home - results in the saving of a quantity of irrigation water one thousand times bigger. Figure 26 illustrates irrigation water use per ton of crop produced in Gaza.

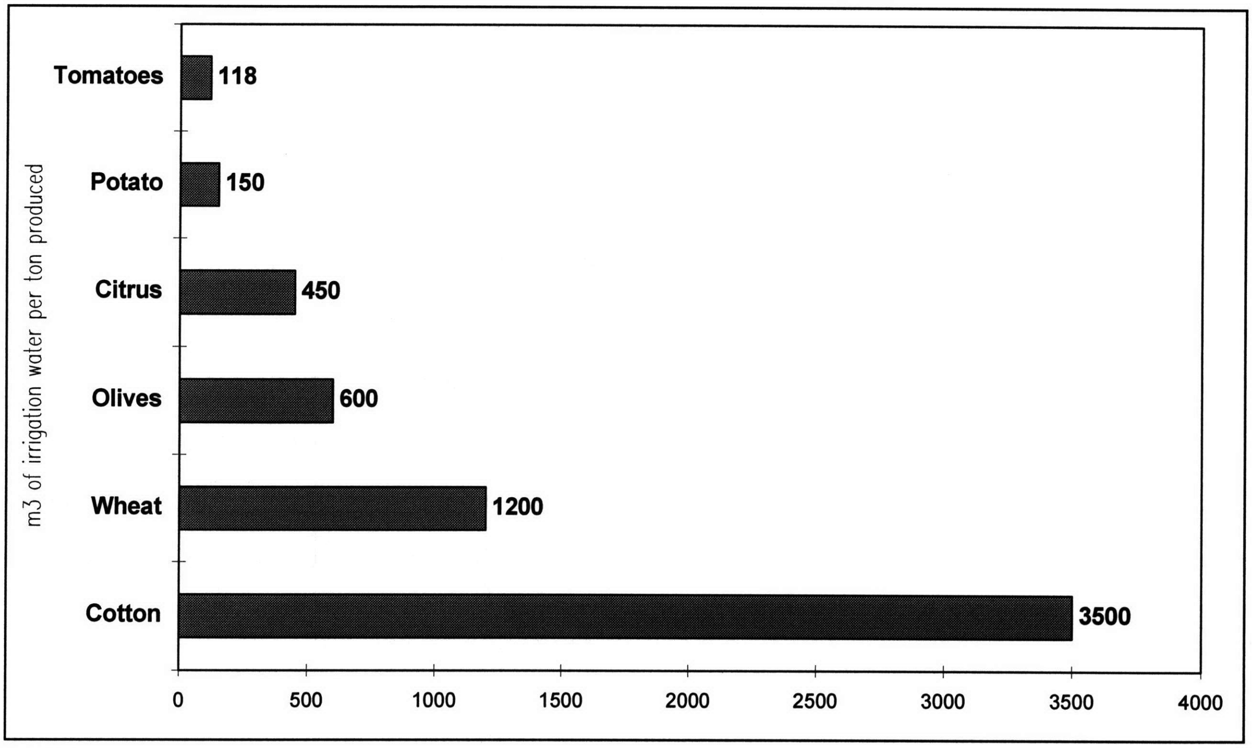


Figure 26 - Irrigation water use for selected crops (per ton produced)

The economy of water in the Middle East depends on the economy of global trade in water supplies. Virtual water, priced for two decades at much less than its production costs on the world market, has been a remedy to the Middle East's water deficit. Countries in the Middle East region are the most dependent on imported cereals, importing an average of 56 percent of their total cereal consumption, up sharply from 39 percent in 1970 (Ingco et al., 1996). It has been shown that the option of moving virtual water has proved to be an extremely effective and economically efficient method of meeting water deficits (Allan, 1996). Virtual water allows water-short economies to balance their water budgets without confronting water using interests.. Policy-makers have done so in the Middle East for the past 25 years when water has been priced advantageously through subsidies born by producers in industrialized countries (Allan, 1996).

Recognition of the increasing severity of the problem of shortage of water in the area has led many researchers and politicians to the assumption that the future of the area is linked to the issue of water, and they believe that water will be the main cause of a future regional armed conflict. Thus Frey and Naff (1985) argued as follows: " The shortage of water is a zero-sum security issue and thus creates a constant potential for conflict". Actually, they do not realise that, taking the economic approach water is not a zero-sum, because it is expendable when food is imported, and armed conflict is thus prevented (Medzini, 1996). The import of food from the world market is the most effective means of compensation for water shortage. At the same time it must be recognized that wealthy countries generate enough income to handle food imports while poorer countries, such as the Gaza Strip, will need to develop their economies. Meeting future food requirements such as food means that exports will have to grow; in the region merchandise exports are the biggest opportunity for the future if there is sufficient progress on trade liberalization and competition policies (Ingco et al., 1996).

As surprising as it might appears, water-short Gaza is exporting large quantities of water to Europe and other Middle Eastern countries. In 1996, Gaza citrus exports were equivalent to more than 30 million m^3 of water, that is, three-quarters of the total domestic water demand. current Europe and the US. Exports of water - even from water-short countries - might be reasonable if the marginal benefit from water embedded in crop exports is higher than the marginal cost of new water supplies. However, Gaza citrus exports are priced at less than \$0.30/ m^3 (see Section 5.5). It means the marginal benefit from water - obtained by deducting the cost of non-water inputs - is much less than \$0.30/ m^3, probably zero or even negative. In Israel exports of virtual water - more than 300 million m^3/year or slightly less than total domestic and industrial consumption - contributed to less than 0.4 percent of the GNP.

The cost of imported virtual water for a given crop can be calculated as follows:

$$PVx = \frac{PMx - Cx}{qx}$$,where:

PVx: market price of crop x

Cx: total cost of non-water inputs in crop was grown locally (land, labor, fertilizers, irrigation systems)

qx: water consumption for crop grown locally

For instance, assuming that the price of wheat on the world market is \$200 per ton, the cost of non-water inputs is \$100/ton of wheat, and the water consumption for wheat grown locally is 1000 m^3/ton of wheat, the cost of virtual water is only \$0.10/ m^3.

This example points clearly to what is the most important point to bear in mind with regard to irrigation water, namely that it is possible to substitute other inputs for water. Instead of using 1000 tons of water to produce one ton of wheat, it is possible to spend \$200 and to purchase the same weight of the crop on the world market. Allan (1996) valued the cost of virtual water for Egypt at \$0.10/ m^3, which is significantly below the real cost of existing water (\$0.25/ m^3).

Virtual water is a cheap and attractive source of water, provided the importing country generates enough exports to afford purchases on the world food market. Importing water from foreign sources at a costs above \$0.50/ m^3 (e.g. from Turkey or Egypt) for use in irrigation is certainly less efficient than importing food (or virtual water) at costs less \$0.10/ m^3.

Figure 27 illustrates the steady decline of the cost of virtual water for wheat between 1960 and 1996.

One way of distributing scarce water resources would be to let the world food market do its job. Reliance on the market to distribute food is now increasing worldwide. Whenever demand outruns supply, the prices rises, reducing demand while encouraging additional supply. From a purely economic standpoint, the market does a good job of balancing demand and supply and distributing food. But from a social point of view, rising food prices can quickly produce a life-threatening situation for the world's poorest (Brown, 1996).

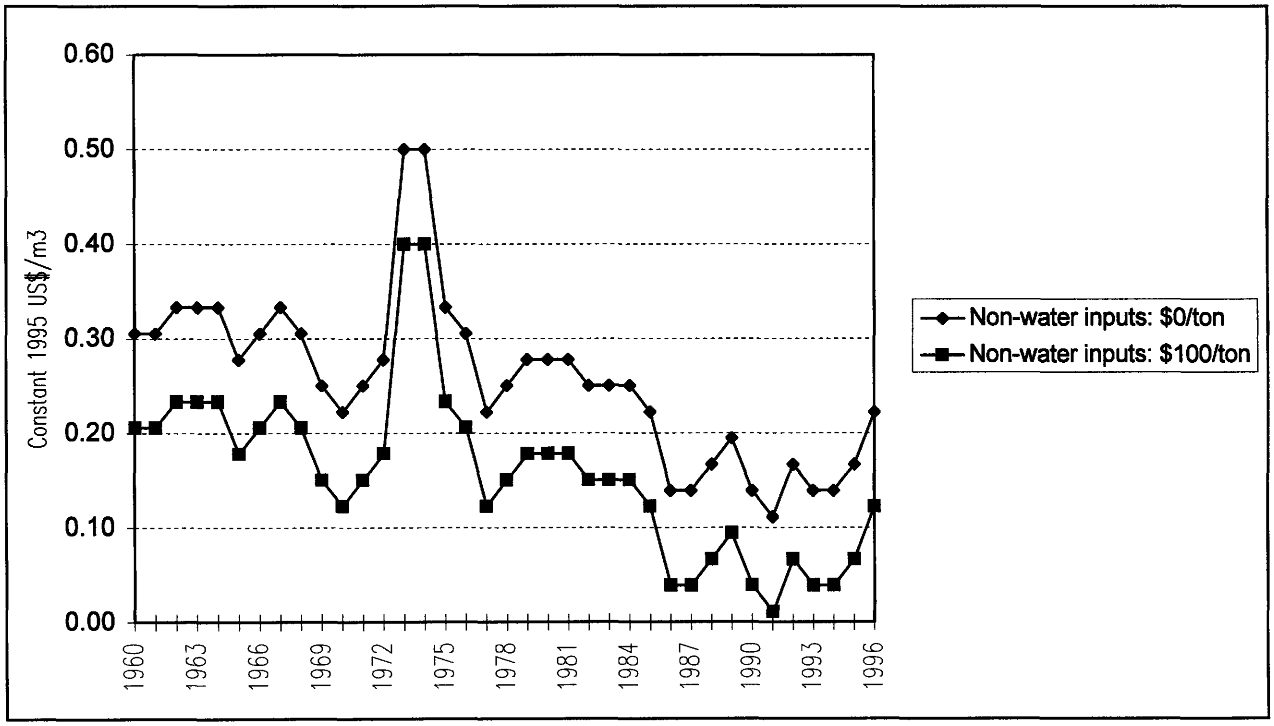


Figure 27 - Cost of virtual water for wheat, 1960-1996 (adapted from Ingco et al., 1996)

For Gaza camp residents who already spend 70 percent of their income on food, even a modest rise in food prices can threaten survival. Rising food prices could lead to potentially unmanageable inflation, abrupt shifts in currency exchange rates, and widespread political unrest. The riots that recently took place in Jordan, following an increase of the price of bread, illustrate the potential dangers of rising food prices.

There is some controversy among agriculture and water experts as to whether cereal world prices will increase in the future. The cost of virtual water will be closely linked to the situation on the world food market. Figure 28 shows an overall decline in cereal prices in the past 35 years.

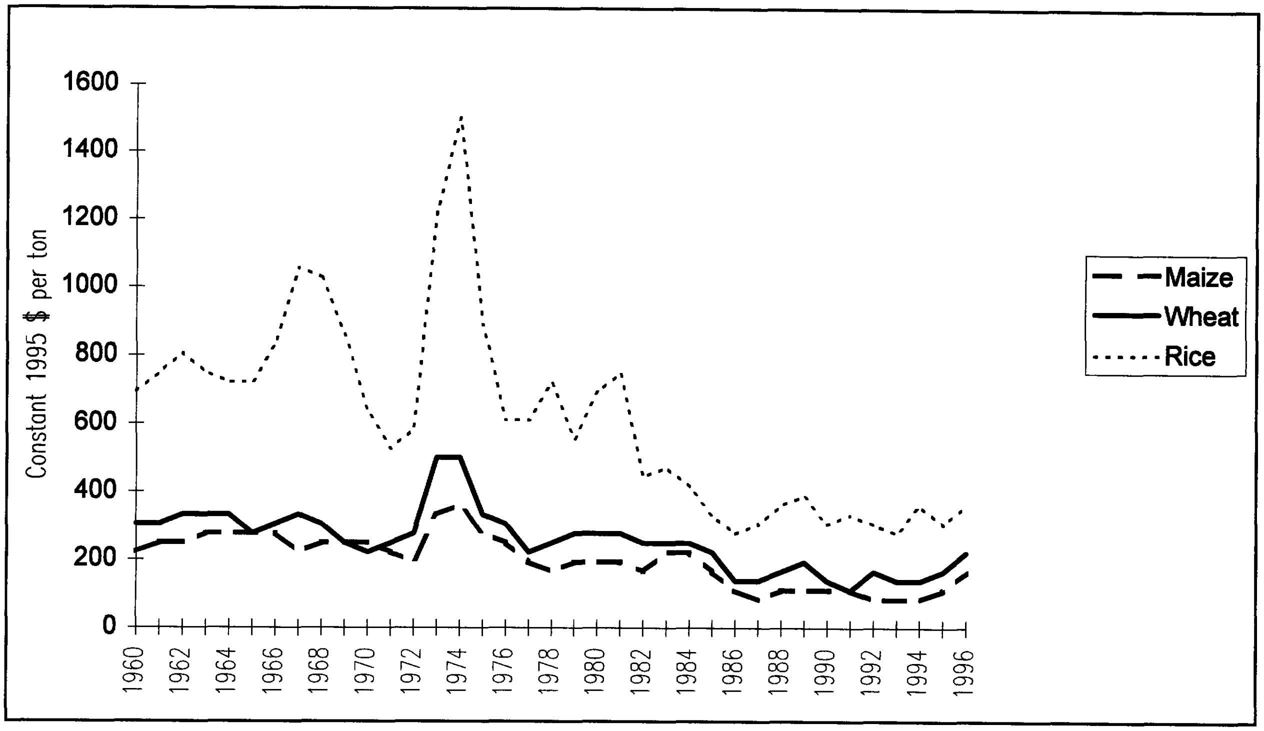


Figure 28 - World Prices for Maize, Wheat, Rice, 1960-1996 (Ingco et al. 1996)

Only very recently did prices rise significantly. Some argue that the growing demand for food, notably due to the entry on the market of China and India, will put pressure on limited supplies, and that prices would rise in the near future. Authors such as Brown (1996) have argued that rising population and incomes will cause China's demand for food, especially meat, to rise faster than supply, causing large increase in imports and sharply higher world prices. In response to these predictions, Crosson (1996) pointed out that Brown failed to consider the fact that the steeply higher grain prices that he foresees would have demand-reducing and supply-increasing effects, and that they are huge areas that could be potentially reclaimed, including the US and Europe where a significant share of cropland has been frozen due to falling prices.

Even if world grain prices doubled, cost of virtual water for cereals would remain in the \$0.20-0.30 range, well below the marginal cost of additional supplies (such as desalination at a cost of \$1/ m^3). Therefore, virtual water would still remain a very good deal. In addition, there is still no engineering measures which could mobilize the between 20 and 30 billion m^3 per year of water needed to produce the grain being imported annually into the Middle East (Allan, 1996).

Demographic circumstances dictate that the Middle East food and water gaps can only increase in the future.

Projections of the world food situation over the next ten to twenty-five years by researchers at the Food and Agriculture Organization (FAO), the Food and Agriculture Policy Research Institute (FAPRI), the International Food Policy Research Institute (IFPRI), the U.S. Department of Agriculture (USDA) and the World Bank are for slower food demand growth and declining real prices. IFPRI projections show a relatively good global food supply and demand balance in 2020. Food production grows fast enough to cause real cereal prices to fall nearly 20 percent between 1990 and 2020. China's grain imports are expected to increase, but not beyond levels that can be supplied by world markets. India is expected to remain nearly self-sufficient in grain (Ingco et al., 1996)

The recent Uruguay Round Agreement on Agriculture is expected to lead to small increases (about 4 percent) in world grain prices and to higher world grain trade. Currently, about 10 percent of world grain production is traded but this percentage will grow as countries are liberalizing their agricultural policies. With a more open trading regime, countries will specialize in producing the commodities that are most profitable for them (Ingco et al., 1996). Water-short countries will eventually come to the conclusion that they are better off by importing grain while reallocating scarce water to higher value uses, and refrain from costly policies of food self-sufficiency.

Decision-makers in the Middle East argue that the chronic political instability in the region forces countries to adopt food self-sufficiency policies. However, food production depends on energy, for which Gaza, Israel and Jordan are completely dependent on imports. For instance, in Israel 20 percent total energy consumption is used to operate water systems, notably the Israeli National Water Carrier. A potential embargo on energy supply would interrupt the operation of water systems, cutting off the water supply to irrigated fields. Increased reliance on food imports (or virtual water), from sustainable and diverse sources, might provide countries in the region with more security than alternatives such as desalination or inter-regional water imports.

6.7 Weather modification

Significant increases in long-range precipitation of the order of 10-20 per cent have been reported worldwide; in Jordan, pilot experiments were carried out using seeding aircraft. The increase in total rainfall was in the range of 20 percent over an area of 8,000 km^2 in the northern part of Jordan (United Nations, 1985).

However, rain-making is a very risky business and its success is not easy to document statistically. Because of the high risks involved, many communities depending on rain would not want to invest in such a venture. Moreover, during a dry or drought period, there are generally not enough clouds suitable for seeding. The technology works better during wetter periods and is most useful for filling reservoirs or recharging aquifers (UN, 1985).

The costs involved with cloud seeding are unknown.

Chapter 7
Optimizing the allocation of water

Several options have been defined and analyzed in Chapters 5 and 6. The development of a comprehensive analytical is required to define priorities in the implementation of alternatives. Given the large amounts of complex quantitative and quantifiable information available, models can be used to quickly evaluate the consequences of various policies. Optimization models should be developed to assist in the appraisal of alternatives, the ranking and selection of projects, under various socio-economic scenarios. Economic models are useful for assessing the social, environmental, and economic effects of development and management policies. Models can assist managers by revealing opportunities for improvement and providing insight into problems that would not be apparent through other means. Actual decisions, however, are constrained social, legal and political considerations and are therefore often influenced by subjective, nonquantifiable criteria. The solution that is technically and economically optimal may be socially unimplementable or politically unacceptable. However, decisions can still be made on the basis of systematic analysis. There is no reason why a model cannot be developed so that the current decisions can be linked to the long-range objectives.

7.1 Framework

The economic nature of the design of water allocation policies and their integration with other water-supply-management measures encourages the use of optimization models, in which the model itself suggests promising combinations of existing and new water options. The water allocation and management options discussed in previous chapters can be integrated in the following analytical framework

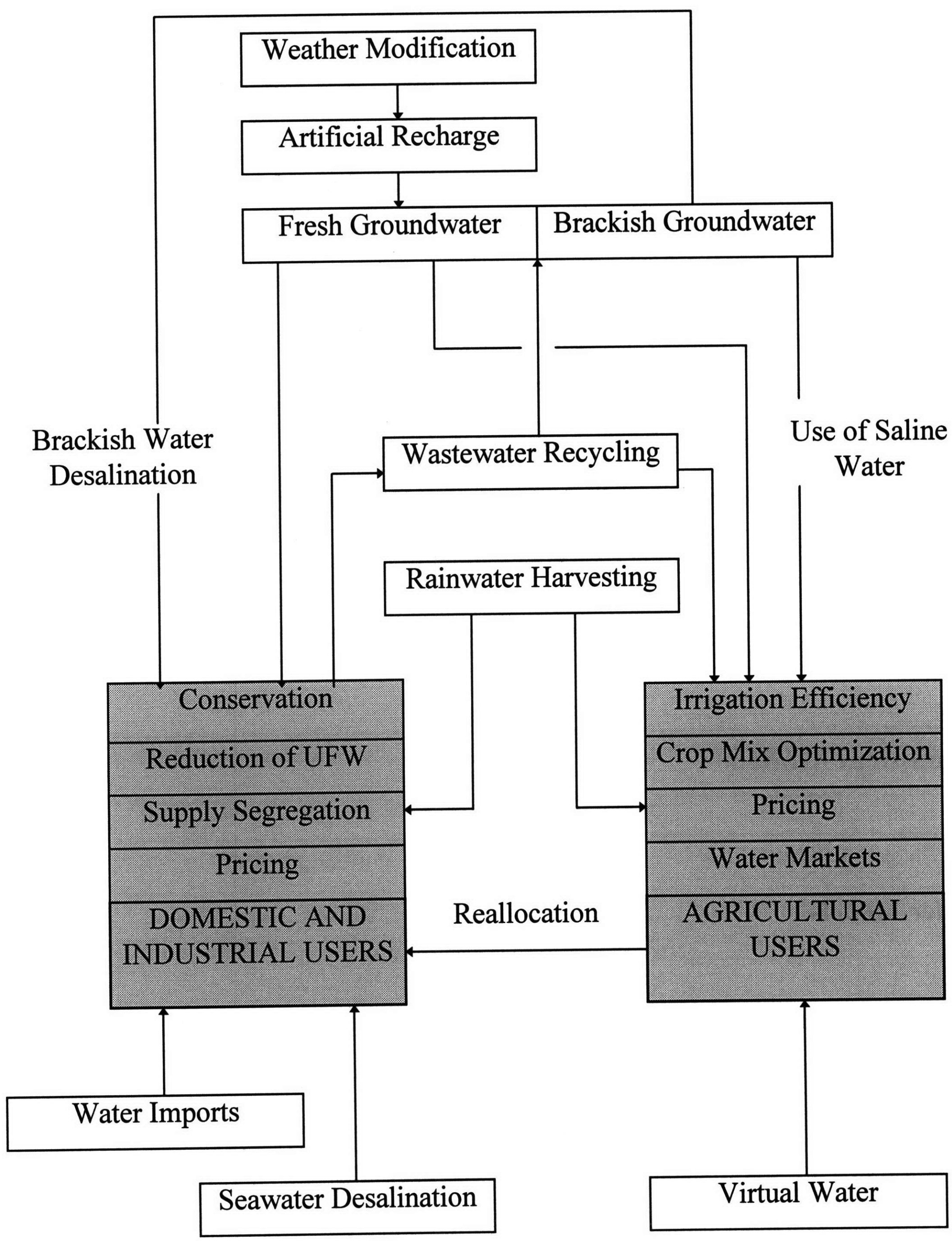


Figure 29 - Optimization Framework

7.2 Analytical tools

In this section, technical and economic models are reviewed. A number of technical models are available in the literature, while fewer attempts have been made to develop economic models. It should be remembered that one of the basic rules of modeling is that models should be kept simple. Ideally, a model should be only as complex as necessary to obtain the information desired. Managers and decision makers prefer simple models that they can understand to complex models whose assumptions may have been hidden and whose outputs may be the result of obscure mathematical manipulations (Biswas, 1985). In general it is worthwhile not to build generalized all-purpose models. They are difficult to understand, except perhaps by specialists, and therefore their acceptability to the decision makers is suspect. The success of a model is often defined by the role users have played in its development. User involvement promotes a greater sense of ownership and enhances communication - perhaps the single most important success factor.

7.2.1 Technical Models

Groundwater Models

Initial efforts to support and improve the development and operation of groundwater systems by simulation and optimization techniques were made in the early 1970s (Maass, 1964 Loucks, 1973). Since then, various types of groundwater management models have been proposed and successfully applied to real-world aquifer systems. Reviews on the types of groundwater management models and their applications are made by Gorelick (1983), Willis and Yeh (1987), and Yeh (1992). Applications of groundwater management models to the optimal control of saltwater intrusion in coastal aquifer systems are presented by Shamir et al. (1984), Willis and Finney (1988), and Finney et al. (1992). While a number of groundwater simulation models have been developed for the management of groundwater resources in the Gaza aquifer system, none have focused on determining optimal development and operating policies via combined simulation-optimization methodology.

An accurate model of groundwater flow is a prerequisite in developing reliable groundwater management models. Abu'Juub (1995) conducted an extensive modeling study of the Gaza aquifer using available data on aquifer hydraulic properties, water levels, and withdrawal rates. Several groundwater management models can be constructed to provide decision-makers with optimal management policies to aid planning and operation of the Gaza aquifer. The factors considered important in the development of the management models are (1) controlled aquifer drawdown (2) meeting water demands (3) preservation of groundwater quality and (4) well-capacity limitations. The prediction of hydraulic head at each well location can be represented in terms of a response matrix. Drawdowns can be constrained so that they do not exceed their allowable limits. For the Gaza coastal aquifer, the main concern is that groundwater development does not lead to further intrusion of saltwater into the aquifer that could cause a worsening of water quality in the wells. Optimal control models have been presented (Willis and Finney, 1988, Finney et al., 1992) in which movement of the freshwater-saltwater interface is modeled.

Extensive parametric analyses should be conducted in the Gaza Strip to assess the effect of allowable drawdowns at the saltwater-control nodes, as well as lower and upper limits of well pumpages or recharge on the optimal aquifer yield, aquiferwide drawdowns and pumping costs. It should be determined by how much the current water demands should be reduced to maintain acceptable drawdowns at the saltwater-control nodes.

For a management objective of minimization of the basin-wide drawdowns, the wells located in highly conductive zones and closer to the constant-head boundaries should be operated. Whereas, for a management objective of minimization of the pumping costs, water demands should be met from wells having low static lifts. It may be possible to reduce the pumping costs if the excess water pumped at low-cost wells is transported to those with high costs. However, this has to be traded off against the cost of water conveyance facilities that may be required

Development of an optimal pumping strategy to control groundwater quality can also be formulated and solved as a multiobjective optimization problem (MOOP). A MOOP is characterized by conflicting objectives subject to different physical, managerial and economic constraints. It determines the optimum value of a vector objective function subjected to specified system constraints.

Network Design Models

The objective is to find the lowest cost network which can supply the demands under the given engineering and technical restrictions (e.g. pressure). Numerous solution methods have been developed to solve the network optimization problem, using different formulations. They range from rules of thumb, based on engineering experience and insight, through heuristic used for specific network types, to optimization by mathematical programming techniques. The last category includes linear, nonlinear, dynamic and mixed integer programming. The linear programming gradient (LPG) method was introduced by Alperovits and Shamir (1977). Eiger and Shamir (1994) developed a branch and bound algorithm, which demonstrate its superiority over previous methods.

Ostfeld and Shamir (1996) developed a methodology which integrates the optimal design and reliability of a multiquality water-supply system. Multiquality water-supply systems are distribution systems in which waters of different qualities are taken from sources, possibly treated, conveyed, and supplied to consumers.

McKinney and Watkins (1997) introduced robust optimization (RO) as a framework for evaluating trade-offs among expected cost, cost variability, system performance and reliability, and controlling the effects of uncertainty in water resources screening models.

Water Management Models

Alkan and Shamir (1980) employed multiobjective optimization method to plan the development and seasonal operation of a regional water resources system. They considered an arid region in the south of Israel. Six objectives were considered for the planning problem. Spatial and temporal variations in demand and supply of water were considered.

Brimberg et al. (1993) presented a management model for the optimal development of marginal water sources in arid zones in conjunction with minimizing the dependence on high-quality water. These marginal sources included saline groundwater, treated wastewater and runoff water that are required to augment limited regional supplies. A novel aspect of the model - taking the form of a mixed binary integer linear problem - was the consideration of water quality as an additional constraint in the decision model. The model was applied to a case study of the Negev Desert in southern Israel: an important conclusion was that saline groundwater production should be increased dramatically for use in irrigation of salt-resistant crops. This model would be particularly relevant to the Gaza Strip.

System-analysis techniques can be of special use in the study of existing and potential water transfers, since simulation and optimization models allow various promising alternatives and combinations to be identified with less trial and error. Lund and Israel (1995) developed a two-stage nonlinear program that illustrates the potential value of system-analysis techniques in designing urban water systems with supply uncertainty, water conservation, and several types of water transfers.

Multi-criterion decision-making (MCDM) theories provide efficient tools to deal with operations research problems containing more than one objective. Using a quantitative technique called ELECTRE. Netto et al. (1996) attempted to put into practice extended MCDM concepts in a real case study from the very beginning of the decision process. Water resource planning is an area where MCDM techniques can be efficiently used to help decision makers, as reviewed earlier in Cohon and Marks (1975).

7.2.2 Economic Models

Water supply projects in developing countries have been largely spared from critical examination by economists. Generally speaking, neither donor agencies nor national governments look carefully at the economics of investments in urban or rural water projects. For example, for the great majority of recent World Bank-financed water supply projects, no attempt was made to estimate the economic benefits of the investment. The standard practice is to carry out a financial analysis in which the benefits of the project are the revenues from water sales. The lack of economic appraisal of water projects has occurred for two basic reasons. First, governments and donor organizations have defined water as a basic right, and therefore there is no need to estimate the benefits of water supply projects, because they have implicitly been assumed to be infinite. Second, the benefits of an improved water supply often prove difficult to measure (Whittington, 1994). Also, water sector policy analysts contend that economics can only be used to evaluate options which have been identified or invented by others. Economics, therefore, typically serves to stop mistakes rather than to identify new and better solutions. However, economic analysis can be particularly useful in situations where, like in the Gaza Strip, the demand for water - at a certain price - exceeds its supply, and where transfers between users are technically and politically feasible. Optimization models can allocate water to maximize the use value of water (the objective function), subject to satisfying a number of constraints.

7.2.2.1 Agricultural models

Agriculture is the main water consuming sector in the Gaza Strip. As shown in Section 5.5, there is scope for crop mix optimization in Gaza. For instance, citrus consume more than half of total irrigation water (or 40 million m^3 per year) but generates only 13 percent of total agricultural income. .The trend is already toward the replacement of citrus by higher-value crops such as tomatoes or other vegetables and will likely continue in the future. The concept of measuring the value of water by its incremental contribution to agricultural income can be developed.

Amir (1996) developed a linear programming model as a decision support tool for planning agricultural production under various water amounts, qualities, timing and prices. By selecting the optimal mix of water consuming activities (crops and fishponds), the model maximizes the annual agricultural net income of a given area. The constraints are mainly water requirements for each combination between four qualities of water (fresh, recycled, brackish and surface), and three seasons (winter, transition and summer). The decision variables are the land areas of the activities. The main components of the agricultural model are shown below (Amir, 1996):

a. Objective function:

$$\max Z = X_i [\sum_j WRC_j - \sum_{i,j} (P_i W_{ij})]$$

where: WRC_j: water related contribution, defined as the gross income of an area unit of the activity *j* minus the direct expenses (machinery, labor, materials, fertilizers), except the expenses for water

P_i: price of 1 m^3 of the *i* water type (quality and season), *i* = 1,...,12;

W_{ij}: demand of water of type *i* for an unit area of the activity *j;*

X_i: land area of the activity *j* (*j*=1,...n decision variables)

Area constraints:

$$\sum X_{jk} \leq A_k$$

where: X_{jk}: area of activity j in the category k;

A_k: total area available for category k

The constraints ensure that the sum of the areas of the crops under each category k will not exceed the area available for that category. The categories are: all activities, all irrigated activities, crops of the same group (field, orchards, flowers, etc.), crops irrigated by the same water quality (fresh, recycled, brackish, surface), crops grown during the same season

Water constraints:

$$\sum W_{ij} X_j \leq W_i$$

where: W_{ij}: demand for water type i per unit area of crop j

W_i: total available amount of water type i

7.2.2.2 Gain-From-Trade Models

The Gaza Strip has an environment where water use is limited by resource scarcity and where the value of water varies between different uses. Thus, provided conveyance systems and appropriate water institutions are in place, trade for water-use rights is expected, both between farmers and urban users and amongst farmers. A farmer would be better off selling water-use rights if the present value of these rights – calculated as the expected value of the discounted marginal product of water – is less than the price offered by a buyer (Hearne, 1995). The difference between the value of the water-use right to the buyer and its value to the seller is society's gains-from-trade.

These concepts can be formalized using the following equations (adapted from Hearne, 1995). Let us assume that each farmer plants one crop in a particular location every year. The value to a farmer i of an endowment of water-use rights $V_t^i(W_t^i)$ is the present value of a discounted stream of profits that can be earned with the use of the water:

$$V_t^i(W_t^i) = \sum_t \frac{(\Pi_t^i(W_t^i, R, P)}{(1+r)^t} \quad t=(1,2,3,...)$$

where: Π_t^i: farmer *i*'s profit function in year *t;*
W_t^i: pre-determined quantity of water-use rights available to farmer *i* in year *t*;
R: a vector of exogenously input prices;
P: the exogenously determined output price

Given an alternative cost of acquiring these water-rights, $P_t^{W(A)}$, the buyer's (e.g. a municipality or an urban water company) maximum willingness-to pay for water-use rights, $V_t^U(w_t^*)$ can be determined as follows:

$$V_t^U(w_t^*) = P_t^{W(A)}\ w_t^*(P_t^X, P_t^W, W_{t-1}^U, D_t^*)$$

where: w_t^*: water rights purchased or obtained through alternative means by the buyer (e.g. urban water company) in year *t*;
P_t^X: a vector of input prices;
P_t^W: the least cost input price of water rights that are either purchased or obtained through alternative means
W_{t-1}^U: the buyer's stock of available water rights in year *t*;
D_t^*: the amount of water that the buyer (urban water company) is required to supply to its customers in year t

For simplicity, assume that an urban water company is buying water-use rights w from farmer i. The net gains-from-trade to society from this transaction is the difference between the value of the water to the buyer and seller less the transactions costs:

$$GFT_t^{U,i}(w) = [\ V_t^U(w) - V_t^i(w(\ W_{t-1}^i - w))] \text{ - } TC^{U,i}(w)$$

where:: $GFT_t^{U,i}(w)$: the gains-from trade to society of a transfer of w from farmer i to the buyer (municipality, water company)
$TC^{U,i}(w)$: the total transactions costs of a transfer of w from farmer i to the buyer (municipality, water company)
$V_t^i(w(\ W_{t-1}^i - w))$: the value of water-use rights w, as a percentage of the average value of total post-trade water-use rights $(W_{t-1}^i - w)$

7.2.2.3 General Microeconomic Models

The demand for water is a factor of economics, specifically the quantities of a commodity that consumers are willing to purchase at various prices. Demand is specified by two variables: quantity and price. Depending on the users and the markets, demand curves for water can vary significantly. For instance, consumers are willing to pay very high prices for residential and commercial water; industrial users are willing to pay considerably less, and agricultural users pay the least. Only small quantities are demanded at high prices and large quantities are demanded at low prices (Rogers, 1993).

The supply curve is created by arranging, in ascending order of cost, the supplies from various sources and at different costs. For example, the first step of the curve would be surface water cost ($0.2/ m^3), the second, groundwater ($0.3/ m^3). The next least expensive would be wastewater reclamation ($0.5/ m^3), and so on until desalinated water which is available in almost infinite quantities but at a high price ($1.2/ m^3).

Economic efficiency requires that:

- marginal benefit of use must be equal or greater than marginal cost of supply
- marginal benefit per unit of resource is equal across all uses

In theory it is possible to derive demand and supply curves which show:

- the marginal benefit obtained from consumption (and the willingness to pay)
- the marginal cost of supply and the willingness to supply at given prices

The most efficient economic solution occurs when the amount a consumer is willing to pay matches the supply price. Accordingly, the market would be at equilibrium at Q=Q* and p=p*, thus maximizing the net benefits from water (shaded area) (see
Figure 30).

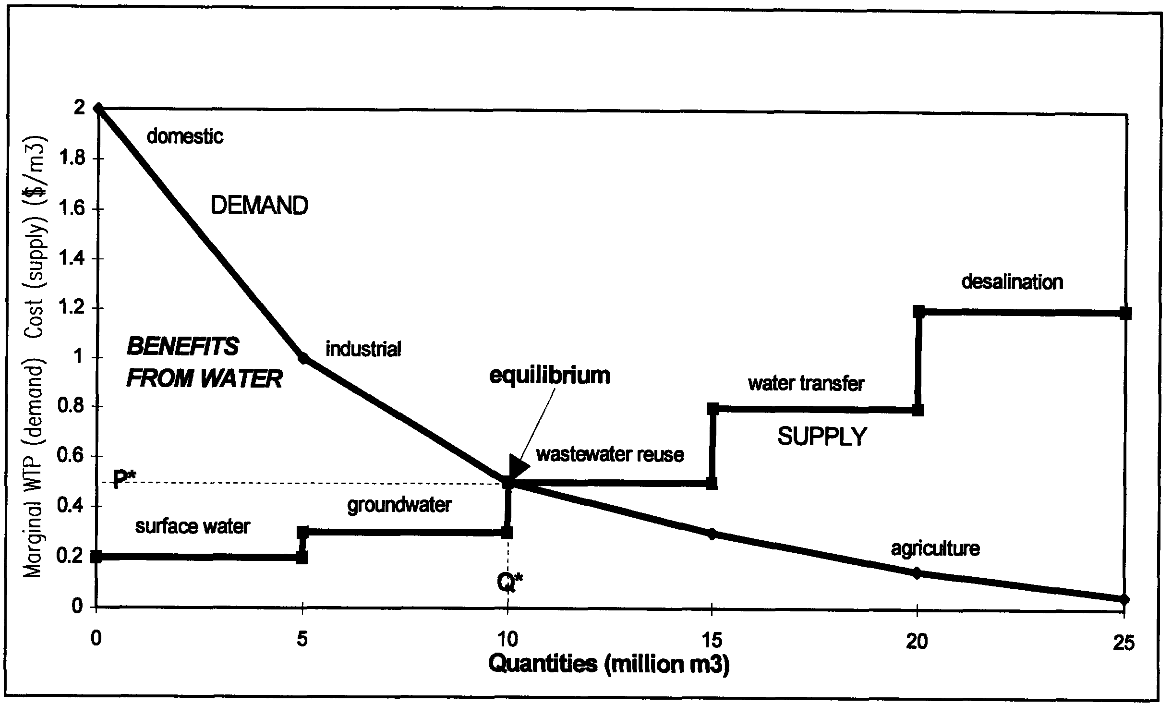


Figure 30 - Supply and Demand Curves

Economically efficient water allocation is derived from the maximization of the aggregate annual economic benefits to both water sellers and water buyers, given water availability in any given year. This approach has been proposed by Fishelson (1993) and Fisher et al. (1995). This procedure determines water transfers between water sources (e.g. groundwater, wastewater) and users (domestic, agricultural sector). Let:

q_{ij} be the amount of water supplied by source j to user i;

q_{*j} be the total amount of water supplied by source j, $q_{*j}=\sum_i qij$, j = 1, ...,n;

q_{*i} be the amount of water consumed by user i, $q_{*i}=\sum_j qij$;

q_j be the annual amount of water available to source j; the q_j are assumed to be independent, stochastic variables with known means $E(q_j)$;

$c_{ij}(q)$ be the cost function of transporting q units of water from source j to user i; this cost is assumed to be paid by the consumers;

$$\frac{\partial 2cij}{\partial q2} \geq 0, \ \frac{\partial cij}{\partial q} \geq 0$$

D_j (q) is the inverse demand function for water of user i;

S_j (q) is the inverse supply function in source j;

The economically efficient allocation of region's water resources is derived, for each realization of the q_j, from the following optimization:

$$\max_{qij} \sum_i \left(\int_0^{qi*} D_i(q)dq - \sum_j cij(qij) \right) - \sum_j \left(\int_0^{q*j} Sj(q)dq \right)$$

s.t. $\quad q*_j \leq qj \forall j$

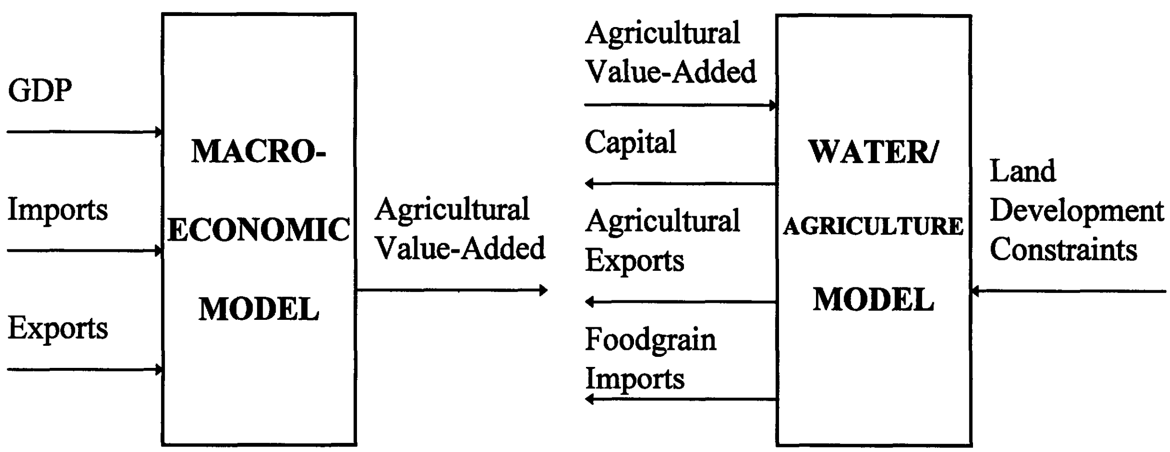
$\qquad q_{ij} \geq 0 \ \forall \, i,j$

This optimization maximizes the net benefit from water, that is, the area between the demand curve and the marginal cost curve. Thus, Q* is the optimal amount of water to deliver (Figure 30). If the constraint on the quantity of water at a particular supplier is not effective (compared with the demand for this water), then the water at source j is not scarce, implying that the shadow price of water at j, reflecting the scarcity rent associated with the resource, would equal zero. In this case, the cost to user i of source j water would equal marginal extraction cost plus marginal transfer cost (from source j to recipient i). The differences in conveyance cost vary accordingly for different buyers. When the quantity of water supply at source j is binding, so that $q_{*j}=q_j$, the shadow price of water at the source would be greater than zero, that is, scarcity rent is now strictly positive, and would be added to the other costs to reflect the full opportunity cost of water.

7.2.2.4 Macroeconomic Models

It is particularly important to gain a better understanding of the role of water in the economy. Water contributes to the economy to various degrees. For instance, industry and services can provide a thousand times more jobs and 20000 times more financial return than would a crop producing enterprise using the same amount of water (Allan, 1996).

Rogers et al. (1993) challenged the traditional approach of water resources planning in developing countries. Their proposal is a methodology that attempts to establish the link between the water resources investment sector and macroeconomic policies. They propose to cast the evaluation of water projects more broadly across sectors, including the overall economy. Given the size of water investments in developing countries economies, they call for some understanding as to the strategic importance of public investment situated in one sector. Rogers et al. built a economy-wide model for Bangladesh which incorporated a detailed water sector and its macroeconomic linkages. Figure 31 shows the inputs and the outputs of these models. Typically, the models would be used separately by different agencies within a country with little or no coordination of the solutions.



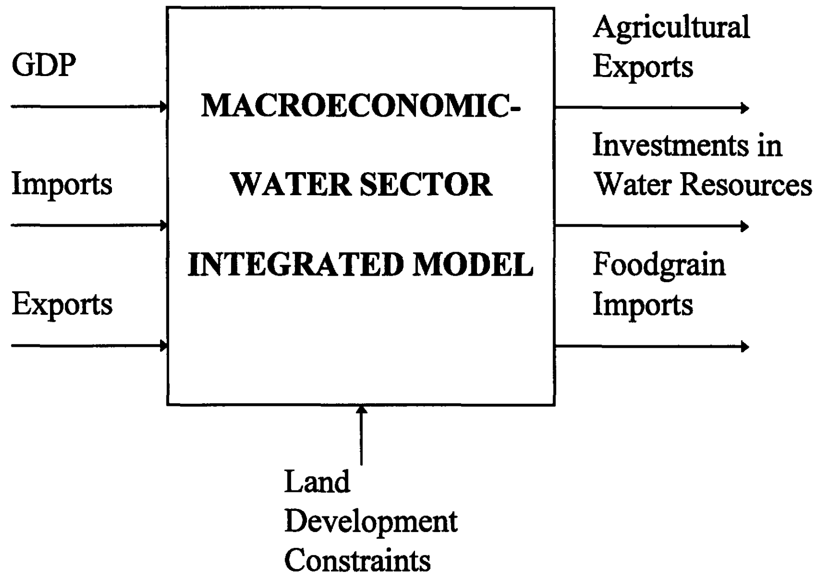


Figure 31 - Schematic of the macroeconomic models (Rogers, 1993)

Rogers et al. proposed the integration of the two models into one optimizing model as shown in Figure 31. They argued that by doing so, it would force the institutions involved in the planning process to integrate their plans and provide output that is relatively easily understood by the policy makers.

Input-Output Models

An approach using input-output techniques could be used for the analysis of the linkages between the water sector and the economy. Such a model could be used to predict the impact of various water allocation strategies on the economy and the labor force. For instance, it may help planners in assessing the third-party effects of water reallocation scenarios, and in preparing for mitigation actions.

An input-output account summarizes all the flows of goods and services that occur in an economy. Each firm in the economy is assigned to a set of n production sectors. The basic logic of the input-output account is that the output of each sector is made up of two aggregate components: *intermediate demand*, which is the sale of goods and services from a production sector to another, and *final demand*, which is the sales of goods and services for a "final" purpose such as consumption, investment, export, or sales to the public sector. Correspondingly, the expenditures of each sector can be broken down into two components: intermediate expenditures, which is the purchase of goods and services from other sectors, and *value added*, which includes payments to labor, capital, and the public sector (taxes) (Xu et al., 1994). simplified input-output table for a regional economy is shown in Table 19.

	INTERMEDIATE DEMAND					FINAL DEMAND							
INPUT/OUTPUT	*Agriculture*	*Industry*	*Construction*	*Transport*	*Commerce and Services*	*Personal Consumption*	*Public Consumption*	*Net Foreign Trade*	*Investment*	*Adjustment*	*Gross Nat. Consumption*	*Net Regional Trade*	Gross National Output
INTERMEDIATE EXPENDITURES													
Agriculture													
Industry													
Construction													
Transport													
Commerce and Services													
VALUE ADDED													
Personal Income													
Operating Surplus													
Depreciation													
Net Taxes													
Gross National Outlays													

Table 19 - Simplified Set of Input-Output Accounts

The basic logic of the input-output model is that in order for the final demand of some sector to expand – as, for example, in the case of increased exports of agricultural products – the output of other sectors must expand as well (Xu et al., 1994). Most economic activities consume water. The quantity of water consumed, and its distribution across categories such as agriculture, industrial, etc. depends on the sectoral composition of the increase in output. Thus, given some assumptions about the relationships between sectoral outputs and land uses, it should be possible to project the amount of water necessary to accommodate an increase in final demand in a given sector. Furthermore, an increase in sectoral output will produce an increase in employment. The extra purchasing power will give rise to increased demand for water.

7.2.3 Optimizing the supply-demand match: Demand Models (CVM)

Investment projects require that decisions be made not only on location, but also on the level of service to be provided and on the prices to be charged. Sometimes overly ambitious, high-tech solutions to problems are proposed and implemented when simpler, low-cost alternatives would have been more appropriate. But it also happens that low-tech solutions are provided when people desire a higher level of service. In both cases resources are misallocated: the technology selected is inappropriate, and soon the facilities are underutilized (Whittington, 1994). For instance, in the Gaza Strip, it is uncertain whether households will be willing to pay for large quantities of costly desalinated water. It is possible that poor households would prefer to be supplied with low grade water while having access to high quality water through vendors or autonomous water stations (see Section 5.9).

Demand curves can be constructed to determine whether residential customers are willing to pay for a higher level of service. Typically, households have a different demand curve for water associated with different uses (Figure 30). This information can enable planners to estimate the potential economic benefits of a new water supply project. For instance, in Gaza, a water resource planner would like to know how a household would respond to the opportunity to have water of better quality – consumption patterns and willingness-to-pay.

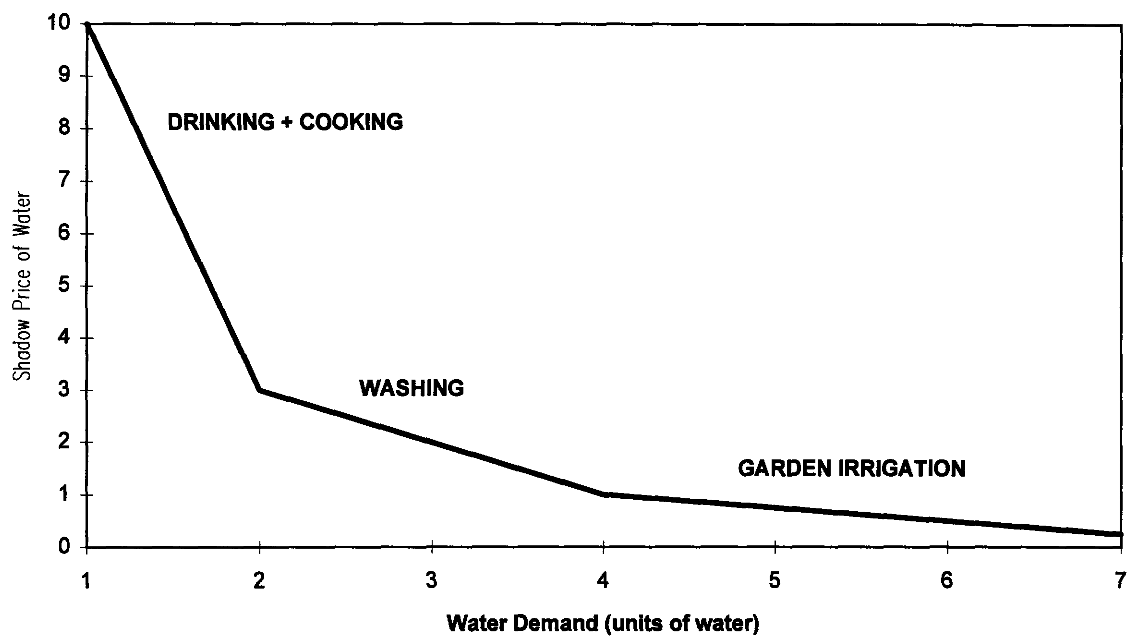


Figure 32 – Household's Water Demand Curve (adapted from Whittington, 1994)

A survey instrument can be helpful to provide detailed information about community preferences. In the past 25 years, contingent valuation method (CVM) has rapidly become a standard method to estimate the benefits for nonmarket commodities. While controversy about CVM still exists, it is increasingly used in cost-benefit planning studies and in estimating the economic benefits of an improved water supply. The contingent valuation method seeks to measure the economic value that individuals place on water by asking them outright how much they would pay for various levels of service (i.e. quantity, quality of water, reliability). In essence, it creates a hypothetical market, a sort of "what if" situation. One of the advantages of CVM is that respondents' answers to questions are easy for policy makers to interpret and understand. One possible drawback is the possibility that the respondent may not know (or may know but do not tell the truth) how he would react if offered a better service level at a specified price.

In addition to households, CVM could also be applied to agricultural users to assess their willingness to pay (and to accept) wastewater for crop irrigation.

Jordan et al. (1993) carried out a survey of Georgia's residents to study people's willingness to pay for improvements in drinking water quality and people's perceptions of potential groundwater contamination. The aggregate willingness-to-pay could serve as an estimate of benefits to consumers from improvements in drinking water quality.

Whittington et al. (1993) conducted a contingent valuation survey in Kumasi, Ghana, to estimate households' willingness to pay for two types of improved sanitation services. The findings indicated that CV surveys can be successfully carried out in cities in developing countries for public services and that reasonably reliable information can be obtained on household demand for different water supply and sanitation technologies.

Contingent valuation techniques can be useful for quantifying environmental values, although anyone using such numbers must be aware of the severe limitations and uncertainties of the method. For instance, one study estimated total visitor and nonvisitor benefits from the preservation of Mono Lake levels to be about $40 per California household, well above the cost of $0.22 per household that would be needed to preserve lake levels by replacing the Los Angeles diversions with water from other sources (National Research Council, 1992).

7.2.4 Application of Models to Water Supply/Demand Alternatives

Various supply-side and demand-side alternatives have been proposed and individually assessed in Chapter 5 and 6. In order to compare the effects of different strategies and define priorities in the implementation of water policies, these alternatives need to be integrated in a comprehensive analytical framework. However, simple auxiliary models can be made first to assess the different options individually before attempts are made to design a larger model.

Groundwater models can help defining aquifer management strategies aimed at safeguarding the remaining freshwater resources of the Gaza Strip. Technical issues pertaining to the development and the management of a large-scale distribution system – conveying potable and recycled water – can be assessed with network design models. Agricultural models can measure the economic benefits of optimizing cropping patterns. Gain-from-trade models can provide policy-makers with estimates of the costs and benefits of reallocation strategies. By developing a range of "what if" scenarios, a microeconomic model can help performing benefit-cost and welfare consequences analysis of investments by comparing changes in benefits to the capital cost. Finally, third-party impacts of reallocation policies and economic implications of a greater reliance on virtual water can be assessed by means of a macroeconomic model such as an input-output model. However, water resources need to be planned in a multidisciplinary context: social, environmental, institutional and political factors must be considered. Typically, a technical or economic model does not account for these factors; therefore, alternative evaluation techniques need to be defined.

7.3 Preliminary Assessment of Alternatives

7.3.1 Introduction

As discussed in Chapter 1, there are major uncertainties in Gaza with respect to the future economic, financial, social and political situation. It is unclear how the political situation will develop, it is unknown whether foreign donors will sustain their financial support, it is uncertain how the economy will develop, to name but a few uncertainties. Persistently unstable conditions caused by internal and external factors do hardly permit to extrapolate past trends. The best water strategy can be defeated by unforeseen changes in the economic or political environment. In such a "world of uncertainty" where no credible optimum can be defined, a scenario approach is a useful planning technique that can help to forecast possible developments. The desirability of a particular option can be assessed in terms of its feasibility and implementation potential, regardless of the scenario. For instance, the protection of the northern aquifer freshwater resources will belong to the theoretical optimal water allocation strategy and should therefore be given priority. Conversely, seawater desalination may be considered only if appropriate financial and human resources are available, and if it appears that regional water trading will not take place in the foreseeable future.

7.3.2 Assessment of constraints and definition of priorities

Further research is needed to assess the technical feasibility and the economic benefits of the proposed alternatives. To this end, several optimization models were presented in this chapter.. However, technical and economic optimality, while a necessary condition, is not sufficient to formulate a sound water policy. It was shown in previous chapters that, in the Gaza Strip, financial, political and institutional factors are determinant and are clearly overriding technical and economic issues. Therefore, there is a need to incorporate these factors in the analysis. This is no easy task, since they are they are difficult to measure and subject to a high degree of uncertainty. In Table 20, attempt is made to assess the feasibility of the various alternatives presented and evaluated in Chapters 5 and 6.

Variables were rated as follows:
++: very favorable, +: favorable, o: neutral, -: unfavorable, --: very unfavorable

Potential (in million m^3/year):
Low: <10 million m^3/year, Medium: 10-50 million m^3/year, High: >50 million m^3/year

Water cost (in $/ m^3):
Low: <$0.20/ m^3, Medium $0.20-0.50/ m^3, High >0.50/ m^3

Option	Potential (million m3/year)	Cost ($/m3)	Technical feasibility	Financing	Operation and management	Internal politics	External politics	Institutional arrangements	Human resources
Groundwater protection (potable quality)	Low	Low	+ +	+	+	o	-	o	+ +
Reduction of Unaccounted-for-Water	Medium	Medium	o	o	o	+ +	N/A	+ +	+
Water Conservation (domestic/industrial)	Low	LowMe	-	o	+	+ +	N/A	+	+
Efficiency in Irrigation	Medium	Medium	+	o	+	+	N/A	o	+
Optimizing Crop Mix	Medium	N/A	o	+	o	o	N/A	+	+
Water Pricing(domestic/industrial)	Low	Low	+	+ +	N/A	- -	N/A	-	+ +
Reallocation to urban uses	Medium	Low	o	-	o	- -	N/A	-	o
Swap freshwater vs. Recycled wastewat	Medium	Low	o	o	+	o	N/A	o	+
Use of saline water in agriculture	Medium	Low	+	+ +	+	+ +	N/A	+ +	+
Supply Segregation	N/A	Medium	+	+	o	+	N/A	+	+
Artificial Recharge	Low	Low	o	+	-	+	o	+ +	+
Water imports	High	High	+	-	+	-	- -	- -	o
Wastewater Recycling and Reuse	High	Medium	+	o	-	+ +	N/A	+	o
Brackish water Desalination	Low	High	+	o	- -	+ +	N/A	+ +	- -
Sea water Desalination	High	High	o	- -	- -	+ +	N/A	+	- -
Virtual Water	High	Low	+ +	-	+	-	+	+	+
Weather Modification	Low	High	-	-	- -	+ +	-	+ +	-

Table 20 – Multicriteria Assessment of Alternatives

Table 21 summarizes the main constraints pertaining to each alternatives and proposes a preliminary priority ranking.

Option	Major Constraints	Overall Assessment
Fresh groundwater protection	Water rights Settlements on top of aquifers	High Priority
Reduction of Unaccounted-for-Water	Optimal reduction of UFW linked to water pricing	High Priority
Water Conservation (domestic/industrial)	Public awareness, Financing of water saving devices	High priority
Efficiency in Irrigation	Financing of irrigation systems Underpricing of irrigation water	Medium priority
Optimizing Crop Mix	Access to external markets for high-value agricultural products	Medium priority
Water Pricing	Political issues	Medium priority
Reallocation to urban uses	Institutional issues with water markets Need to build conveyance systems	Medium priority
Swap freshwater vs. Recycled wastewater	Conveyance systems, reliability of treatment plants, incentives for farmers	High priority
Use of saline water in agriculture	Introduction of technologies (cooperation with Israel)	High priority
Supply Segregation	Selection of distribution system (dual system, trucking, water stations)	High priority
Artificial Recharge	Land availability (pools), aquifer Contamination, O&M (reinjection wells)	Medium priority
Water imports	Political issues (agreement on water rights, Israel's willingness-to-sell)	Depends on outcome of negotiations (high pr.)
Wastewater Recycling and Reuse	Selection of appropriate treatment technology, O&M, conveyance systems	High priority
Brackish water Desalination	O&M, damage to aquifer	Medium priority
Sea water Desalination	Financing, O&M, brine disposal	Low priority
Virtual Water	Exports need to grow to pay for additional food imports	Medium priority
Weather Modification	Unpredictability of results Cooperation with Israel	Low priority

Table 21 – Assessment of Alternatives – Constraints and Priorities

Several alternatives seem particularly promising: fresh groundwater protection for potable use, reduction of UFW, conservation, wastewater recycling and reuse, swap freshwater vs. recycled water, supply segregation. These alternatives should be further evaluated, using benefit-cost analyses and the models described in Section 7.2.

7.3.3 Scenarios

Feasibility of alternatives will be closely linked to the political situation. The definition of a water strategy will be dependent on donor funding, prospects for regional cooperation, internal politics and capacity building. Accordingly, in order to account for future uncertainties, three socio-economic development scenarios are formulated. Each of them is based on a set of assumptions that are a mix of a wide range of conditions (MOPIC, 1996).

Status Quo Scenario

The status quo scenario is based on extrapolation of recent developments.

Main assumptions:

- The peace process remains stalled, and there is significant potential for political unrest. Final status talks have been postponed indefinitely. Strategic uncertainty affects the decision process. In the water sector, there is a slow progress in building capacity and appropriate legal and regulatory systems.
- Little capital investment has taken place and the economy is still in a state of crisis. Unemployment remains at very high levels.

- A major share of donor funding supplements government budget. Private foreign investment is restricted to investment in housing by expatriate Palestinians. As a result, investments in infrastructure are very limited.
- Due to population growth, water withdrawals increase and further damage the aquifer. Most of the water pumped into the network is brackish.
- Water salinity affects the agricultural sector. Many farmers, particularly citrus growers, are driven out of business or have to shift to salt-tolerant crops.
- Several wastewater treatment plants have been completed. However, lack of funding limits the possibilities to reuse wastewater for crop production.

Consequences for the water sector:

- Supply segregation alternative is implemented. More than half of the population is supplied from autonomous water stations and/or bottled water to meet their potable water needs.
- Groundwater protection zones have been established to safeguard the remaining portion of freshwater.
- Small brackish water desalination plants have been completed and supplement high quality water supply.
- Techniques to use saline water in irrigation are being introduced.

Autonomous Growth Scenario

The autonomous growth scenario assumes that Gaza develops its own economy with little interaction with Israel. Access to foreign markets, notably in the Arab countries and Europe, is significantly improved. Export oriented growth and an influx of foreign funds contribute to the development of a strong economic base.

Major assumptions:

- Full formal government power is established for the Palestinians, although sovereignty is limited in matters related to defense, foreign affairs, and natural resources management. Relations with Israel remain tense.
- Access to foreign markets is secured by the completion and full operation of the Gaza seaport and airport
- Sufficient funds (from domestic and foreign sources) are available to finance the heavy investments in infrastructure

Consequences for the water sector:

- A large scale water distribution system covering the entire Gaza Strip has been built. The system enables the transfer of water of different qualities – freshwater, brackish and recycled.
- Treated wastewater is extensively used in irrigation. As a result, large quantities of freshwater are made available for urban uses.
- Institutional mechanisms have been established to enable water marketing. Economic growth and competition for land provide incentives for water transfers.
- Water-intensive crops such as citrus are no longer produced; instead, they are now imported.
- Pricing, introduction of water-saving technologies, and implementation of awareness programs contribute to active water conservation in the urban and agricultural sector.
- Additional water resources are made available to Gaza through seawater desalination and/or imports from Egypt.
- Cooperation programs with foreign consultants and universities promote capacity building and development of human resources

Social Welfare Scenario

Open borders, regional trade and cooperation, and a "warm" peace with Israel characterize the social welfare scenario. Lower birth rates and free movement of persons between Gaza and the West Bank contribute to the reduction of population pressure.

Major assumptions:

- A successful final peace settlement results in normalization of political and trade relations with all neighboring countries. Regional cooperation in all fields of mutual interest has become a reality, and shared natural resources are jointly managed.
- Decisions on investments in the water sector are made largely on the basis of considerations of socio-economic development and regional cooperation, rather than on political and security issues.

Consequences for the water sector:

- Water is traded on a regional basis, and allocated according to economic principles. As a result, irrigation water is reallocated from the Israeli to the Palestinian sector, for the benefit of both. Israeli consumers can purchase food at a lower price, and Palestinians can further develop their economy.
- Food self-sufficiency policies become less relevant because of increased regional security and improved terms of trade. As a result, irrigation water use declines, particularly in Israel, thereby freeing additional water for urban uses. Desalination projects and imports of water can be replaced by an increased reliance of imports of virtual water.

Chapter 8

Conclusions and Recommendations

The Gaza Strip's water resources crisis is threatening people's livelihoods and economic growth. Currently, the poor overall performance of the water and sanitation sector is critical; moreover, the imbalance between supply and demand is expected to worsen due to the high population growth rate. But the looming disaster is not inevitable. It can be averted, but the need for action is urgent and will require a concerted and sustained effort. This will demand massive investments in rebuilding and expanding the water infrastructure, and the development of an appropriate institutional framework.

This thesis contended that the current water crisis is partly the product of misallocation of water resources, both in the Gaza Strip as well as the regional level. Underpricing and poor efficiency of water systems have led to a waste of scarce water resources. In Gaza, more than half of the water pumped into the network is lost, and the agricultural sector is consuming the lion's share of water while generating negligible or even negative marginal benefits. Some future plans, such as seawater desalination, if implemented, will only exacerbate the current misallocation. Indeed, desalination at costs of $1 per cubic meter will not be efficient as the quantity equivalent to the total current domestic consumption, which is used to grow citrus, yields an income of less than $0.30 per cubic meter. In this thesis, it had been shown that many options on the supply- and demand-side exist, and that they should be carefully evaluated in an integrated framework. Appropriate models should be developed to determine the sets of optimal allocation of water under different socio-economic scenarios.

Models can lead to a better understanding of what will happen if certain actions are taken or not taken, and which of several possible combinations of alternatives is likely to be the optimal solution. However, models do not account for the highly unpredictable social, economic, legal and political processes which influence water planning and management in the Gaza Strip. Consequently, a technically and economically optimal solution may be unacceptable to the policy makers because it contradicts immediate political imperatives. Policy makers have a marked preference for solutions that do not make any waves. For instance, a reallocation of water is politically difficult because those who may loose will likely scream louder than those who will gain. Here, decision-makers may feel safer in inaction than action. Therefore, while models can help in discovering tradeoffs and joint gains, it should be recognized that there is no one uniquely right solution, and that the traditional decision-making approach is incremental.

Although considerable work remains to be done in the formulation of a water policy, where optimization models may help define long-term plans, a desirable incremental approach would include the following elements:

Short-term Actions

- Establish groundwater protection zones to preserve Gaza's remaining freshwater resources to guarantee potable water needs for the coming 50 years

- Establish a separate distribution system for high quality water. The immediate objective of this investment should include access to drinking water of good quality for all cities and rural communities.

- Continue to rehabilitate the water systems in order to achieve a significant reduction in water losses

- Pursue the renovation and upgrading of wastewater collection and treatment systems and initiate wastewater reuse in irrigation. Reuse of wastewater in agriculture (particularly for citrus production in the first stage) will free up freshwater for higher-value use.

- Promote water conservation by introducing watersaving technologies, and by launching public awareness campaigns

Medium-term Actions

- Build a distribution system that covers the entire Gaza Strip. The system should enable the transfer of water of different quality – freshwater, recycled waters – and promote efficient allocation of water of among competing local users. In the long run, this system could be integrated into a regional water network operating on the basis of tradable water rights.

- Price water at its true opportunity cost, while keeping lifeline use affordable to the poor.

- Identify new water supplies to keep up with the growth of consumption and the reduction of groundwater extraction to safe yields. Several alternatives have been proposed in this study, ranging from small-scale options (rainwater harvesting, artificial recharge, brackish water desalination) to more ambitious schemes (seawater desalination, inter-regional transfers). They will have to be studied carefully in the framework of integrated water resources management.

The successful implementation of these alternatives will depend upon the availability of funds and donor support, human resources development, and the establishment of an appropriate institutional framework.

Most of the funding will have to come from multilateral and bilateral donors. In the long term, when the Gaza Strip has achieved institutional and political stability required to attract major private investment, government or international banks' guarantees could make private financing of water projects possible. To ensure the sector's sustainability, cash generation should be increased and operation and maintenance of the water systems should be self-financed.

As shown in earlier chapters, markets and prices can improve the allocation of water among competing users. In Gaza, policy makers should gradually shift from regarding water as a free and renewable resource to understanding its economic value, and change policies to emphasize proper incentives, pricing, and regulation.

In order to avoid duplication and fragmented actions, government and donor efforts in the water sector will have to be harmonized. In particular, clear guidelines and standards should be rapidly defined, as well as the level of service to be provided. The technologies selected should be appropriate for the factor endowments and stage development of the Gaza Strip. Central policy making should remain with a single independent water authority but operational management should be decentralized. A better quality of service at lower cost will be achieved by decentralizing water service delivery responsibilities to local governments and transferring some functions to financially autonomous entities, and community organizations such as water user associations. A critical factor for the success of any water resources development is the real involvement of all users of water resources in a region. This implies that the planning and implementation of water programs and policies must be subjected to the widest public scrutiny, involving participation by all interested parties. This will require institutional structures which are responsive to public concerns.

The main problem of the donors' program is its lack of emphasis on developing human resources when, in fact, water professionals in the Gaza Strip are in desperate need of appropriate skills training. A constructive step that the donor community can take is to assist in the training of the next generation of water experts in the region. One of the most valuable benefits of such programs would be the creation of an informal network of individuals in Israel and Gaza with personal relationships and shared understanding of the region's management issues.

The long term solution to the region's water problems will rest in the reevaluation of agricultural policies. Food exports – that is, exports of virtual water – will probably need to be discontinued. The gradual removal of subsidies for irrigation water will improve access to local markets for food imports and decrease water consumption in agriculture. Additional water resources will therefore be freed up for urban uses, and opportunities for regional water trading – based on economic principles – will open up. A recent Israeli report called for a significant increase in charges for water supplied to the agricultural sector, while offering farmers alternative help. In any case, urbanization and economic growth will lead to a gradual decline of the importance of agriculture in the economy. However, food self-sufficiency policies are dictated by security and political imperatives, and will remain in place as long as the conflictual atmosphere prevails in the region. While the current political situation does not encourage optimism, it is clear that the resolution of Gaza's water problems is predicated upon the recognition of equitable water rights for the peoples of the region and the establishment of a favorable political and economic climate.

A social and political explosion is looming in the Gaza Strip, which will be compounded by the destruction of the aquifer. However, as discussed in this thesis, solutions do exist. They will depend on the financial support of the donor community, Israel's goodwill, and the political will and management ability of the Palestinian leadership to formulate and implement a sound water policy. When all this comes to pass, Gaza can become again that for which it has been famous for centuries: a key commercial outpost, and the first source of freshwater north of the Sinai Desert for caravans traveling between Asia and Africa.

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