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WATER AND PEACE IN THE MIDDLE EAST

Edited by

J. Isaac

H. Shuval

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Proceedings of the First Israeli-Palestinian International Academic Conference on Water, Zürich, Switzerland, 10-13 December 1992

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WATER AND PEACE IN THE MIDDLE EAST

Proceedings of the First Israeli-Palestinian
International Academic Conference on Water

December 10-13, 1992

Held at the Swiss Federal Institute of Technology—Zurich (ETH)
Hosted by the Center for Security Studies and Conflict Research, ETH

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PREFACE

By

Dr. Jad Isaac and Professor Hillel Shuval
Conference Co-Chairpersons

This book is the fruit of several years of cooperation and dialogue between Israeli and Palestinian water scientists, which started with informal, behind the scenes discussions in Jerusalem, and developed into the plan to organize the First Israeli-Palestinian International Academic Conference on Water which was successfully held in Zurich ,December 10-13, 1992. Fifty Israeli and Palestinian water scientists together with fifty international experts participated in that conference where some forty scientific papers were presented and discussed in an open and free academic environment.

The conference served as an important mile-stone in the process of what is called a "second track" dialogue and cooperation between unofficial Israeli and Palestinians academics on vital shared problems whose resolution is vital to the peace process. The actual holding of the Conference was an important accomplishment in itself, since it demonstrated to both peoples and the world at large that Israelis and Palestinians can meet and discuss approaches to resolving their shared problems in an environment of frankness combined with mutual respect.

No less important a product of these years of cooperation is this book containing forty-one original papers presented at the Conference dealing with almost all aspects of the Middle Eastern water problems. It is our belief that many of the studies, analyses, ideas and approaches presented in these papers will serve as sources of vital information and stimulation to those on all sides involved in the peace negotiations. In addition this book should serve as a useful reference to students, scholars and policy makers all over the world interested in understanding the complexities of the Middle East water conflicts.

The Conference would not have been possible without the encouragement and generous financial support of the Commission of European Communities, the Government of

Canada, The Swiss Development Cooperation, The Ford Foundation and The Jackson Foundation.

The sponsorship, or assistance of the following organizations was also vital to the success of the Conference: The International Water Resources Association-IWRA, the International Research Development Center-IDRC, Canada, Israel-Palestine Center for Research and Information IPCRI, and the Swiss Environmental Services AG -SESAG.

Special thanks are given to the Conference host, Professor Kurt R. Spillman and the Center for Security Studies and Conflict Research of the Swiss Federal Institute of Technology-(ETH), Zurich .

This Conference never would have taken place without the devoted work of the two Conference Coordinators Dan Bitan of the Truman Institute and Issa Khater of MAQDES and the Conference Manager Ms. Idit Avidan in Jerusalem. The conference management in Zurich was handled devotedly by Mr. Hans Lehman of SESAG in Zurich. This intrepid team assured the smooth coordination and successful management of a very complex international conference.

Last but not least we wish to express our sincere appreciation and thanks to the two Israeli and Palestinian institutions which accepted the responsibility of sponsoring and organizing the Conference. The Harry S Truman Research Institute for the Advancement of Peace of the Hebrew University of Jerusalem and its Director Professor Moshe Ma'oz together with the The Jerusalem Center for Strategic Studies- MAQDES and its Director Professor Sari Nusseibeh took upon themselves, a bold initiative during a period when not everyone on both sides accepted the idea of such public Israeli-Palestinians dialogue.

What follows are the opening remarks at the Conference of the two Conference Co-Chairpersons:

OPENING REMARKS

by

Professor Hillel Shuval, Conference Co-Chairperson

The idea of an Israeli-Palestinian academic conference on water was born in Jerusalem in 1990 as an outgrowth of the ongoing academic dialogue between Israeli and Palestinian water scientists. The dynamics of those discussions had begun to generate a sense of mutual understanding and respect for each others problems. We became aware that despite the deep conflicts between our peoples, we share a common geography and common hydrology and thus must join together in a common effort to understand our mutual problems, concerns and anxieties. As our respect for each other grew we decided that an open academic conference on the water problems we share was the next logical step in promoting better understanding and in broadening the circle of Israelis and Palestinians who would gain by being exposed to the process of free and open dialogue and exchange of ideas.

The Truman Institute for the Advancement of Peace of the Hebrew University and the Palestinian, Jerusalem Center for Strategic studies- MAQDES responded with enthusiasm and agreed to serve as the organizers of this pioneering Israeli-Palestinian academic meeting.

This is a truly academic conference at which papers will be presented and discussed in the classical tradition of free and open academic exchange of ideas. The goal of the conference is to provide information and present different positions and views in the spirit of mutual understanding and respect.

It is recognized that many of the topics to be raised at the conference are the subject of Bi-lateral and multi-lateral negotiations as part of the peace process initiated in Madrid. This conference is in no way part of the negotiation process and the views expressed are those of the individuals who present them and do not necessarily represent those of any of the bodies involved in the negotiation process.

We have been asked whether this meeting will, nevertheless contribute to the peace process. Indirectly it will...by demonstrating that we can talk together, learn from each other, understand a bit more about each others problems and possibly most important of all... demonstrate that academics and scientists through their collegial relationships and developing friendships can become living examples that we can and must learn to live together in peace.

We are aware that certain words and certain terms used in discussing the Israeli-Palestinian issues are loaded with significant meanings often with deep emotional overtones. Those of us who have participated in such dialogues for some time now have learned to avoid terms that grate unnecessarily on the ears of our colleagues. One highly sensitive example are the terms used to describe the territories occupied by Israel as a result of the 1967 War, which formerly where administered by the Hashemite Kingdom of Jordan. We recognize that there is no agreement on these terms and each side places great national and political significance in their use. However at this academic meeting we are interested in concentrating on the substance of the water issues rather than the emotions of the conflicts. We would like to emphasize the hydrology, the geography, the engineering and the legal aspects. We want to avoid needlessly stepping on emotionally charged land mines in the form of geographic terms. We would like to suggest that we all try to use the rather neutral word "The Occupied Territories" which in the terms of the diplomat Henry Kissinger can be considered an example of "constructive ambiguity". However since this is a free and open academic conference, with no censorship, some speakers may use other more emotionally loaded words. The two conference Co-Chairman join together in requesting that we all relate to such use of words, which may be hard on the ears of some, with a sense of tolerance and patience. In time we will improve our skills of communicating with each other so that we can devote our energy to understanding each others problems and searching for just solutions which will meet the legitimate needs of both sides.

While we recognize that there are strong feelings and differences of opinions on many subjects I am pleased to say that after almost two years of working together to organize this Conference, the two Co-Chairpersons, the Institutions they represent and the Israeli-Palestinian Steering Committee feel more united than ever in our mutual desire to find solutions to our shared water problems so that our two peoples can live together side by side in peace based on justice, honor and mutual respect.

The conference organizers--The Truman Institute and Maqdes purposely choose the name "First" for the Conference since we see it only as a first step in future programs of mutual cooperation. To the extent that we can prove to each other that the process of cooperation and dialogue really works, then we will be able to move forward to deepening the areas of cooperation. All the participants are warmly encouraged to help make this pioneering effort a symbol of cooperation and tolerance so as to assure a successful meeting aimed at promoting mutual understanding among people and groups with divergent views who are searching for peaceful ways of solving their shared problems.

Opening Remarks

by
Dr. Jad Isaac, Conference Co-chairperson

Ladies and Gentlemen,

On behalf of the Jerusalem Center for Strategic Studies (MAQDES), I would like first to extend our deep gratitude to the conference sponsors, supporters, organizers and participants. It is both a pleasure and an honor that this historical conference is host to such a distinguished audience. I hope that this conference will set a precedent for cooperation and dialogue on the vital issue of water in the Middle East and result in a better understanding of the dimensions of the present situation, as a step towards identification of creative solutions. I look forward to the upcoming three days of deliberations and discussions which are expected to shed new light on this important issue.

Water, as a substance, is colorless, tasteless and odorless. Yet, its role in world affairs is critical. Water is a unique compound in its chemical and physical properties that entitles it to be the irreplaceable component in all fabrics of life. Water is a source of life that has been both worshipped and fought over. Early civilizations held water as one of the essential four elements of earth. The Holy Koran states that "OF WATER, ALL LIVING THINGS ARE CREATED." Thus, it is appropriate, that humankind choose wisely the ways in which to preserve this precious resource.

Water has historically played a significant role in shaping the geopolitical boundaries of the Middle East. To a large degree, the current water "allocations" in the area are a result of force and/or military action, creating a web of relations between water resources, conflict, competing ideologies, nationalistic agendas and human needs. Unless this complex interplay is taken into consideration, water issues will take the peoples of the Middle East into further conflict.

The water situation in Gaza has approached a catastrophic stage. The drop in groundwater levels in the shallow aquifers of Gaza has resulted in the intrusion of seawater. The salinity of Gaza's groundwater increases at a rate of 15-25 ppm chlorine annually, although rates vary considerably from place to place depending upon hydrogeological factors and pollution rates. In Gaza, nearly 60% of groundwater stocks have reached a salinity of over 600 ppm.

In the West Bank, Israelis use 485 mcm from its ground waters per year, while Palestinians use only 115 mcm of their own water. Israeli restrictions have drastically limited the water available to irrigate Palestinian lands and thus, today less than 6 percent of the land cultivated by Palestinians in the West Bank is under irrigation, the same proportion as in 1967. By contrast, about half of the cultivated land in Israel is irrigated while more than 70 percent of the area cultivated by Jewish settlers in the West Bank is irrigated.

The current status quo is completely unacceptable. A dispassionate and sustainable formula is urgently needed to rally broad support and to end existing waste and inequity. It is this sense of urgency that drove us to organize this conference,the idea which originated two years ago in one of the roundtable discussions between Israeli and Palestinian water scientists organized by the Israeli Palestinian Centre for Research and Information (IPCRI).

All of the parties involved in the dilemma of sharing the waters of the Middle East have contrasting opinions regarding a solution. On one side, the Israelis envision a solution by securing additional outside supplies to satisfy the region's demands, as this would also eliminate the immediate need for a discussion of allocation rights. On the other hand, Palestinians insist that the region's water be viewed as a limited natural resource and that sustainable and creative ways be devised to conserve and distribute it. The Palestinians would like to set an allocation schedule that would define their national water rights, as well as the rights of all the other parties in the region. The Palestinians believe that the nations of the Middle East should live in harmony with their environment capitalizing on the available natural resources and maintaining the natural equilibria.

This conference is a meeting of academics and water scientists. It is not intended to be a forum for negotiations or political debate. Each participant comes here as an individual and not representing nations or institutions. However, we realize that your deliberations will surely provide insight to decision makers in the current peace process, which may indeed set before us an unprecedented opportunity to achieve a comprehensive and just peace in the region. Nothing is more basic, more vital, than water, and few issues stir as much emotion. For any peace to be lasting, it must successfully formulate an equitable sharing plan of the region's water.

Although international water law is still too underdeveloped to provide much assistance in disputes as complex as the one in the Middle East, existing principles of international law must form the basis for comprehensive solutions. For without acceptable international standards in the region, any settlement is a temporary one.

Vital to a responsibly planned future is the studied and thoughtful formulation of an underlying philosophy which will guide policy and priorities at national level. Indeed, any future edifice will surely reflect the foundations we lay now. Questions of water allocation can only become more important, as populations expand and place increasing demand upon limited resources. The transition from the present to the future must be based on both the mistakes and the successes of the past, and today's decisions must, to every extent possible, be made with tomorrow in mind.

This conference provides a golden opportunity for Israeli, Palestinian and international water experts to learn from each other, to explore new ideas and reflect on ways to achieve a sustainable solution to the current water crisis.

Thank You.

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General introduction

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VISION CAN MAKE A DIFFERENCE: TRANSBOUNDARY ISSUES

Glenn E. Stout

Vice President and Executive Director, International Water Resources Association, University of Illinois, 205 North Mathews Avenue, Urbana, IL 61801 U.S.A.

Abstract

Water makes earth unique among the planets in the solar system. People, plants, and animals cannot survive without water. Cultures develop that revolve around water. Then cultures establish guides or principles for living. These principles, however, must change as the increasing human population threatens to undermine the health of earth's ecology. Increased demands for national resources strain the freedom of people who live in a competitive, economic society. People are naturally aggressive as they try to satisfy their demands for living. This aggressiveness creates conflicts that should be resolved by peaceful solutions. Political aspirations must be tempered with negotiations in lieu of military action when seeking solutions to issues involving water allocation and appropriate use.

Processes must be developed by the citizens of this rapidly changing world, if we are to resolve issues over our shared water resources. More than 200 river basins are shared by two or more countries, an area that comprises about 50 percent of the planet's land surface. These processes include: collection of appropriate high-quality data, education of water resources, users, and demands upon academia to examine and to convey potential solutions to these issues with national and binational leaders. These processes must be investigated at this first conference of academic water professional.

INTRODUCTION

I am indeed delighted to be a part of this historic event and to share with you some of my fifty years of research and management experiences on all aspects of the hydrological cycle. I trust there will be many more academic conferences on Middle East water issues to exchange vital information and develop sustainable, but flexible, development plans and management models that will guide many binations in resolving transboundary water issues.

When Professor Shuval called me several weeks ago, I was surprised to learn that Dr. M. Abu-Zeid, President of IWRA had to attend a conference in Washington, DC. Dr. Abu-Zeid recommended that I represent the International Water Resources Association. Since I have not been a scholar on the Middle East issues as most of you in academia are, I was very hesitant to say "yes." However, as Professor Shuval and I talked, an idea developed that I should speak on new innovations in resolving present and future water issues that will most certainly multiply from population growth and the increased demand for water.

I hope something really positive will develop during these four days. I will begin by defining vision as "looking forward to seeking a solution to an issue." I like to use issue because conflict denotes an impossible problem. We need to understand the historical heritage and should be prepared to take a positive and objective position on the future.

Increasing population creates many problems in the world. As evidence that population growth increases the demand for our limited water resources, the editorial in the October 1992 issue of *U.S. Water News* reads, "EXPLODING WORLD POPULATIONS DEMAND ASTUTE WATER PLANNING." The population of the world is now twenty-seven times greater than it was 2000 years ago. Each day, almost 400,000 people are born on our planet. The Earth's exploding exponential population growth, along with its resultant industrial, agricultural, recreational and domestic water use, requires water resource planners and managers, particularly in developing nations, to produce and keep current long range water supply plans.

Only 200 million people were on Earth 2000 years ago. By the time Europeans first settled in America, 1600 years later, the world population had grown to 500 million. In the next 250 years, by 1850, human population grew to one billion, and then, more than doubled in the next 100 years to 2.5 billion. Now, in just the last forty years, the earth's population has more than doubled again to 5.4 billion people.

World population grew by a record 92 million in 1991 as the result of 143 million births and 51 million deaths, according to the Bureau of Census. William Meyer of Clark University in the same editorial estimates global human water use is currently thirty-five times what it was three centuries ago. (1) Due to population growth, the vision here is "to constructively think big, as well as be efficient in the use of water" in order to meet future demands.

COMMUNICATIONS

As representatives of academia, new techniques must be developed to expand the knowledge base of decision-makers in order to manage our natural resources wisely and to educate future scientists and technicians. Secondly, the general public should be exposed to the cost to produce, treat, and distribute water. The public must learn how to use water wisely. Thirdly, they must eventually pay for treated and delivered water.

Therefore, massive public and technical educational programs are needed. I learned in September on a trip to Moscow that the citizens of Russia are now being assessed a fee for water service. This, apparently, is a part of their transition to the economic world. Water cannot be a free service. It is a necessity of life and everyone must pay for it.

The rapid transmission of news by television and communications by telephone and telefax must be a part of our vision for the future. How can we encourage the media to inform children and adults that delivered, high-quality water is a commodity that has a "value" and must be purchased just as we buy food to maintain our bodies? At the International Conference on *Water and the Environment: Development Issues for the 21st Century*, on December 31 - January 1, 1992 in Dublin, Ireland the NGO's professional water organizations like IWRA pushed the United Nations agencies to adopt the concept that water has "value" and it should be included as one of the recommendations for the UNCED meetings in Brazil in June 1992. The easy and cheap solutions for water supplies already have been implemented in many areas. Future developments, away from population centers, recycling, recharging aquifers, reclaiming waste water, and treatment of brackish and saline water are costly. The user must be prepared to pay!

INCREASED WATER COSTS

The developing world produces billions of tons of toxic chemicals. Due to chemical pollution of water supplies, the U.S. Environmental Protection Agency is promoting major water quality monitoring of urban water systems and better control of waste water. It is estimated that local governments in the U.S. will need $400 billion in the next two decades to meet federal water and sewer standards. Annual household bills in large cities will increase from $135 in 1985 to $1,100 in the year 2000. Construction costs in New York City alone will be $10.4 billion; Boston costs will exceed $8 billion.

If U.S. families in large cities must pay $1,100 for water ($90/month) to drink and bathe in, how will they, and other highly industrialized nations, continue to support large grants to donor agencies for a water-for-peace plan or support large United Nations relief operations to feed drought-stricken governments. Water issues in one region of the earth will certainly impact future decisions in other regions. New thinking on economic support for water supplies has to be initiated.

DATA REQUIREMENTS FOR CONFLICT ISSUES

In the Middle East, literature indicates a great lack of complete and accurate data. There are no central or regional repositories for data on the surface and groundwater resources. Paul Kay (2) in Canada found a shortage of complete precipitation records for the Golan in a study of the time series of regional precipitation. Throughout the world, sharing of data between countries has always been very limited.

About five years ago, UNESCO/IHP hydrologists in the United Kingdom, Germany, and the Nordic countries began a comprehensive program to develop hydrologic data by watersheds in the Northwestern countries of Europe. This UNESCO/IHP program known as FRIEND has now spread to other sections of Europe and the Mediterranean.

A similar program is needed for the Middle East. One cannot perform comprehensive water planning, development and management without appropriate, long-term, high quality data. The countries should be responsible for collecting quality data with a willingness to share. This program should be initiated promptly. Thirty or more years of data are often needed for many water budget studies, and fifty years may be necessary due to the greater variability of climatic data in arid and semi-arid regions. As a result of this conference we should examine the need for the expansion and collection of data that are required to regionally manage these water resources.

LAND VERSUS WATER RIGHTS

Naff has proposed that Middle East land disputes need to be resolved before water rights are developed. However, with the apparent deadlock in the current peace negotiations, has anyone suggested that water experts and planners should develop comprehensive watershed plans and a master regional water plan for allocation of amounts, rights, and protection of the quality of the resources? Perhaps land disputes will be easier to resolve, once water aspects are fully assessed. (3)

FUTURE VISION TO SAVE HUMAN LIVES

In April 1915, the Germans introduced the use of poisonous gas when they sent clouds of chlorine gas against the allied forces. Casualties from poisonous gas accounted for nearly 30 percent of the American soldiers killed or wounded in World War I. The horrible possibilities of chemical warfare were then considered by the nations in the International Conference on Limitation of Armament which was held in Washington, DC in 1921. By 1936, thirty-nine nations had agreed to accept a League of Nations ban against the use of poisonous gas in warfare. Currently, many countries are reluctant to develop water supplies and transmission systems from great distances because they might be destroyed during warfare or by terrorist acts. Grave destruction, loss of life, food production, water storage, and loss of electric power could occur.

Since the United Nations now accepts the concept that water has a "value," let's conduct investigations to show the potential impact on the destruction and/or contamination of water and water facilities in any military or small scale terrorists actions. A large educational program for the public and informed citizens should be encouraged and academia should take the lead in developing and implementing plans.

NEGOTIATING PROCESS

For many arid and semi-arid countries, a regional water source may be the only new additional source of water that could economically be developed to meet the ever increasing demands. There are over 200 separate river basins in the world which are shared by two or more countries. Together they comprise about fifty percent of the land on our planet earth. Agreements between co-basin countries are necessary if such sources are to be developed properly. While some attempts are now being made to develop laws for non-navigable uses of international water courses, regrettably not enough attention has been paid to reviewing the negotiating process that lead to successful water treaties. A.K. Biswas describes the negotiating process that resulted in the Indus River Treaty between India and Pakistan in 1960. (4) This treaty took forty years of negotiation between the two parties. Finally, the personal involvement of the president of the World Bank in 1960 produced the treaty. New visions are needed in the negotiations process. Major international organizations and bilateral aid agencies could play an important role in possible resolution of conflicts on many watercourses in developing countries. The author suggests that these organizations need to play a more direct and catalytic role than has been witnessed in recent decades.

INTELLIGENCE

Three weeks ago at the University of Liege I saw the following poster:

> "HOW IS IT THAT CHILDREN ARE INTELLIGENT AND MEN ARE STUPID? IT MEANS EDUCATION DOES IT."

As academia, we must correct this impression if the public perceives that education does not create intelligence.

SUMMARY

I have tried to stimulate your interest and concern about seeking new solutions to local, binational and regional water planning, development, management, and its operations. As educators, we must be prepared to educate students, the public and decision makers.

Water is a free product found in nature, but it requires economic resources to deliver it to the user. The user must be prepared to pay for delivered, high-quality products. Enhancement of basic data needs and its sharing are urgently needed for planners. Population growth creates new priorities on the urgency of developing new negotiating processes.

An international ban on the destruction or contamination of water supplies and facilities should be initiated by academia in order to remove the risk factor of large scale binational developments.

Legal solutions to transboundary issues should be developed in order to seek peace for any watershed conflict in the world. Since we are concerned about Israeli-Palestinian issues, a step-by-step solution for this region would serve as a model for the other 199 binational watersheds in the world.

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Welcome
by Glenn E. Stout
on behalf of
Mahmoud Abu-Zeid
President of International Water Resources Association

I bring greetings to you, Dr. Jad Isaac and Professor Hillel Shuval, colleagues and the one-hundred attendees of "*The First Israeli-Palestinian International Academic Conference on Water*" from the International Water Resources Association which was organized about twenty years ago in order to promote integrated water management throughout the world. Dr. Abu-Zeid, the sixth President of IWRA, sends his regrets since he wanted to be a part of this important forum. He is attending another conference in Washington, DC this week.

As some of you know, Dr. Abu-Zeid's home country is Egypt which is quite interested in the Middle East water issues. He looks forward to being a part of future meetings. He hopes that this conference will develop some insights and strategies in order to manage the waters of the Middle East whereby everyone can have adequate potable water, and water for agriculture, industry and recreation which has been used and reused many times in the natural environment and for man's activities. He looks forward to hearing reports from this conference and receiving copies of the papers.

IWRA is one of several international professional water associations which fosters an exchange of information among academic and scientific personnel throughout the world. I suspect some of you are members of either IAH, IAHR, IAHS or IWSA. We are known as NGO's which stands for Non-governmental Organizations.

IWRA's first president for six years was Ven T. Chow, Professor of Hydrosystems at the University of Illinois from 1947-81. He was well known for his handbook and publications to apply hydrology and hydraulics to water management. IWRA is the youngest of these NGO professional organizations, but we have been growing rapidly in membership, program and stature because of the importance of the holistic management, efficient use of water, and sustainability of high quality water resources. Our primary support comes from the members, conference and publications that we volunteer their services in the exchange of information. We are currently organizing or co-sponsoring ten or more conferences each year. We invite you to become a member. There will be literature for you to pick up for your information and action.

If you are not acquainted with the quarterly journal of IWRA, *Water International,* I have copies to distribute to you. *Water International* is the official magazine of the International Water Resources Association for the past seventeen years. It serves as a vehicle to bring to its readers current news about the Association, activities of IWRA, its committees, members, and other important and interesting events in the international water resources field. As an international forum for water resources activities, it also carries reports on important water projects around the world concerning their financing, planning, development, design, construction, operation, and management;

socioeconomic, ecological, and environmental problems of international interest related to water; reviews state-of-the-art reports, and world news of the water resources profession; information on professional and educational water programs, opportunities, and assistance; and announcements on various products and services in the field of water resources.

The IWRA sixth World Congress in Ottawa in May 1988 organized a special session on "Resolving Water Conflicts". The December 1990 issue of *Water International* was a special issue on *Water, Peace and Conflict Resolution* with papers from the Congress and several others in order to cover the subject area. Four articles on Middle East water issues were published in the September 1992 issue which includes Professor Shuval's paper as presented in Stockholm. Our March 1993 issue will contain eight articles which were presented at the University of Waterloo Conference which was held last May in Waterloo, Canada. So, you can see we are quite concerned about exchanging information on water planning, development and management to resolve issues in providing adequate and high-quality water to users throughout the world.

The objectives of IWRA are to promote the advancement of water resources planning, development, management, science, technology, research and education on an international level; establish an international forum for planners, administrators, managers, scientists, engineers, educators and others who are concerned with water resources; encourage collaboration with and support of international programs, including cooperation with other organizations in activities of common interest.

I believe I enhanced the development of this first academic conference when I met Professor Shuval at the Stockholm Water Festival in August 1991 and introduced him to a young hydrologist from Palestine. Since we have worked together for over a year on this conference, I am pleased to see the program and your presence.

I look forward to interesting exchanges of information in the development of positive conclusions and planning for a second academic conference on Middle East water issues.

In summary, let's maintain the classical tradition of free and open academic exchange of ideas which the conference organizers have asked us to do.

Isaac/Shuval (Eds), Water and Peace in the Middle East
1994 Elsevier Science B.V.

A projection of the demand for water in the West Bank and Gaza Strip, 1992-2005

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Abstract

This study analyses the estimated demand for water in the occupied Palestinian territories bewteen 1992-2005 based on a number of assumptions and variables. Per capita consumption is expected to rise as well as population due to birth rate, conditions in the Gulf States, and a peaceful settlement. Industry and agriculture will also require a greater annual allotment, particularly if the occupied territories are to develop and experience economic growth. Moreover, irrigated agriculture is expected to utilize more dunums than at present. Lastly, greater efficiency in water consumption as well as water distribution and conveyance will allow Palestinians to better conserve water.

SUMMARY

This study is aimed at estimating the demand for water in the occupied Palestinian territories during 1992-2005. The estimates are made on the following assumptions:

1. Population is expected to rise from 1.92 million residents in 1991 (end of year) to 3.47 million in 2005. This increase assumes the return of 60,000 residents from the Gulf and Jordan during 1992 and 1993. It is also estimated that 300,000 other residents will return during 1994 through 2000, following agreement on an interim peaceful settlement.
2. Total consumption in the base year of 1990 is reported at 215 million cubic meters, as versus 1750 mcm in Israel and 879 mcm in Jordan. Overall per capita consumption is calculated at 129 cubic meters in the Occupied Territories, as compared to 376 in Israel and 255 in Jordan.
3. Total domestic consumption is expected to rise from 73.7 million cubic meters (mcm) in 1992 to 223.4 mcm in 2005. Per capita consumption in 2005 is projected at 64.6 cubic meters for the West Bank and 57.5 for Gaza Strip.
4. Water used in industry is estimated at 8.5 million cubic meters in 1992, and it is projected to rise to 29.3 mcm in 2005.
5. The quantity of water used in agriculture is estimated to rise from 153.4 million cubic meters in 1992 to 244 mcm in 2005. This estimate is based on the following assumptions:

a. The area under irrigation in the West Bank will rise from

95,000 dunums in 1990 to around 300,000 dunums in 2005 (60% of irrigable land). No increase in irrigated area is anticipated in Gaza Strip, mainly due to severe competition on land and scarce water resources for urban purposes.
b. Further improvement is anticipated in the efficiency of water use, so that by 2005 the quantity of water allocated per dunum is projected at 613 cubic meters in the West Bank and 570 in Gaza Strip.
6. Based on previous estimates, total water consumption is estimated to rise from 235.6 million cubic meters in 1992 to 496.7 mcm in 2005.
7. The demand for water has to account for the quantity of water wasted in the conveyance and distribution systems, which is estimated at 20 percent of total consumption in 1990. By 2005, the loss ratio is expected to drop to 8 percent of total consumption. This will raise the gross demand for water from 278 million cubic meters in 1992 to 536.4 mcm in 2005.

INTRODUCTION

Research relating to water issues has been the subject of serious interest and concern for all countries in the Middle East during the past few years. Given the relative scarcity of water resources in the region and rapidly growing demand, the conflict on water resources between Palestinians and Israel has always occupied significant position on the agendas of both sides. For understandable reasons, the focus so far has been on the supply side, that is on the relative share of each side in ground water resources and on riparian rights to river and wadi flows. But as aggregate supply is limited and offers little room for expansion, questions and issues relating to the demand side are gaining greater attention.

OBJECTIVES

This study is targeted at projecting the demand for water in the West Bank and Gaza Strip during the period 1992-2005. Estimates will comprise quantities required to meet domestic, irrigation, and industrial needs.

Ascertaining consumption needs is of immense use for planning purposes, especially at this point in Palestinian history. In addition, such information serves a vital purpose in the context of negotiations on water.

Consumption estimates will be compared with Jordan and Israel, the two countries with whom Palestinians share most of their water resources, and with whom they eventually have to establish cooperative water policies.

METHODOLOGY

The bulk of background information needed for the purpose of this study, such as that related to population and agricultural production data, has been solicited from official sources. Demand projections were based on consumption estimates for 1990 as a benchmark.

Domestic consumption for 1990 was assessed on the basis of the following information:

1. Municipal records of all major towns.
2. UNRWA records (for water consumption in refugee camps).
3. A sample study of households in rural areas and refugee camps.
4. Ramallah Water Undertaking and Bethlehem Water Authority.
5. Water Departments in the West Bank and Gaza Strip.
6. Interviews made with a number of leading local experts.

Consumption in agriculture is based on data collected from the Departments of Agriculture and Water, leading farmers and experts, and owners of artesian wells in major production areas.

1.0 Population size

Changes in population size during 1992-2005 reflect the net outcome to the interaction of attributes relating to size of initial population, fertility rate, mortality rate, and net migration balance.

1.1 The base population

The size of West Bank population on the eve of Israeli occupation is estimated at 843,000, and that of Gaza Strip at 460,000 (see Table 1-1). The population of the two territories underwent a sudden drop of 287,000 inhabitants during and shortly after the June 1967 war. According to a census conducted by Israeli authorities in September 1967, that is when the exodus of refugees subsided, the population of the occupied Palestinian territories was ascertained at 1,015,700 inhabitants (Table 1-1). All subsequent population data published by the Central Bureau of Statistics are based on statistical models and not on census (two full censuses were conducted in Israel during that period, one in 1972 and another in 1983).

Table (1-1)
Major population shifts
(thousands)

	West Bank		Gaza	
	Total	E.Jerusalem	Strip	Total
May 1967	845.0		460.0	1303.0
Sept. 1967	661.7	65.8	354.0	1015.7
Dec. 1968	656.6	73.5	356.8	1013.4
Dec. 1991*	1155.0	149.0	676.0	1831.0

*Estimate

Sources: 1. Jamil Hilal, West Bank: Economical and Social Structure (1948-1974), Beirut: PLO Research Center, 1975, p.180.

2. Israel Defence Forces, Census of Population 1967, Vol.I, p.x., and Census of Population in East Jerusalem, 1967, Vol.I, p.x.
3. Jerusalem Statistics Yearbook, Jerusalem: The Israel Institute for Jerusalem Studies, 1989, p.26.
4. Statistical Abstract of Israel. Jerusalem: Central Bureau of Statistics, 1992, p.732.

1.2 Changes in population since 1968

The population of the occupied Palestinian territories has incurred an overall increase of 81 percent during 1968-1991, i.e. over a period of 23 years (see Table 1-1). The increase in population was the ultimate outcome of the following demographic transformations (CBS Pop. Projections):

a. Crude birth rates remained during 1969-1984 within the high range of 46-49 in Gaza Strip and 43-46 in the West Bank.
b. Total fertility rate for 1983-1987 amounted to an average of +6.5 births per woman in the West Bank and 7.2 in Gaza Strip.
c. Infant mortality dropped steadily reaching to 60 per thousand by the early 80's.
d. Total rate of mortality in the West Bank has dropped from 24.1 per thousand in 1968 to 15.8 in 1977, and then to approximately 8 per thousand in 1987.
e. A large number of Palestinians were forced to return back home in the aftermath of the Gulf war. This is especially clear during the year 1990-1991, where population increased by 82,000, i.e. about twice the usual increase in previous years.

1.3

Because of depending totally on the results of a census collected 24 years ago and under very unusual circumstances, the Central Bureau of Statistics population estimates are seriously contested by many experts, whether Israelis or Palestinians. In particular, the CBS estimates for Gaza Strip are believed to be significantly low. A conservative estimate for 1991, as based on information gathered from municipal sources and UNRWA, is 765,000 residents. This is the size of population used for projection purposes in this study.

Table (1-2)
Number of emigrants with local ID cards
(1968-1988)

	No. of emigrants
West Bank	165.3
Gaza Strip	106.4
Total	271.7

Source: Statistical Abstract of Israel, 1989, p.700.

1.4 Net migration

The entire post-occupation period has been characterized by a relatively high rate of net emigration. The total number of emigrants during 1968-1988 (i.e. residents with local ID cards) amounted to nearly 272,000 (see Table 1-2), i.e. around 20 percent of the average population during that period.

1.5 Projected population size

Projections of population will be heavily affected by anticipated transformations in the demographic attributes outlined earlier. Total fertility rates are expected to drop by 0.5 every five years, reaching by 2000 to an average of 5.0 in the West Bank and 5.7 in Gaza Strip (CBS). Life expectancy at birth was estimated during the beginning of the 80's at 63 for both territories, and it is projected to rise to 69 by 2000, i.e. at the rate of two years every five year period. Infant mortality will drop to 30 per thousand, at the reduction rate of 10 infants per thousand.

Population shifts ensuing to migration are very difficult to predict, mainly because of their strong bearing on uncertain political developments. Based on current trends, however, there seems to be three exclusive political scenarios in regard to future migration dynamics:

a. Long tern emigration forces of the 70's and 80's may continue through the 90's, but at slightly lower rates. In this case net emigration accruing to "normal" push and pull factors will proceed at the modest rate of 0.8 percent of average population size in the West Bank, and 0.5 percent in Gaza Strip.

b. The Gulf crisis has generated deep anxieties and strong feelings of insecurity among Palestinians in the Gulf states. As a result of increasing restrictions, it is expected that around 60,000 Palestinians with Israeli ID cards will be forced to return to their homeland during the course of 1992 and 1993 (30,000 per year).

c. Another major development bearing on emigration is that ensuing to arriving at a peaceful settlement to the Palestinian-Israeli conflict. It is of course very difficult to envisage the detailed outcome of such a settlement. But even a modest formula which grants Palestinians some form of incomplete sovereignty, for instance, something in line with Camp David's "total autonomy" formula, is still likely to trigger an influx of returnees. However, in view of political limitations and economic constraints, the return of Palestinians will be partial and gradual.

It is expected that 300,000 Palestinians will come back to the emerging political entity in the West Bank and Gaza Strip, at the rate of 50,000 per year. The return of Palestinian residents from the diaspora is expected to commence in 1994 and continue through the end of the decade. The bulk of returnees will come from among refugees living now in Lebanon. The rate of return will be higher and faster should negotiations lead to complete independence of the forthcoming Palestinian entity. All returnees are expected to settle in the West Bank, as Gaza Strip is already over-crowded.

The population of the West Bank and Gaza Strip during 1991-2005 has been calculated in view of all previous assumptions. Table (1-3) shows that total population of both territories will rise from around 2.0 million in 1991 to 3.5 million in 2005.

Table (1-3)
Population estimates 1991-2005
(thousand)

Year	West Bank	Gaza Strip	Total
1991	1155	765	1920
1992	1212	801	2013
1993	1271	838	2109
1994	1360	866	2226
1995	1454	895	2349
1996	1551	925	2476
1997	1651	955	2606
1998	1752	987	2739
1999	1856	1020	2876
2000	1914	1053	2967
2001	1971	1087	3058
2002	2030	1122	3152
2003	2089	1157	3246
2004	2149	1193	3342
2005	2240	1230	3470

1.6 Distribution of population by type of settlement

The distribution of population by type of settlement is of special importance for the sake of this study. The only field data available in this regard is that derived from the 1967 census. In 1987, however, a field study was conducted to ascertain the geographical distribution of population in the West Bank and Gaza Strip. Table (1-4) shows that there has been a marked degree of urbanization in the two territories during 1967-1987.

Table (1-4)
Distribution of population by types of settlement

West Bank	% 1967	% 1987
Rural	61.4	52.4
Urban	30.1	37.8
Refugee camps	8.5	9.8
Gaza Strip		
Rural	9.6	8.5
Urban	42.1	48.2
Refugee camps	48.3	43.3

Sources: 1. Israeli Defence Forces, Census of Population 1967, Vol.I, p.x. and Census of Population in East Jerusalem, 1967, Vol.I, p.x.
2. M. Benvenisti and S. Khayat, The West Bank and Gaza Atlas, Jerusalem: The West Bank Data Base Project, 1988, p.28.

2.0 Estimates of present water consumption

2.1

Consumption estimates for 1990 were assessed on the basis of detailed pieces of information and data ascertained from a variety of sources, as explained earlier in the section on methodology. According to these estimates, total consumption in the West Bank amounted in 1990 to 118 million cubic meters (mcm) and to 97 mcm in Gaza Strip (see Table 2-1).

Table (2-1)
Present water consumption - 1990
(in million cubic meters)

	W.Bank	G.Strip	Total	Israel	Jordan
Total consumption	118	97	215	1750	879
Agriculture	84	68	152	1162	657
Domestic	29	27	56	482	179
Industry	5	2	7	106	43
Av. Population (1000)	936	730	1666	4660	3455
Per capita (m3):					
Overall	126	133	129	376	255
Domestic	31	37	34	103	52

Sources: 1. Statistical Abstract of Israel, 1991, pp. 8-42.
2. M. Bilbaisi and M. Bani Hani, Jordan's water resources and the expected domestic demand by the years 2000 and 2010, a paper in Jordan's Water Resources and Their Future Potential, pp. 14-25.
3. For the West Bank and Gaza, see section on methodology.

2.2

Water consumption in Gaza Strip seems to have dropped markedly during 1980-1990, from around 120 to 97 million cubic meters per year (Kanan, p.24). This drop, however,is manifest only in regard to irrigation water, and not to water used for domestic purposes.

The substantial decline in the volume of irrigation water has been precipitated in response to a number of measures and policies, most importantly the following:

- Imposing a strict quota on water allocated for each type of irrigated pattern of farming. Until recently, those quotas were in most cases lower than common rates used in irrigating major farming patterns.
- Encouraging citrus farmers to replace their orchards with perennial crops, on account of low profitability. In line with this policy no licences are being granted for planting citrus orchards. Notwithstanding Israeli encouragement measures, however, farmers in Gaza Strip are so deeply discouraged by the declining profitability of citrus that many of them have voluntarily opted to uproot their orchards and cut heavily on the quantity of water used in irrigation.
- Israeli policies forbidding the drilling of new wells was an

important factor in reducing the quantity of water available for irrigation. This factor, however, was of little impact during the intifada, due to difficulties encountered by government authorities in enforcing regulations.

- Farmers are actively encouraged to modernize their irrigation techniques by providing them with subsidies. This process has been particularly successful in the vegetable subsection, where 88 percent of all land area is irrigated by modern drip techniques (56% in the West Bank). See Table 5-3.

2.3

Comparisons with Israel and Jordan indicate great disparities in per capita rates and in total consumption. Overall per capita consumption in each of Israel and Jordan was 2.9 and 2.0 times higher, respectively, than the average for the Occupied Territories (for 1990).

Aggregate water consumption in Jordan has risen by 20 percent during 1989-1990 (estimated at 733 mcm for 1989). This increase is attributed mainly to the influx of returnees from the Gulf. Furthermore, there has been a continuous rise in the quantities of water used in agriculture and industry.

In contrast to Jordan, water consumption in Israel has undergone steady decline during the past few years. After getting to a peak of 1987 million cubic meters in 1986, total consumption has declined steadily in subsequent years. By 1990 it was 237 mcm lower (12 percent) than its 1986 level.

3.0 Domestic water consumption

3.1

Domestic water consumption is depicted to include water consumed in the following areas:

a. Home uses.
b. Irrigating gardens surrounding homes.
c. Public utilities.
d. Trading, services and repair shops.
e. Industrial firms which demand less than 500 cubic meters per year.

3.2

Domestic per capita water consumption has a strong positive correlation with living standards. This relation involves numerous hygienic and cultural implications bearing on water consumption patterns. In general, the main criterion for measuring improvement in living standards is that of per capita income.

Irrespective of differences in living standards, actual rates of water consumption fluctuate markedly from one community to another, again in direct correlation with the degree of urbanization. This correlation is the resultant of differences in the volume of water supply available to households, ease of conveying water to consumers homes, type of sewage system available, average area of houses inhabited, and the presence of gardens around those houses.

Obviously, there could be marked differences in regard to some of these attributes between the three major types of settlements in the Occupied Territories, namely, urban towns, villages, and refugee camps. For instance, consumption rates in towns with modern pipe systems and uninterrupted flow are much higher than in small villages where drinking water is still procured from collection cisterns, or carried over relatively long distances by lorry tankers.

3.3

Taking all the above-mentioned attributes into consideration, a weighted average of per capita domestic water consumption has been projected for 1992-2005 (see Table 3-1). It is assumed that consumption will rise at the uniform overall rate of 5 percent per annum in the West Bank and 3 percent in Gaza Strip. These rates are assessed in the light of the following assumptions:

a. GNP per capita will rise during this period at about 5-7 percent per annum. Such modestly high rates of growth are anticipated during an interim period of a peaceful settlement. Higher rates of income will result in raising rates of domestic water consuption, specially when consuption rates are still within low brackets.

b. Small industries will continue to proliferate, possibly at higher rates, due to anticipated improvement in investment climate and market population growth.

c. Domestic water consumption will be positively influenced during the forthcoming decade by the eventual growth in the tourism sector. Growth in this sector will result in tangible improvements in the level of supportive services, such as swimming pools and other outdoor auxiliary services.

Table 3-1
Per capita consumption of domestic water
(in cubic meters)

Year	West Bank	Gaza Strip
1990	31.0	37.0
1991	32.6	38.1
1992	34.2	39.2
1993	35.9	40.4
1994	37.7	41.6
1995	39.6	42.8
1996	41.6	44.1
1997	43.7	45.4
1998	45.9	46.8
1999	48.2	48.2
2000	50.6	49.6
2001	53.1	51.1
2002	55.8	52.6
2003	58.6	54.2
2004	61.5	55.8
2005	64.6	57.5

d. Viewed in comparative terms, growth rates in domestic water consumption as projected in this study are still lower than those of Jordan as they were during 1980-1990. Total consumption increased during that period at 8-10 percent per annum (Bilbaisi and Bani Hani, p.65), and population grew at the annual rate of about 3.5 percent. Per capita consumption in Jordan is projected to rise until it reaches a maximum of 65.7 cubic meters in the year 2005, (equivalent to 180 liters per capita per day)- Source Bilbaisi, op.cit, p.24.

It is clear from the above comparisons that projected consumption rates in Jordan will remain higher than those projected for the West Bank and Gaza Strip (see Table 3-1).

3.4 Domestic consumption

Domestic water consumption for each of the two occupied territories is calculated in Table (3-2), as based on population projections and per capita consumption estimates computed earlier.

Table 3-2
Domestic water consumption
(million cubic meters)

Year	West Bank	Gaza Strip	Total
1990	34.5	29.3	63.8
1991	37.7	30.2	67.9
1992	41.5	31.4	72.9
1993	45.6	33.9	79.5
1994	51.3	36.0	87.3
1995	57.6	38.3	95.9
1996	64.5	40.8	105.3
1997	72.1	43.4	115.5
1998	80.4	46.2	126.6
1999	89.5	49.2	138.7
2000	96.8	52.2	149.0
2001	104.7	55.5	160.2
2002	113.3	59.0	172.3
2003	122.4	62.7	185.1
2004	132.2	66.6	198.8
2005	144.7	70.7	215.4

3.5 Consumption by Palestinian "visitors"

The previous estimates of domestic water consumption are based only on population residing inside the Territories, more or less on a permanent basis. But in addition to resident inhabitants, the West Bank and Gaza receive annually a great number of visiting Palestinians who come back home to spend their summer vacations or attend to their businesses. The annual number of "visitors" amounted in the late 70's and early 80's to around 125,000, but it later dropped to around 80,000 during the middle 80's (Judea, Samaria and Gaza Area Statistics, Jerusalem: Central Bureau of Statistics, 1986 (2), p.2). This drop is attributed largely to the exorbitant fees imposed on permits by

Israeli authorities: in 1992 around $950 for family of six (calculated from tariff instructions at local post offices). A major factor relates also to the excessive delays and harassments inflicted on visitors on the Israeli side of the bridges.

The average duration of stay by visitors coming into the Territories is around 30 days, coinciding with the summer months. Per capita water consumption of visitors is believed to be higher than that for dwellers in local urban areas, estimated by municipal water experts (for 1990) at about 70 cubic meters per year. When discounted for a period of one summer month, per capita consumption in the base year (1992) is estimated at 8 cubic meters per annum.

No figures are yet available on the number of visitors during 1989 or 1990, but they are estimated at 60,000 and 80,000, respectively. The number of visitors for 1992 is estimated tentatively at 100,000. Visitors will increase tangibly during subsequent years as a consequence to expected relaxation in entry regulations in the aftermath of a peaceful settlement. Their number is expected to rise at about 20 percent per annum up until the year 2000, and then the rate of increase will probably drop to 10 percent per annum. Per capita consumption is projected to rise by an annual increment of 3 percent.

Based on previous assumptions, the quantity of water consumed by visitors during 1992-2005 is calculated in Table (3-3).

Table (3-3)
Water consumed by "visitor" Palestinians

Year	No.of visitors (1000)	Per capita cons (cubic meters)	Total cons (1000 m3)
1992	100	8.0	800
1993	120	8.2	984
1994	144	8.4	1210
1995	173	8.6	1488
1996	208	8.9	1851
1997	250	9.2	2300
1998	300	9.5	2850
1999	360	9.8	3528
2000	432	10.1	4363
2001	475	10.4	4940
2002	522	10.7	5585
2003	574	11.0	6314
2004	631	11.3	7130
2005	694	11.6	8050

3.6 Total domestic consumption

Total consumption of water for domestic purposes for the period under study has been ascertained in Table 3-4. Consumption is expected to rise from 64.4 million cubic meters in 1990 to 223.4 millions in 2005.

Table (3-4)
Domestic water consumption
(million cubic meters)

Year	W. Bank	G. Strip	Visitors	Total
1990	34.5	29.3	0.6	64.4
1991	37.7	30.2	0.7	68.6
1992	41.5	31.4	0.8	73.7
1993	45.6	33.9	1.0	80.5
1994	51.3	36.0	1.2	88.5
1995	57.6	38.3	1.5	97.4
1996	64.5	40.8	1.8	107.1
1997	72.1	43.4	2.3	117.8
1998	80.4	46.2	2.9	129.5
1999	89.5	49.2	3.5	142.2
2000	96.8	52.2	4.4	153.4
2001	104.7	55.5	4.9	165.1
2002	113.3	59.0	5.6	177.9
2003	122.4	62.7	6.3	191.4
2004	132.2	66.6	7.1	205.9
2005	144.7	70.7	8.0	223.4

4.0 Water for industry

4.1

Industry is of relatively minor significance in the economies of the occupied Palestinian territories. The industrial sector's share in the gross domestic product of the Territories is only around 10 percent, and its share in the labor force is 15.5 percent (Statistical Abstract of Israel, 1992, p755). Industrial firms in the West Bank and Gaza are characterized by their small size and household nature. The vast majority of firms are merely small workshops which are located mostly within municipal boundaries of major towns. Consequently, they derive their water supply from municipal sources. As has been already noted, the demand for this kind of activity is accounted for within domestic consumption estimates. This is probably one important reason for the relatively high per capita consumption in urban centers as compared with rural areas.

4.2

The nature of the Palestinian industrial sector and its role in the local economy have undergone pronounced transformations since the middle 80's, and more so since the outbreak of the intifada. Palestinian enterpreneurs have succeeded in initiating a wide range of import substitution industries. Some of them have developed the quality of their products and their price competitiveness to the point where they have become export-oriented. Prominent examples include margarine, textiles, shoes, stones, marble, and agricultural machinery.

The remarkable successes of the past few years have created new aspirations for Palestinian entrepreneurs. These expectations are reinforced by the growing conviction that a large population cannot be sustained solely by agriculture and that much could be done to promote the two other major sectors, industry and tourism.

4.3
Expanding industrial activity beyond its household size will result in rapidly rising demand for water. This applies for instance, to such industries as stone cutting operations, hide tanning factories, and stone washing laundries. Total water consumption of industrial plants located outside municipal boundaries is estimated for 1990 at 7 million cubic meters. Based on estimates solicited from the chambers of commerce and a number of sampled industrialists, water consumption by industry is likely to rise at the rate of 10 percent annually, to reach 21 mcm in 2000 (see Table 4-1). This quantity amounts to only 39 percent and 20 percent of Israel's industrial water consumption in 1960 and 1988 respectively.

Table (4-1)
The Territories' industrial water consumption
1990-2000

Year	Million cubic meters	Year	Million cubic meters
1990	7.0	1998	15.0
1991	7.7	1999	16.5
1992	8.5	2000	18.2
1993	9.4	2001	20.0
1994	10.3	2002	22.0
1995	11.3	2003	24.2
1996	12.4	2004	26.6
1997	13.6	2005	29.3

4.4
At the present levels of water use in industry, and in the light of relatively low prices of water, no serious efforts have been exerted to develop or introduce water saving techniques in industry. A limited degree of re-use is common in certain industries, but this is too small to affect tangible demand projections. This applies even more so to recycling techniques, since they may require capital investment of a size which is too high for the vast majority of Palestinian industrialists.

5.0 Water for irrigation

5.1
Irrigated farming occupies a dominant role in the agricultural sector and economy of the occupied Palestinian territories. Sectoral analysis of income from agriculture for the 1989-1990 season reveals that irrigated farming patterns contributed 32 percent of total agricultural income (24 percent in the West

bank and 60 percent in Gaza Strip). Exports of irrigated farm produce, consisting mainly of citrus and vegetables, constitute on the average 26 percent of total exports.

Irrigated agriculture can also help generate additional employment opportunities and satisfy rapidly growing demand for food. Both of these objectives will become more critical in the wake of a peaceful settlement, which will result in an influx of Palestinian returnees.

For all these reasons Palestinian authorities will attempt expanding irrigated agriculture to the furthest limit permitted by over-riding constraints.

5.2

The physical area of land under irrigation, i.e. after discounting for inter and double cropping, was estimated for 1990 at 205,400 dunums, a little more than half of it is located in Gaza Strip. Table (5-1) shows that the area under irrigation makes up only 5 percent of the area under cultivation in the West Bank, and 58 percent in Gaza Strip. The West Bank is also lagging far behind Israel and Jordan in this regard.

Table (5-1)
Area under cultivation-thousand dunums (1990)

	Total land area	Total cultivated area	Irrigated Area	%Irrigated to cultivated
West Bank	5572	1793	94.9	5.3
Gaza Strip	363	189	110.5	58.2
Israel	21501	4333	2142	49.4
Jordan	89206	3080	506	16.4

Sources:
1. Agricultural Statistics Quarterly, 1990 (1),p.65.
2. Departments of Agriculture in the West Bank and Gaza.
3. Statistical Abstract of Israel, 1990, p.7.
4. Agricultural Statistics Indicators, 1981-1988. Amman: Ministry of Agriculture, 1989, p.7.

5.3

Water consumption in agriculture is markedly influenced by types of crops and geographic location of farms. Table (5-2) shows that 68 percent of total irrigated area in the West Bank is grown by vegetables, and 25 percent by citrus orchards. In Gaza Strip, by contrast, citrus orchards comprise 55 percent of the irrigated area, and vegetables occupy only 37 percent.

Table (5-2)
Distribution of irrigated area by region and types of crops 1990 (dunums)

	Citrus	Other trees	Vegetables	Total
West Bank	23,700	6,900	64,300	94,900
Gaza Strip	60,284	9,000	41,238*	110,522

*This includes 7500 dunums irrigated by subsurface water (called locally mawassi irrigation).
Source: Departments of Agriculture in the West Bank and Gaza Strip.

5.4
A major determinant of the volume of water used in agriculture is that relating to methods of irrigation, which have witnessed a remarkable improvement over the past 15 years. All crops grown inside greenhouses, and most of those in open vegetable farms are served by highly efficient drip irrigation techniques. The overall ratio of modern drip techniques used on vegetable farms amounts to 69 percent of total irrigated area in the West Bank and 85 percent in Gaza Strip (see Table 5-3). The area of tree orchards served by modern methods, on the other hand, is much lower, amounting to 18 percent of total irrigated orchards in the West Bank and 49 percent in the Strip.
The relatively slow progress in irrigation technology in citrus orchards is attributed to two main reasons. Firstly many farmers believe that after having used flood irrigation in their orchards for so long (25 years or more), the root systems of trees have spread out to such extensive sizes that it is no more practical to deliver water into the root zone by drip techniques. This claim, however, has been contested by irrigation experts who have been interviewed in the course of this study. Secondly, the lack of adequate funding sources has constituted an important deterrent to modernization of irrigation technology, especially in tree orchards, where cost of installation is higher than for vegetable crops.

Table (5-3)
Methods of irrigation - 1990

	West Bank		Gaza Strip	
	Dunums	%	Dunums	%
Total irrigated	94,900		110,500	
Vegetables		100.0		100.0
Modern techniques	38,000	59.1	35,000	85.0
Old techniques	26,300	40.9	6,200	15.0
Tree orchards		100.0		100.0
Modern techniques	5,400	17.6	33,800	48.8
Old techniques	25,200	82.4	35,500	51.2

Source: Departments of Agriculture

5.5
Water rates applicable to West Bank and Gaza farms vary considerably, depending mainly on the type of crops, geographic location, and methods of irrigation used. The following are the rates as in the late 80's.

	m^3/year
Vegetables in greenhouses	
- West Bank	650
- Gaza Strip	570
Bananas in the Jordan Valley	2000
Citrus - Jordan Valley	1200
- Tulkarm	850
- Gaza Strip	810
Olives in Gaza Strip	240

It is important to note that the rates mentioned above are those recommended by the Department of Agriculture and not those actually applied by farmers. In some cases actual rates are higher because of still using old irrigation techniques. In many cases, especially in Gaza, farmers use less water than recommended so as to minimize cash expenses.

5.6
Based on previous data in regard to areas under irrigation and prevailing rates of water application, the volume of water used in agriculture, as in 1990, is estimated at 84 million cubic meters in the West Bank and 68 million cubic meters in Gaza Strip.

5.7
The ruling prices of irrigation water pose a serious problem for farmers in the Occupied territories. The price of irrigation water in major farming areas, as in the summer of 1991, was 22 cents per cubic meter in the West Bank and 14 cents in Gaza Strip, compared to around 9 cents in Jordan and 14 cents in Israel. The cost of irrigation water at these prices has become a primary obstacle to increased competitiveness of Palestinian farmers, especially in the West Bank. For instance, the cost of water amounts currently to US$ 175 per dunum of citrus and $102 per dunum of green house vegetables, i.e. 67% and 10%. respectively, of the total cost of purchased inputs (H. Awartani and S. Joudeh, Irrigated Agriculture in the Occupied Palestinian Territories, Nablus: An-Najah University, 1991, p.26). Given the present low profitability of most farming patterns, farmers will find little or no incentive to expand their scale of operation. Consequently, farmers will need more water only if the economics of agriculture are improved.

5.8
The future demand for irrigation water in the occupied Palestinian territories is ascertained in view of the following assumptions:
a. A primary assumption is that Palestinians in the West Bank and Gaza Strip have strong reasons to attempt expanding the area under irrigation to the furthest possible limit. This objective helps maximize the employment potential of agriculture, and it secures food supplies for a rapidly growing population. Besides, a larger agricultural sector should help the new Palestinian

entity rectify anticipated deficit in its balance of trade.
b. Achieving a considerably higher area of irrigated farming, however, is severely constrained by important obstacles, most importantly the following:
- small area of land fit for irrigation,
- inadequate water supply available to farmers,
- high ruling prices irrigation water, and
- prohibitive regulations promulgated by the ruling authority.
c. Despite current problems ensuing to agricultural surpluses, it does not necessarily follow that increasing output will lead to worsening in profitability of farming patterns. An expansionary agricultural policy may still be able to cope with surplus hazards, if the following conditions are satisfied:
- Implementing a vigorous process of diversification, targeted both at substituting imports and at meeting the specific needs of export markets. The potential in both directions is far from being exhausted. The Territories, for instance, are still heavily dependent on Israel for their domestic demand of several food items, many of which can be produced locally (i.e. persimmons, dates, avocados, peaches, early grapes, and fodder crops for livestock).
- The Territories can go a long way towards expanding those agro-industries which are based on local raw materials. Until now, and despite acute occasional surpluses of several fruits and vegetables, the status of agro-industries is very unsatisfactory, both in size and technological level.
- It is further assumed that any Palestinian entity emerging in the West Bank and Gaza in the wake of a political settlement will be accorded enough sovereignty to be able to negotiate equitable terms of trade, both with Israel and with neighboring Arab countries. And assuming that Palestinian growers attain a sufficiently high level of competitiveness, then any loosening in current trade barriers will endow them with a wider export potential.
d. The efficiency of using water in agriculture is expected to undergo further improvement, mostly in the following areas:
- Modernizing facilities installed on artesian wells, especially by discarding worn out engines and pumps and replacing them by more efficient equipment.
- Renovating pipe systems which are used at the present in conveying water from tube wells to destination farms,
- Promoting wider application of modern irrigation techniques on tree orchards, which are estimated to consume about 4% of all water used for irrigation in the Territories.

5.9
The area of land fit for irrigated cultivation in the West Bank is restricted by rigid determinants relating to topographic features, especially in regard to slope and rockiness, and by the shallowness of surface soil. An aerial classification of West Bank's land area indicates that only 10 percent of total area (i.e. 612,000 dunums) is fit for irrigated farming (see Table 5-4) . Of that area , only around one fifth is already under irrigation.

Table (5-4)
West Bank's land by cultivation characteristics

Class	Area (1000 dun.)	Percent of total	Description
	5877	100.0	Total
1	172	2.9	Fit for irrigation
2	440	7.5	Potentially fit for irrigation
3	3693	62.8	Fit for rainfed farming
4	591	10.1	Fit only for grazing
5	981	16.7	Sometimes fit for grazing

Source: Unpublished report at the Department of Agriculture.

5.10
Notwithstanding topographic characteristics, the actual area of land which is realistically fit for irrigation is further constrained by problems relating to the ongoing conflict on land between Israel occupation authorities and Palestinians. A significant part of cultivable land, especially in the Jordan Valley, has been rendered inaccessible to local farmers for a variety of reasons. Large stretches were closed or confiscated for military and settlement purposes. Other areas were labelled as government land or were placed under custody because owners were "absent". Large areas have been used for a variety of public services, eg., roads, construction sites,...etc.

In view of all these constraints and barriers, it is estimated that the total West Bank area which is fit or potentially fit for irrigation is about 500,000 dunums. This area includes land which has fallen under Israeli control, as it is assumed that Palestinians will restore all their land resources, especially those in the Jordan Valley.

5.11
The area of irrigable land in Gaza Strip is estimated at 200,000 dunums, which is nearly twice the area presently under irrigation. But unlike the West Bank, there is no way that irrigation water supply from local reserves can be increased. On the contrary, a realistic policy in the short term should be targeted at cultivating the same area by using smaller quantities of water. Other prompt measures have to be taken in order to alleviate eventual deficit, such as implementing massive recharging schemes and exploiting an increasing quantity of sewage water after reclaiming it to a quality level fit for agricultural purposes.

5.12
Reaching the under limit of irrigated area in the West Bank (500,000 dunums) and in Gaza Strip (200,00) should be viewed as a long term strategic objective. Such an objective may become accessible once irrigation water is secured in quantities much larger than could be provided by locally available resources and then lift it to locations of higher elevation than that of potential sources of supply.

5.13
According to an Israeli study, the quantity of water needed to meet the under limit of irrigated land in the West Bank is estimated at 339 million cubic meters, and in Gaza Strip at 150 mcm (see Table 5-5). These quantities are 4.0 and 2.6 times larger than those used for agricultural purposes in both territories at the present.

Table (5-5)
Demand for water-upper limit

	Area 1000 dunums	Water rate m3/dunum	Quantity of Water needed (1000m3)
West Bank-total	500		339,000
Coastal plains	90	700	63,000
Hilly areas	270	550	148,000
Eastern foothills	60	800	48,000
Jordan Valley	80	1000	80,000
Gaza Strip-total	200	750	150,000
Grand total	700		489,000

Sources: Elisha Kally, Water and Peace, University of Tel Aviv, an unpublished manuscript, 1990, p.130.

5-14
Full-fledged development of irrigated farming in the West Bank at a scale like that mentioned in Table (5-5) is contingent on implementing massive regional water projects and arriving at total evacuation of Israeli settlements and military forces from the West Bank and Gaza. These hypotheses need to be cautiously qualified.

An advanced degree of cooperation between Israel and its neighbors is not feasible as long as all Arab countries (with the exception of Egypt) are in a state of war with Israel. Even Egypt, which may play a vital role in regional water cooperation schemes, refuses to normalize relations with Israel to the point where such projects can be seriously considered, until a peaceful settlement is arrived at to the Palestinian conflict. Any such settlement has to result in restoring sovereignty on all occupied Palestinian territory. On the other hand, it is not likely that Israelis agree and carry out a total withdrawal from those territories within the time span in question.

5.15
Taking into consideration over-riding political constraints and reservations, estimates of irrigation water needs are projected in Table (5-6) on more realistic assumptions. The area of irrigated land is expected to rise slowly during 1992-1996, and then at a faster pace in subsequent years. By the year 2005 the area of irrigated land in the West Bank is estimated at around 300,000 dunums, i.e. around 60 percent of the total area fit for irrigation.

Irrigation rate is projected to drop slowly but steadily until it is 31 percent lower than it was in 1990. The quantity of water allocated per dunum is expected to decrease all through the projection period, due to using more efficient irrigation techniques. The rate per dunum is likely to decrease by around 3 percent annually during 1990-1996, and then by 2 percent during 1997-2005.

Table (5-6) shows that the demand for irrigation water in the West Bank is projected to rise from 84 million cubic meters in 1990 to 184 mcm in 2005.

Table (5-6)
Demand for irrigation water - West Bank

Year	Area (1000 dunums)	Rate (m3/dunum)	Water (1000 m3)
1990	95	884	84,000
1991	98	857	83,986
1992	102	831	84,762
1993	107	806	86,242
1994	112	782	87,584
1995	118	758	89,444
1996	124	735	91,140
1997	134	720	96,480
1998	150	706	105,900
1999	170	692	117,640
2000	200	678	135,600
2001	220	664	146,080
2002	240	651	156,240
2003	260	638	165,880
2004	280	625	175,000
2005	300	613	183,900

5.16

Projecting the demand for irrigation water in Gaza is based on the following assumptions:

- There will be a severe competition on land between farming and settlement project of refugees. And due to the enormous size of the refugee settlement program, it will be very unlikely that more land can be allocated for agriculture.
- Because of acute and accumulated water deficit, no increase in the quantity of water is anticipated during 1992-2005. On the contrary, it will be necessary to curtail the volume of water used in agriculture so that water discharge is kept as close as possible to the level of renewable reserve.
- The present rates of irrigation in the Strip vary widely from one type of farming to another. Counting on the overall average for 1990, the rate of application for that year is estimated at 636 cubic meters per dunum.
- The rate of application will witness a slow drop, again because of anticipated improvement in the efficiency of irrigation techniques, especially in regard to tree orchards. The overall rate of decrease in irrigation rates is estimated at the annual rate of 1 percent.

Table (5-7) shows the quantity of irrigation water consumed in

Gaza Strip during the period 1990-2005. Demand projections indicate that the quantity of irrigation water will decline from 70 million cubic meters in 1990 to around 60 mcm in 2005.

Table (5-7)
Demand for irrigation water - Gaza Strip

Year	Area (1000 dunums)	Rate (m3/dunum)	Water (1000m3)
1990	110	636	70,000
1991	110	630	69,300
1992	110	624	68,640
1993	110	618	67,980
1994	110	612	67,320
1995	110	606	66,660
1996	110	600	66,000
1997	110	594	65,340
1998	110	588	64,680
1999	110	582	64,020
2000	110	576	63,360
2001	110	570	62,700
2002	110	564	62,040
2003	110	558	61,380
2004	110	552	60,720
2005	110	546	60,060

5.17 Total demand for irrigation water

The total amount of water required for irrigation in the West Bank and Gaza Strip during 1992-2005 is projected to rise by 59 percent, from 153 million cubic meters in 1992 to 244 mcm in the year 2005 (see Table 5-8).

Table (5-8)
The annual demand for irrigation water
(thousand cubic meters)

Year	West Bank	Gaza Strip	Total
1990	84,000	70,000	154,000
1991	83,986	69,300	153,286
1992	84,762	68,640	153,402
1993	86,242	67,980	154,222
1994	87,584	67,320	154,904
1995	89,444	66,660	156,104
1996	91,140	66,000	157,140
1997	96,480	65,340	161,820
1998	105,900	64,680	170,580
1999	117,640	64,020	181,660
2000	135,600	63,360	198,960
2001	146,080	62,700	208,780
2002	156,240	62,040	218,280
2003	165,880	61,380	227,260
2004	175,000	60,720	235,720
2005	183,900	60,060	243,960

6.0 Total water consumption

6.1

Based on previous estimates, total consumption of water (for all purposes) is projected in Table (6-1). The quantity consumed is expected to rise from 236 million cubic meters in 1992 to 497 mcm year 2005.

Table (6-1)
Projections of total water consumption
(million cubic meters)

Year	Domestic	Industry	Agriculture	Total
1990	64.4	7.0	154.0	226.4
1991	68.6	7.7	153.3	229.6
1992	73.7	8.5	153.4	235.6
1993	80.5	9.4	154.2	244.1
1994	88.5	10.3	154.9	253.7
1995	97.4	11.3	156.1	264.8
1996	107.1	12.4	157.1	276.6
1997	117.8	13.6	161.8	293.2
1998	129.5	15.0	170.6	315.1
1999	142.2	16.5	181.7	340.4
2000	153.4	18.2	199.0	370.6
2001	165.1	20.0	208.8	393.9
2002	177.9	22.0	218.3	418.2
2003	191.4	24.2	227.3	442.9
2004	205.9	26.6	235.7	468.2
2005	223.4	29.3	244.0	496.7

6.2 Projected water

The above estimates of water consumption do not account for water lost in the conveyance systems before water is delivered to destinations of actual consumption. Irrigation experts and water officials in municipal authorities emphasize that the loss rates in the conveyance systems are still of alarming levels, despite marked improvement in recent years. Water loss due to leaks in the conveyance system in the Ramallah Water Undertaking, which is the largest and probably the most modern in the Territories, is reported for 1989 at 13.5 percent, presumably about half of prevailing rates (Progress Report, 1990, Ramallah Water Undertaking, p.25).

There have been many reasons for the high loss ratio in the delivery system, chronic shortage in financial resources necessary to modernize those systems. There have also been many barriers relating to administrative difficulties pertaining to occupation.

Conveyance loss in the irrigation water delivery system is particularly high in soem parts of the country where water is transported in open canals for long distances. For instance, the loss ratio is around 30 percent in the Wadi Fara's Canal. But the loss ratio is lower in pipe systems, depending on the quality of pipes. Loss ratios in distribution systems connected to artesian wells vary from 10 percent to 20 percent. It is of course expected that water loss in the conveyance system will decrease during 1992-2005. But this process will take place gradually, and it may pick up momentum later when a national water authority launches a concerted and vigorous effort for that purpose. The loss ratio is assumed to drop from an overall average of 30 percent in 1990 to 8 percent in 2005.

6.3 Projected total consumption

Table (6-2) projects the total demand for water in the occupied Palestinian territories after allowing for anticipated losses in the conveyance system. Total consumption is expected to rise from 278 million cubic meters in 1992 to 536 millions in the year 2005.

Table (6-2)
Gross water demand 1990-2005
(million cubic meters)

Year	Total consumption	Percent loss	Quantity lost	Gross demand
1990	226.4	20	45.3	271.7
1991	229.6	19	43.6	292.2
1992	235.6	18	42.4	278.0
1993	244.1	17	41.5	285.6
1994	253.7	16	40.6	294.3
1995	264.8	15	39.7	304.5
1996	276.6	14	38.7	315.3
1997	293.2	13	38.1	331.3
1998	315.1	12	37.8	352.9
1999	340.4	11	37.4	377.8
2000	370.6	10	37.1	407.7
2001	393.9	10	39.4	433.3
2002	418.2	9	37.6	455.8
2003	442.9	9	39.9	482.8
2004	468.2	8	37.5	505.7
2005	496.7	8	39.7	536.4

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WATER MANAGEMENT POLICY IN ISRAEL: A COMPREHENSIVE APPROACH

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Abstract

The problem identified in the study is water scarcity as opposed to the proper allocation of existing water resources. In principle, it is improbable that parties to the "water conflict" may reach any agreement on proper principles (namely distribution of existing sources) in the face of an absolute supply constraint. One must work, then, with the assumption of one single society between the Mediterranean and Jordan and the assumption that this society will face a common challenge at the beginning of the next century when its total potential of fresh water is fully exploited for drinking purposes.

The problems of an acute supply shortage, protection of existing fresh water resources from contamination, and the preparation of non-conventional water resources must be dealt with from a multi-disciplinary standpoint. It is necessary to set priorities in dealing with the above issues as it is deemed unfeasible to cope with the challenges of sewage reclamation and sea water desalination at the same time.

- In terms of the water supply problem (current shortfall/ future supply), while the future resource of water is indeed the sea, this need only holds true once all fresh water is exploited for drinking purposes and all reclaimed sewage is treated for agricultural use. The additional cost added to sewage treatment is lower than the cost of desalination as well as the cost of using conventional water resources. Moving to the sea therefore depends on the extent to which the cost of desalinated water will or will not increase the cost of food production. A broad economic approach is advocated: While constructing sewage treatment plants it is necessary to simultaneously initiate the planning of desalination projects (given an implementation period of 15-20 years).
- In terms of water quality/contamination problem, the main concern lies with Israel's sea shore aquifer. The danger to the aquifer's water quality comes from constant seepage of encroaching sea water and the constant recycling of the same resource for irrigation. It is felt that the only way to restore the aquifer's water quality is by ceasing recycled usage of its water. It is suggested that water from the aquifer should be pumped and carried away for irrigation and that the aquifer should simultaneously be replenished with sweet water brought in from outside (i.e. desalination).

Desalination is therefore advocated as a (conditional) source for additional water and for the reclamation of the sea shore aquifer. The Jezreel Valley Canal Scheme authored by Shlomo Gur is felt to be the most feasible desalination scheme as it saves 60 percent of the energy required by other desalination

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methods. Cooperation is needed between Israel and Jordan for the implementation of this scheme.

1. WATER MANAGEMENT POLICY IN ISRAEL: A COMPREHENSIVE APPROACH

Before going to the core of the topic, I have to make a few opening remarks, the first of which is, that I am not advocating any official policy; I am speaking for myself only. My second remark refers to the definition of the topic on the agenda. The subject is generally defined as the problem of proper principles of water resource allocation between the peoples of the region. I am very well acquainted both with the figures and the claims of the parties involved; still, I stress that the problem is water scarcity, not proper allocation. I know that I may be blamed for ignoring the accusation against Israel for discriminating its neighbors; nevertheless, I insist that the parties can never agree upon proper principles when there is an ongoing acute shortage of water. I support any agreement on better exploitation of the Jordan and the Yarmuk resources, but there still remains the question of additional quantitites—the amount at our disposal is simply not sufficient to meet the essential demands. I suggest that we assume there is one society between the Mediterranian and the Jordan and that this society will be facing a common challenge at a certain appointed time at the beginning of the coming century, when the total potential of fresh water will be exploited for drinking purposes.

The main question to be answered by the parties involved in the dispute is about their choice-whether to go on squabbling about what has happened since 1948 and 1967, trying to turn the wheel backwards; or to face reality, and strive to achieve a solution for a better future. Needless to say that I am in favor of the second alternative. I hope that after the presentation of my view, it will be clear that if my proposal is accepted, equality of rights for water will be sustained and respected.

I do believe that drinking water as an essential source—not for quality of life, but for life itself—should be allocated on the basis of equality. I refer to the water balance between the Mediterranean and the Jordan intentionally, regardless of the nationality of the people in the region, or of the political regime. I refer to this area, because within 15-20 years its total amount of fresh water will be needed for drinking purposes. Agriculture will have to depend on reclaimed sewage only. At that appointed time when the whole resource of fresh water is required for essential human needs, water will be allocated on an equal per-capita basis.

If the approach I am about to present is accepted by the parties, then both sides will have to joint efforts—both for the creation of new water resources; and for the protection from contamination of the current resources at our disposal.

The only resource that can barely be considered as a season-to-season regulator is the coastal aquifer, and this resource is the most endangered by chemical contamination, meaning salinity. Its progressive increase in salinity is due, not only to the deficit of quantities and the long interface with the sea; but mainly to the recycling of its water, and having the sweet water evaporated while the salty concentrated water seeps into the aquifer. Studies have estimated our grace period as one decade only.

This is one of the points I would like to refer to in this presentation. The other one is the term used in our country, "water balance" or "water potential". I would like to emphasize that there is a meaning to this term only as long as the biggest consumer is agriculture, which is a flexible consumer. On the other hand, the urban consumer is a rigid consumer, and his water balance will equal the annual amount of water obtained from precipitation at every specific year.

Taking the above into consideration, one must remember the long duration of development of non-conventional resources; if we bear in mind that the time period needed for planning and construction of such projects is 15-20 years, then we must admit that arguing about the current allocation and use is no longer relevant. Preparation for a non-conventional water era should be initiated by the peoples of our area right now; otherwise, we are sowing the seeds of the coming conflict instead of bringing it to an end. In this context, may I add that we should deal with enriching the water supply of the peoples of the Jordan basin.

2. FORECAST OF THE FUTURE DEMAND

The population between the Mediterranean sea and the Jordan river has already reached the figure of seven million people. When the per capita consumption in Judea, Samaria, and the Gaza Strip equals the rate prevailing within the green-line boundaries, and the population reaches 15 million people, we shall then be very close to the time predicted, when all the available fresh water will be consumed for drinking purposes. One might think that this appointed time is somewhere over a far horizon, but one must bear in mind the rate of population growth among the Palestinians on the one hand, and, on the other, the expected immigration of Jews to Israel. Moreover, the time period needed for planning and developing a large-scale water project is usually 10-20 years. The peoples between the Mediterranean and the Jordan are going to face an entirely new situation sometime during the first decades of the coming century: insufficient fresh water resources. This forecast is extremely realistic and calls for careful strategic planning.

The multifaceted challenge of bearing the responsibility for an ongoing water supply, for protection of water resources from contamination, and for the preparation of non-conventional resources, can be dealt with only in a multi-disciplinary framework. There is more than one aspect involved, and each has its impact upon policy-making. The optimal solution to this complex problem does not lie solely in the technical field, nor in the economy itself; neither is it a purely environmental issue. The subject is a combination of various components. The question is not only the proper assemblage of the various components, each according to its relative weight, but the consideration of the appropriate time for each activity. Choosing the correct technology without proper timing is as much of a failure as is choosing the wrong technology.

I dare say that the name of the game for the coming decade will be coordination–coordination between capital resources and technologies on the one hand, and correct management of water resources on the other. We cannot afford the total exploitation of either of them.

3. SETTING OF PRIORITIES

The recent years of drought have generated an atmosphere of emergency, not only in the public sector, but also among the policy-makers. The general concept is that unless immediate action is taken, catastrophe is imminent. Needless to say that two alternatives have come up at the same time: sewage reclamation and water desalination.

To my regret, some of the policy-makers believe that they are facing the two options simultaneously. I reject the belief that we can cope with two challenges of such magnitude at the same time. The real meaning of policy-making is, to my mind, setting priorities within limited resources, however difficult that might be: it is well-known that resources are always limited.

4. SEA WATER DESALINATION

There is no doubt that the main source of water for human consumption, in the future, will be desalinated sea water. The question of when this will become so is not a marginal one. The problem as defined is not only whether our capital resources are sufficient to accomplish two such large development schemes simultaneously. The ability of agriculture to cover the cost of desalination is also a key issue which should be considered before making the decision to initiate desalination. If we rush in too early, then the demand of agriculture for water-subsidy will be too heavy a burden for the public sector to bear. In other words, if agriculture is forced to become dependent upon desalination before the development of agricultural technology which will optimize the cost of desalination, we shall endanger the very existence of agriculture.

I repeat, mankind's future resource of water is the sea, but not before every drop of fresh water is exploited for drinking purposes and every drop of reclaimed sewage has been treated to the standard of unrestricted use in agriculture. In due time, society must come to recognize and accept that we have turned to desalination not because fresh water resources have been totally utilized for urban purposes. The additonal cost that has to be added to secondary treatment of sewage is lower, not only than desalination, but also than conventional resources. Being able to produce water for unrestricted irrigation, at such a low price, will enable us to provide agricultural products for wide groups of population, at a price they can afford.

To put it in other words, the move towards the sea as our future resource is not a step which is limited to the technical field only. It means a major change in the whole socioeconomic structure and implies changes in the rate of the industrial per-capita production and costs as well as in per-capita income; so that the consumer of agricultural products can cover the cost of desalination, either bearing the current cost of desalination, or contributing towards a sharp reduction in the cost of desalination. All of these factors depend upon the degree to which the use of desalinated sea water will or will not increase the cost of food production.

5. A COMPREHENSIVE APPROACH

Progress cannot be achieved on a narrow front. It can only be achieved if all components which are linked to each other are confronted simultaneously. Still, there is one field on which I think I have to focus in closer review: this particular field is governmental finance for agricultural research and the research priorities. Some shallow-minded economists argue that the agricultural sector should, bu itself, cover the cost of agricultural research. This, they argue, is because the farmer benefits from sophisticated know-how, which is true only to a very limited degree: the divergence from the natural bounty of rain resources to desalination is an entirely new capacity, and will be a milestone on the main road of human progress. A narrow economic approach should not and cannot be our guide on this main path of universal benefit to humanity.

When referring to agricultural research, may I comment on the definition of goals and the setting of priorities of agricultural research. It has been, and still is, a widely accepted fact that the answer which agriculture should give to the high cost of desalination is hig-quality products. Truly, expensive products can cover the predicted expensive cost of desalination; but our goal, notwithstanding the high cost of water, should be the highest yields obtainable from every drop of water. High yields should, on the one hand,cover the cost of desalination, and on the other hand, respond to vast public demand for agricultural products at affordable prices. Our future obligation is feeding the increasing population of the area and dare I add, the world, in spite of the increase in cost and demand for water.

We are at the end of the era of fresh water as our sole resource; we must adapt ourselves toward desalination. This process requires a carefully planned multidisciplinary approach. During the transition period, sewage reclamation is the immediate environmental and economic solution.

In my previous remarks I made two statements that seem to be contradictory: on the one hand, I say that agriculture, by any account was not yet able to carry the burden of the cost of desalination, and that we should not rush into it; on the other hand, I claimed that the main source for human use would be desalinated sea water–but I also added that the time period needed for planning and developing a large scale water project would usually be 10-20 years. Putting it in a concise manner, I would say that while constructing sewage treatment plants—thus protecting our water resources from contamination and recovering our main resource for the near future—we have to initiate the planning of desalination projects for the coming century.

6. WATER QUALITY

Our main aquifer is the seashore aquifer. This aquifer is the only one with a volume that justifies the definition of a season-to-season regulator. This aquifer is also the one most endangered by contamination. On the one hand, this resource has a long interface with the sea, being therefore under permanent danger of encroachment by the sea. On the other hand, there is a constant seepage of concentrated salt water, caused by the constant recycling of the same resource for irrigation. This activity causes the fresh water to eventually evaporate, while salt water continually seeps underground. Even if the deficit of quantities of this aquifer is recovered, either by natural rainfall replenishment or by recharging it artificially, the danger to its quality still remains. Although there is a linkage between quantities and quality, there is, nonetheless, a reduction in water quality; the trend of quality has been studied, and the grace period we have been accorded is no longer than one decade.

7. THE IMPERATIVE NEED FOR DESALINATION

The only way to restore the quality of the sea-shore aquifer is to stop the recyled usage of its water. Water should be pumped and carried away for irrigation; the aquifer should be replenished with sweet water brought from outside.

Practically speaking, we have two alternatives. The first is quite simple to explain: desalination projects along the sea, either sea water or brackish water, and reinfiltration of the sweet water into the underground aquifer. This solution is technically fairly simple, but its cost is high. The second solution is less costly, but is rejected by the environmental authorities. The general idea is to divert part of the upper Jordan river before it spills into the Sea of Galilee, letting it drop directly, by gravity, into the National Water Carrier. The advantages of this scheme are twofold: saving energy by avoiding the need to pump the water from 209 m. below sea level–from lake Kinneret to the National Carrier at 140 m. above sea level; also, avoiding the mix of the Jordan fresh water with the saline water of lake Kinneret. Having done so, we get large quantities of water fit to improve and restore the quality of the sea shore aquifer. This scheme is rejected by those who claim that it will certain ruin the ecosystem equilibrium of the Sea of Galilee.

8. DESALINATION AS A SOURCE FOR ADDITIONAL WATER AND FOR THE RECLAMATION OF THE SEASHORE AQUIFER

As I have said before, the use of high-cost desalinated sea water should not be applied to agriculture. Agriculture in our region will put to use reclaimed sewage as a low-cost, reliable source. But one question still remains: what will be the additional source of fresh water for both urban consumption and recovery of the sea shore aquifer? I am glad to be here, to present the Jezreel Valley Canal Scheme, on behalf of my good friend Shlomo Gur, who was prevented, for health reasons, from doing so himself.

The general idea is to dig a canal, starting at the Mediterranean, and ending up 275 m. below sea level at Beisan Valley. From a given location, east of the low point at the Beisan Valley, 50 m. above sea level, the salty sea water will flow by effect of hydrostatic gravity pressure, directed into desalination facilities located at the low point in the Beisan Valley, operating under the reverse osmosis system. The hydrostatic gravity pressure exploited by the reverse osmosis method could save approximately 60% of the energy required by other desalination methods. I need not go into details and figures yet; but if this scheme is adopted by the two countries, both will profit from large additional quantities of sweet water. Jordan will be able to direct its share directly into its water system; Israel will be able to store its own share in the Sea of Galilee, to compensate for the amount of water diverted from the upper Jordan directly by gravity into the National Carrier; this will save energy, and, at the same time, protect the quality of the Lake of Galilee and the sea shore aquifer.

In conclusion, I declare that we are at the end of the age of dependence upon natural fresh water resources, and that we must adjust, and look towards desalination. This process requires—if the above-mentioned scheme is accepted by the parties—cooperation between Israel and Jordan, in order to implement a carefully planned multidisciplinary approach. Both parties bear the responsibility for beginning a new trend in the most vital matter for essential human survival–water; we can bear the burden if we start a new era of cooperation.

Isaac/Shuval (Eds), Water and Peace in the Middle East

REDUCING THE RISKS OF CONFLICT OVER FRESH WATER RESOURCES IN THE MIDDLE EAST

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1. INTRODUCTION

Shared fresh water resources have been the source of international frictions and tensions for many years, in many places. Worldwide, approximately fifty percent of all land area is in an international drainage basin, and more than 200 rivers are shared by two or more nations. This geographical fact has led to the geopolitical reality of disputes over shared international rivers, including the Nile, Jordan, Litani, and Euphrates in the Middle East, the Indus, Ganges, and Brahmaputra in southern Asia, and the Colorado, Rio Grande, and Paraná in the Americas. As growing populations demand more water for agriculture and economic development, strains on limited water resources will grow, and international disputes in water-short regions will worsen. While various regional and international methods exist for reducing water-related tensions, these mechanisms have never received the support or attention necessary to resolve many conflicts over water. Indeed, there is growing evidence that existing international water law may be unable to handle the strains of ongoing and future problems.

Shared water resources are an especially strong source of conflict in the Middle East, particularly in the Jordan, Tigris, and Euphrates river basins. In these regions, water and water-supply systems have been the roots, means, and causes of war. Access to shared water supplies has been cut off for political and military reasons. Water-supply systems have been used as the tools and targets of war. Sources of water supply have been among the goals of military expansionism. And inequities in water use have been the source of regional and international frictions and tensions. Not all water resources disputes will lead to violent conflict; indeed most lead to negotiations, discussions, and non-violent resolutions. But in the Middle East, water is a scarce resource that has become increasingly important for economic development. In this region, the control and allocation of water has evolved into an issue of "high politics," and it has been explicitly made a part of the ongoing bilateral and multilateral peace negotiations.

The focus of this paper is on the role of fresh water resources in regional and international conflicts, and on mechanisms and principles that can play a role in reducing those conflicts. Examples of water-related conflicts in the region abound today, but they can also be found in ancient Mesopotamia as far back as 3000 BC. Given the current volatile political situation, the unfavorable demographics, and the limited absolute amount of fresh water, tensions over water are likely to increase greatly in the near future. The adoption of some critical principles outlined here would help reduce tensions and encourage effective and productive negotiations by the parties involved. These principles include (1) the complete sharing of all hydrologic data, including water supply and water use data; (2) the equitable allocation of limited water resources in a way guaranteeing a fixed minimum water supply ("minimum water requirement") to all;

(3) the allocation of additional water supplies based on proportional rather than fixed strategies; and (4) the commitment to resolve water-related disputes peacefully, through direct negotiations involving both resource experts and politicians, perhaps through the formation of a cooperative Regional Water Resources Commission that includes representatives from all affected parties and appropriate independent parties. In addition, tensions over limited water supplies in the Middle East will also be reduced if agricultural water subsidies in the region are reduced, if on-farm management of water is improved, if water distribution systems are made more efficient, if methods to improve water-use efficiency are widely disseminated and implemented, and if environmentally and economically acceptable new sources of supply can be found.

2. THE GEOPOLITICS OF SHARED WATER RESOURCES

The history of water-related disputes goes back to antiquity, from conflicts over access to adequate water supplies to intentional attacks on water systems during wars. Table I presents a chronology of early water-related conflicts in the Tigris-Euphrates river valleys going as far back as 3000 BC, as reconstructed from early recorded histories, myths, and legends. Such disputes and conflicts will continue to occur around the world -- and in some places grow more intense -- as growing populations and development compete for limited supplies of some resources.

Interstate conflicts are caused by many factors, including religious animosities, ideological disputes, arguments over borders, and economic competition. Although it is difficult to disentangle the many intertwined causes of conflict, resource and environmental factors are playing an increasing role in such disputes.[1] This section identifies several classes of water-related disputes and presents brief historical examples of each.[2] These classes are not completely unrelated; in some regions water may play multiple roles in contributing to regional conflicts. These categories do, however, provide a useful way to think about not only how conflicts over water may arise, but also how they may be prevented.

2.1 Water resources as military goals

Since the end of World War II, academic political science has defined "international security" in the context of "geopolitics" or "realpolitik," which stresses the concept of power politics as the root of conflict. In this analysis, a resource can be a goal of military action when it is a defining factor in the power of a nation.[3] Oil is the classic example of a resource that has contributed to conflicts throughout the 20th century, including World War II, the Falklands War, and the recent Persian Gulf War. As far back as 2,500 years ago, Thucydides describes conflict between the Athenians and Thasians over control of mineral resources during the Peloponnesian War.[4] Although non-renewable resources such as oil and other minerals are more typically the focus of traditional international security analyses,[5] water fits into this framework if it provides a source of economic or political strength. Under these conditions, water provides a justification for going to war or becomes an object of military conquest.[6]

The characteristics that make water a source of strategic rivalry are (1) the degree of scarcity, (2) the extent to which the water supply is shared by more than one region or state, (3) the relative power of the basin states, and (4) the ease of access to alternative fresh water sources. Perhaps the best example of a region where fresh water supplies have had clear strategic implications is the Middle East.*

This region, with its many ideological, religious, and geographical disputes is also extremely arid. Even those parts with relatively extensive water resources, such as the Nile, Tigris, and Euphrates river valleys, are coming under increasing population, irrigation, and energy pressures. And every major river in the region crosses international borders. As far back as the 7th century BC, Ashurbanipal, King of Assyria from 669 to 626 BC, seized water wells as part of his strategy of desert warfare against Arabia.[7]

In modern times, the most pressing water conflicts in this region have centered on control of the Jordan River basin. This region has been the center of intense interstate conflict since the establishment of Israel in 1948, and the dispute over the Jordan River and its related ground water basins is an integral part of the ongoing conflict. Although by international standards the Jordan is a small river, its basin is shared by several antagonistic parties with extremely volatile political and military dynamics, and there are few alternative sources of water supply. One outcome of the 1967 Arab-Israeli War was the occupation of much of the headwaters of the Jordan River by Israel, and the loss to Jordan and residents of the West Bank of a significant fraction of their available water supply. By some estimates, forty percent of the ground water upon which Israel is now dependent -- and more than thirty-three percent of its sustainable annual water yield -- originates in the occupied territories.[8] Indeed, almost the entire increase in Israeli water use since 1967 derives from the waters of the West Bank and the Upper Jordan River.

The Nile River is also an international river of tremendous regional importance. It flows through some of the most arid regions of northern Africa and is vital for agricultural production in Egypt and the Sudan. Ninety-seven percent of Egypt's water comes from the Nile River, and more than ninety-five percent of the Nile's runoff originates outside of Egypt, in the other eight nations of the basin: the Sudan, Ethiopia, Kenya, Rwanda, Burundi, Uganda, Tanzania, and Zaire. A treaty signed in 1959 resolves a number of important issues, but was negotiated and signed by only two nations, Egypt and the Sudan.[9]

Additional water development in other upstream nations, particularly Ethiopia, could greatly increase tensions over water in this arid region. Indeed, President Anwar Sadat said in 1979, "The only matter that could take Egypt to war again is water."[10] More recently, Egypt's Foreign Minister, Boutrus Ghali, now Secretary General of the United Nations, was quoted as saying "The next war in our region will be over the waters of the Nile, not politics."[11] While these statements partly reflect political rhetoric, they also given an indication of the importance of the Nile to Egypt.

2.2 Water resource systems as instruments of war: Targets and tools

The usual instruments of conflict are military weapons of destruction, though the use of water and water-resources systems as both targets and tools also has a long history. As early as 2500 BC, conflicts between the city-states of Umma and Lagash over fertile fields in Mesopotamia were fought by diverting irrigation water away from the other side (see Table I). Sargon II, the Assyrian king (720 - 705 BC) destroyed the intricate irrigation network of the Haldians after his successful campaign through

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* The term Middle East, as used in the United States, is quite imprecise, but typically refers to the region of the eastern Mediterranean, the Persian Gulf peninsula, and northern Africa.

Armenia. When Sennacherib of Assyria destroyed Babylon in 689 BC as retribution for the death of his son, he pulled down temples and palaces and destroyed the water-supply canals to the city.[12]

According to inscriptions recorded during the reign of the Esarhaddon (681-669 BC), the Assyrians besieged the city of Tyre, cutting off food and water. Similarly, in campaigns against both Arabia and Elam (645 BC), Assurbanipal, son of Esarhaddon, destroyed wells to deprive opposing troops of water. In another account, in 612 BC a coalition of Egyptian, Median (Persian), and Babylonian forces attacked and destroyed Ninevah, the capital of Assyria by diverting the Khosr river to create a flood.

In this century, hydroelectric dams were bombed during World War II and the Korean War. Irrigation systems in North Vietnam were bombed by the United States in the late 1960s. When Syria tried to stop Israel from building its National Water Carrier in the early 1950s, fighting broke out across the demilitarized zone, and when Syria tried to divert the headwaters of the Jordan in the mid-1960s, Israel used force against the diversion facilities to prevent their construction and operation. These military actions contributed to the tensions that led to the 1967 war.[13]

Most recently, dams, desalination plants, and water conveyance systems were targeted by both sides during the Persian Gulf War. Most of Kuwait's extensive desalination capacity was destroyed by the retreating Iraqis, and in mid-1992, the Iraqis were still suffering severe problems rebuilding Baghdad's modern water supply and sanitation system, intentionally destroyed by the allied coalition during the Persian Gulf War.[14] As water supplies and delivery systems become increasingly valuable in water-scarce regions, their value as military targets also increases.

While fresh water resources are renewable, in practice they are finite, poorly distributed, and often subject to substantial control by one nation or group. In such circumstances, the temptation to use water for political purposes may prove irresistible. Even the perception that access to fresh water could be used as a political tool by another nation may lead to violence.

In the Middle East, hydroelectric and agricultural developments on the Euphrates River have been the source of considerable international concern. Both Syria and Iraq depend heavily on the Euphrates River for drinking water, irrigation, industrial uses, and hydroelectricity, and view any upstream development with concern. In 1974, Iraq threatened to bomb the al-Thawra dam in Syria and massed troops along the border, alleging that the flow of water to Iraq had been reduced by the dam. More recently, Turkey has implemented an ambitious water-supply scheme to increase its hydroelectricity production and to irrigate an additional two million hectares of land. In 1990, Turkey finished construction on the Ataturk Dam and interrupted the flow of the Euphrates for a month to partly fill the reservoir. Despite advance warning from Turkey of the temporary cutoff, Syria and Iraq both protested that Turkey now had a water weapon that could be used against them. Indeed, in mid-1990, Turkish President Ozal threatened to restrict water flow to Syria to force it to withdraw support for Kurdish rebels operating in southern Turkey. While this threat was later disavowed, Syrian officials argue that Turkey has already used its power over the headwaters of the Euphrates for political goals and could do so again.[15]

The ability of Turkey to shut off the flow of the Euphrates, even temporarily, was noted by political and military strategists at the beginning of the Persian Gulf conflict. In the early days of the war, there were behind-the-scenes discussions at the United Nations about using Turkish dams on the Euphrates River to deprive Iraq of a significant fraction of its fresh water supply in response to its invasion of Kuwait.[16]

While no such action was ever taken, the threat of the "water weapon" was again made clear. Indeed, the ability of Turkey to control the flow of water remains a major stumbling block over plans to divert water from Turkish rivers via a "peace pipeline" to other nations in the region.

2.3 Other links between conflict and water

Water-related conflicts may arise over the secondary impacts of water development schemes such as irrigation facilities, hydroelectric developments, and flood-control reservoirs, and over inequities in water supply and use. Major water developments often lead to the displacement of large local populations, adverse impacts on downstream water users, changes in control of local resources, and economic dislocations. These impacts may, in turn, lead to disputes among ethnic or economic groups, between urban and rural populations, and across borders.

In South Africa in 1990, a pro-apartheid council cut off water to the Wesselton township of 50,000 blacks following a protest over miserable sanitation and living conditions.[17] Zimbabwe recently reported that its output of ethanol, which is mixed with gasoline to reduce the country's fuel imports, has dropped because of the severe African drought that has crippled sugar cane production.[18] This has a direct impact on Zimbabwe's economic strength and relations with its neighbors. Violent conflicts have arisen over water allocations in India, most recently in early 1992 following a court decision to allocate the waters of the Cauvery River between two Indian states, Karnataka and Tamil Nadu. The Cauvery River originates in Karnataka, but the greatest use of the water is in Tamil Nadu, before it flows to the Bay of Bengal. Over fifty people were reported killed in riots following the allocation of additional water to Tamil Nadu.[19]

In the Middle East, the conflict over the ground water resources of the West Bank arises in large part from concern over the control of those resources and the gross inequities in use between the Israeli and the Palestinian populations. Unless these issues are dealt with directly, the chances of resolving other water problems in the region are limited.

3. FUTURE CONFLICTS OVER WATER

Water has already been a source of conflict among nations and groups. We fight for access to water, we use water as a tool and weapon in battle, and we target the water facilities of our enemies. While water resources have rarely been the sole cause of conflict, conflicts over access and possession are likely to worsen in arid and semi-arid areas of the world where water is already a vital resource.

Several problems may make these tensions worse, particularly demographic trends and the new danger posed by the so-called "greenhouse effect". Some arid regions today have adequate water for their current populations. But populations continue to grow, either through natural increases or through immigration. In some of the most water-short regions of the Middle East, most notably Israel, the occupied territories, Jordan, and Syria, populations are expected to grow extremely rapidly. At the same time, new demands for water by agriculture and industry are putting additional pressure on existing supplies. In Israel alone, projected population growth could require the severe restriction or complete elimination of irrigated agriculture over the next several decades, just to free up sufficient water to provide a reasonable minimum amount to its population. The identical problem exists in Jordan, given expected increases in population.

All of the previous discussion has assumed that natural water availability in the future will not change, and will be subject only to natural variations in flow. In fact, this assumption may no longer be true because of future changes in the global climate.[20] Global climatic change will affect water availability in many ways, though the precise nature of such changes is still obscure. Climatic changes could both increase and decrease the likelihood of international frictions and tensions over water resources at different times and in different places.[21] Our challenge is to identify those cases in which conflicts are likely to be exacerbated and to work to reduce the probability and consequences of those conflicts.

Future climatic changes effectively make obsolete all our old assumptions about the behavior of water supply. Perhaps the greatest certainty about future climatic changes is that the future will not look like the past. We may not know precisely what it will look like, but changes are coming, and by the turn of the century, many of these changes may already be apparent.

4. REDUCING THE RISKS OF WATER-RELATED CONFLICTS

How can we reduce the risks of water-related conflict? International law and international institutions must play a leading role. There have already been some attempts to develop agreeable international law protecting environmental resources, but almost all of these focus on attempting to limit environmental damages from conflict and war.[22]

These kinds of agreements and statements, however, carry little weight in the international arena when politics, economics, and other factors are considered more important. And virtually no effort has been made to address the equally important problem of preventing conflicts over resource disparities or environmental damage. Another problem is that most international statements of principle lack effective enforcement mechanisms. Until the ideals expressed by these agreements are considered true facets of international law and behavior, they will remain ineffective.

No satisfactory water law has been developed that is acceptable to all nations, despite years of effort by various organizations. Developing such agreements is difficult because of the many intricacies of interstate politics, national practices, and other complicating political and social factors. For nations sharing river basins, factors affecting the successful negotiation and implementation of international agreements include whether a nation is upstream, downstream, or sharing a river as a border, the relative military and economic strength of the nation, and the availability of other sources of water supply.

Recently, some international organizations have attempted to derive more general principles and new concepts governing shared fresh water resources. The International Law Association's Helsinki Rules of 1966 (since modified) and the work of the International Law Commission of the United Nations are among the most important and relevant examples. In 1991, the International Law Commission completed the drafting and provisional adoption of 32 articles on the Law of the Non-Navigational Uses of International Watercourses. Among the general principles set forth are those of equitable utilization, the obligation not to cause harm to other riparian states, and the obligation to exchange hydrologic and other relevant data and information on a regular basis. Some of these principles are described below in the context of Middle East water problems. While questions remain about their relative importance and means of enforcement, the principles described below should be adopted by all parties in Middle East water disputes as guidelines for their behavior and negotiations.[23]

4.1 Obligation to share data

This principle is reaching widespread acceptance, but there are still several regions of the world, including especially (but not exclusively) the Middle East, where water resources data are considered classified and are withheld from neighboring nations and users. Without shared, accurate data available to all parties, fair negotiations cannot be conducted or completed. One implication of concealing data is that unintentional changes in flow (due to natural variability or global climate change) could be perceived and misinterpreted by downstream nations as intentional manipulations rather than geophysical events. Unless basin states share hydrologic data, no satisfactory agreements on allocations, responses during shortages, and flood management and planning can be reached. International organizations, such as independent scientific associations or organizations under the umbrella of the United Nations, have a major role to play in encouraging the collection and open sharing of water resource data.

4.2 Obligation to resolve water-related disputes peacefully

The Charter of the United Nations requires that nations resolve all disputes, not just those over water resources, without resorting to force. Because shared water resources in the Middle East have been the source of conflict in the past, international negotiations over water in this region must take special care to explicitly adopt this provision. International law devotes considerable time and effort to identifying non-violent approaches to resolving disputes, and there should be no objections to adopting these by all parties. It may be appropriate to form a joint commission under whose auspices water-related disputes can be negotiated for particular river basins or shared sources of supply.

4.3 Equitable utilization

The principle of equitable utilization means that each basin state is entitled to a reasonable and equitable share in the beneficial use of shared water. This is in contrast to the Harmon Doctrine, which holds that a state can use the water within its borders without restriction, even if that use substantially injures a neighbor. While some upstream nations still cite the Harmon Doctrine, more than 100 river treaties almost universally reject this practice and restrict the freedom of action of upstream nations. "Equitable" does not mean equal use. Rather, it means that a large variety of factors, including population, geography, availability of alternative resources, and so on, must be considered in the allocation of water rights.

This principle is one of the most important developed by the ILC and the Helsinki statements. At the same time it is one of the most difficult to define, given the multitude of variables that should be taken into account. Early and serious efforts to define fair allocations of water in the Middle East should be undertaken.

4.4 Prevention of significant harm to other states

Another rule considered fundamental, though perhaps subordinate to the principle of equitable utilization, is the obligation not to cause significant harm to others through actions involving international watercourses. Often the maxim, "sic utere tuo ut alienum non laedas" -- use your property in a way not to injure others -- is cited. This principle says that a state is responsible for preventing actions within its borders that harm the activities or property of another state. As sometimes applied, however, this principle permits harmful actions but requires compensation or mitigation as acceptable alternatives. A major complication in applying this principle is the difficulty in quantifying downstream environmental and economic impacts and in determining the extent to which the upstream riparian is responsible.

4.5 Obligation to notify and inform

This principle concerns the responsibility of a nation to notify other nations of any activities that will affect them. Such notification permits the affected state to negotiate mitigation or to protest and, perhaps, modify or prevent the action. One recent example of this was the closure of the Ataturk Dam on the Euphrates River. Prior to taking action, Turkey notified the downstream nations of this closure, which effectively reduced the flow in the river to zero. Although both Syria and Iraq complained, Turkey's obligation to notify was met. The subsequent ramifications and implications of this action are discussed earlier in this paper.

4.6 Cooperative management of international rivers

The International Law Commission is considering adoption of a "principle of participation" that affirms the duty of all basin states to participate in the development, use, and protection of shared water resources. Such participation generally takes the form of a joint basin commission empowered to negotiate disputes and resolve questions of resource allocation. Establishing such a commission does not ensure successful or effective management, in part because nations only reluctantly grant decisionmaking power to multinational bodies. Other problems arise if the commission does not include all affected participants. One example is the Nile commission -- the Permanent Joint Technical Committee -- set up by the 1959 treaty signed by the Sudan and Egypt, which does not include the other seven riparian nations along the Nile.

Up until now, individual water treaties covering river basins have been more effective, albeit on a far more limited regional basis, than the broader principles described above. International treaties concerning shared fresh water resources extend back centuries, and there are hundreds of international river treaties covering everything from navigation to water quality to water rights allocations. These treaties have helped reduce the risks of water conflicts in many areas, but some of them are beginning to fail as changing levels of development alter the water needs of regions and nations. The 1959 Nile River Treaty, the 1977 Agreement on Sharing of the Ganges Waters (now expired, but still observed), and some limited bilateral agreements on the Euphrates between Iraq and Syria, and Iraq and Turkey, are good examples.

One final problem in the Middle East is that the Palestinians are not officially a "state," in the parlance of the international legal community, though they are one of the principal actors. While this has significantly complicated the application of the principles laid out above, it seems more of a semantic than practical problem. Indeed, it could be argued that these principles of water law, particularly those of equitable utilization and the obligation not to cause harm to other basin users, apply to occupied territories, or even to the entire internal population of a nation.

5. SOME SPECIFIC RECOMMENDATIONS

To make both regional treaties and broader international agreements over water more flexible, detailed mechanisms for conflict resolution and negotiations need to be developed, basic hydrologic data need to be acquired and completely shared with all parties, minimum water requirements ("MWR") need to be identified and then allocated to each person in a region, flexible rather than fixed water allocations are needed for the distribution of additional water supplies, and strategies for sharing shortages and apportioning responsibilities for floods need to be developed <u>before</u> these crises occur.

1. As described above, sharing water resources data is considered a basic tenet of international law, yet accurate long-term data on shared and disputed water resources in the Middle East are often restricted. This must stop if any progress is to be made in resolving water disputes, and all data on water supply <u>and</u> water use should be made available for review and analysis.
2. A minimum amount of water for basic human needs must be identified and then allocated to all inhabitants of a region on an equitable basis. This "minimum water requirement" should be for domestic drinking water, sanitation, and modest commercial and industrial activities. An initial estimate of this MWR is between 75 and 150 cubic meters per person per year.[24]
3. Additional allocations of water above the MWR should be made on the basis of proportional shares, rather than on the basis of fixed amounts of water. Shares should be determined based on a range of factors, as described by the International Law Commission principle of "equitable utilization." Fixed-level agreements frequently lead to additional political problems because of inaccurate estimates of long-term water availability (as was the case with the Colorado River between the U.S. and Mexico) and because of short-term or long-term changes in flow (as is the case with droughts and the issue of global climatic changes).
4. Detailed mechanisms for conflict resolution and for the structure of negotiations need to be developed and codified in advance of a new Middle East water crisis, to reduce the risk of later disputes over a treaty or over some aspect of the management and distribution of water resources not resolved in the initial agreement. This has proven effective in southern Asia. A cooperative Regional Water Resources Commission that includes representatives from all basin parties is strongly recommended.

In addition to these legal and policy recommendations, several other actions would greatly increase the ability of regional water managers to adapt to shortages. These include:

1. Agricultural water subsidies need to be eliminated, perhaps gradually, particularly for water-intensive crops that can be grown more efficiently elsewhere.
2. On-farm management of water needs to be improved. This includes the choice of

crops, the choice of irrigation methods, and the management of irrigation water.
3. The efficiency of water-distribution systems needs to be improved, including the lining of canals and aqueducts to reduce water losses during transfers, and the accurate metering of water.
4. Overall improvements in water conservation and reuse throughout are possible and desireable. While Israel already is far more efficient than almost any other nation, further improvements can reduce pressures over limited supplies.
5. As is true elsewhere in the world, there are vociferous debates going on about developing new sources of supplies for the Middle East, including desalination, water transfers from Turkey or the Nile, towing or shipping of water, and so on. Each of these alternatives has economic and political costs that are debated, and environmental costs that are more often ignored. In general, new sources of supply are available at total costs that are thought to exceed the cost of improving the efficiency of current use. The loud debate over this point simply indicates that far more effort should be put into actually identifying the true costs of supply alternatives, rather than simply evaluating their engineering feasibility.

6. CONCLUSIONS

Water already contributes to conflicts among nations and future conflicts over water are increasingly likely. We fight over access to water resources in some regions of the world, we use water and water supply systems as instruments of war, growing populations and development increase the competition for limited water supplies, and many countries depend on sources of supply that are under the control of other nations. Nowhere is this more true than in the Middle East.

Human needs for water in this region are growing. Water is already a scarce resource, to be used and reused many times, and occasionally to be fought over. Many countries in the Middle East and elsewhere already use water at a rate faster than natural processes can replenish it, leading to falling ground water levels, reliance on expensive desalination projects, and imports of water across borders. Oddball schemes that would have been laughed at a few decades ago are now being implemented or seriously considered, including the importation of water in tankers, pipelines thousands of kilometers long, or the diversion of icebergs from the polar regions.

Water-related disputes in the Middle East and elsewhere are more likely to lead to political confrontations and negotiations than to violent conflict. But the disturbing trend toward the use of force in resource-related disputes, the apparent willingness to use water-supply systems as targets and tools of war, and growing disparities among nations between water availability and demand needs to be countered. As a first step in the Middle East, all water resources data should be immediately and fully released to all parties and the principles laid out here should be discussed and adopted by the participants in the water negotiations of the ongoing Bilateral and Multilateral peace talks. If methods for using water more efficiently can be disseminated, and if guiding principles for allocating shared water resources can be adopted, then the risks of future conflict over fresh water can be greatly reduced.

Table I [a]

CONFLICTS OVER WATER IN THE ANCIENT NEAR EAST: 3000 BC TO 500 BC

DATE (BC)

3000 The Flood

An ancient Sumerian legend recounts the deeds of the deity, "Ea," who punishes mankind for its sins by inflicting the earth with a six-day storm. The Sumerian myth parallels the Biblical account of Noah and the Deluge, although some details differ.

2500 Lagash-Umma Border Dispute

The dispute over the "Gu'edena" (edge of paradise) region begins. Urlama, King of Lagash 2450-2400, diverts water from the region to boundary canals, drying up boundary ditches to deprive Umma of water. His son, Il, cuts off Girsu's (city in Umma) water supply.

1790 Code of Hammurabi (Sumer)

The famous Code of Hammurabi lists several laws pertaining to irrigation that provide for possible negligence of irrigation systems and water theft.

1720-1684 Abi-Eshuh vs. Iluma-Ilum

Grandson of Hammurabi, Abish or (Abi-Eshuh), dams the Tigris in order to prevent the retreat of rebels led by Iluma-Ilum who declared independence of Babylon.
This failed attempt marks the decline of the Sumerians who had reached their apex under Hammurabi.

1200? Moses and the Parting of the Red Sea

In biblical legend, when Moses and the retreating Jews find themselves trapped between the Pharaoh's army and the Red Sea, Moses miraculously parts the waters of the Red Sea, allowing his followers to escape. The waters close behind them and cut off Egyptians.

720-705 Sargon II (Assyrian) Destroys Armenian Waterworks

After a successful campaign against the Haldians of Armenia, Sargon destroys their intricate irrigation network and floods their land.

705-682 Sennacherib (Assyrian) and the fall of Babylon

In quelling rebellious Assyrians (695), Sennacherib razes Babylon and "even diverted one of the principal irrigation canals so that its waters washed over the ruins."

Sennacherib and Hezekiah

As recounted in Chronicles 32:3, Hezekiah digs a well outside the walls of Jerusalem and uses a conduit to bring in water. Preparing for a possible siege by Sennacherib, he cuts off water supplies outside of the city walls, and Jerusalem survives the attack.

681-669 Esarhaddon (Assyrian) and the Siege of Tyre

Esarhaddon refers to an earlier period when gods, angered by insolent mortals, create a destructive flood. According to inscriptions recorded during his reign, Esarhaddon besieges Tyre, cutting off food and water.

668-626 Assurbanipal, Siege of Tyre, Drying of Wells

Assurbanipal's inscriptions also refer to a siege against Tyre, although scholars attribute it to Esarhaddon. In campaigns against both Arabia and Elam (645), Assurbanipal, son of Esarhaddon, dries up wells to deprive Elamite troops, while he guards wells from Arabian fugitives in an earlier Arabian war. On his return from victorious battle against Elam, Assurbanipal floods the city of Sapibel, an ally of Elam. According to inscriptions, he dams the Ulai River with the bodies of dead Elamite soldiers and deprives dead Elamite kings their food and water offerings.

Table I (continued)

612 Fall of Nineveh in Assyria and the Khosr River

A coalition of Egyptian, Median (Persian), and Babylonian forces attack and destroy Ninevah, the capital of Assyria. Nebuchadnezzar's father, Nebopolassar, leads the Babylonians. The converging armies divert the Khosr river to create a flood, allowing them to elevate their siege engines on rafts.

605-562 Nebuchadnezzar Uses Water to Defend Babylon

Nebuchadnezzar builds immense wall around Babylon, using the Euphrates and canals as defensive "moats" surrounding the inner castle. Berossus describes Nebuchadnessar's plan to create an impregnable city, stating "He arranged it so that besiegers would no longer be able to divert the river against the city by surrounding the inner city with three circuits of walls..."

558-528 Cyrus the Great: The 360 Canals

On his way from Sardis to defeat Nabonidus at Babylon, Cyrus faces a powerful tributary of the Tigris (probably the Diyalah). According to Herodotus' account, the river drowns his royal white horse and presents a formidable obstacle to his march. Cyrus, angered by the "insolence" of the river, halts his army and orders them to cut 360 canals to divert the river's flow. Other historians argue that Cyrus needed the water to maintain his troops on their southward journey, while another asserts that the construction was an attempt to win the confidence of the locals.

539 Cyrus the Great: Invasion of Babylon

According to Herodotus and other sources, Cyrus invades Babylon in 539 by diverting the Euphrates into the desert above the city and entering the city along the dry river bed. This popular account describes a midnight attack which coincided with a Babylonian feast.

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[a] This table compiled by H. Hatami, 1992, Pacific Institute, Oakland, California.

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Palestinian water supplies and demands

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Abstract

In addition to a fairly good winter rainfall, the main water resources in the Occupied Palestinian Territories (OPT) are the surface waters of the Jordan and Yarmouk Rivers and the national ground water aquifers. Since 1967, the Palestinian people in the OPT have had a very limited access to water resources due to the various restrictions imposed by the Israeli authorities. The Palestinian water demands have surpassed many years ago the amount of water allocated to the Palestinians by the Israelis. The domestic demand is expected to reach 726 MCM per year in the year 2020 while the agricultural demand is expected to reach 500 MCM per year.

As the water resources in the area are very limited and cannot satisfy the expected increasing demands, it is necessary for the Palestinian people during this interim period to use all possible water enhancement systems, for example, setting-up a system for national water resources management and demand; recycling of wastewater for irrigation purposes; winter rains/flood water storage, including artificial groundwater recharge, rain harvesting and small dams; construction of the Western Ghor Canal; and conducting studies and research on transferring appropriate water technology and regional transfer of water.

1. BACKGROUND

At the beginning of this century, Palestine was part of the Turkish Empire. During the First World War, the area was conquered by the British and Allied Forces in 1917 and 1918. Britain ruled over Mandatory Palestine until 1948.

In 1948 the British Mandate was terminated and Palestine was split into three regions - Israel, the Gaza Strip and the West Bank - while Israel declared its independence on the coastal areas ceased, the other two parts, the West Bank and Gaza Strip, remained as Palestinian Arab Territories with no real leadership. Soon after this tragic event, the West Bank was unified with Jordan which was created by the British Mandate in 1922 on the area situated east of the River Jordan. The Gaza Strip was administered by Egypt from 1948-1967.

During the Six-Day Israeli-Arab War in 1967, the Israeli military defeated all Arab armies and occupied the West Bank and Gaza Strip. Since that time, these areas have been referred to by the United Nations and in various official world bodies and governments as the Occupied Territories or Occupied Palestinian Territories (OPT) and this terminology will be used in this paper.

As a result of the 1948 and 1967 wars, hundreds of thousands of Palestinians fled from the Mandatory Palestine to the neighboring Arab countries, mainly Jordan, Lebanon and Syria. These refugees, as well as those remaining under Israeli occupation, have since been waiting for return, compensation and/or both along with a peaceful comprehensive solution to the Arab-Israeli conflict.

On November 15, 1988, the Palestine National Council (PNC) in a move of reconciliation and later called moderation (and by some Palestinians even defeatism or surrender) proclaimed the establishment of the State of Palestine to be sovereign over only the West Bank and Gaza Strip with Jerusalem (the Eastern part) its national capital. However, other than the PLO government in exile, which handles some of the Palestinian affairs, the actual control of these Palestinian territories remained in the hands of the Israeli Military Government which the Israelis themselves refer to as the Civil Administration. But the Civil Administration is not Palestinian and the control of every single sector affecting Palestinian lives and aspirations is controlled by the Israeli Military Laws and Rules, including that of water.

The proclaimed State of Palestine comprises the West Bank and Gaza Strip and has a land area of 6257 square kilometers. The West Bank extends over an area of 5879 square kilometers while the Gaza Strip extends over an area of 378 square kilometers. (Al-Quds, 1992).

2. POPULATION

No population census by Palestinians has ever taken place in the West Bank and Gaza Strip. The Israelis held a census in 1967. Therefore, population information is often based on different official Israeli statistics and non-official Palestinian estimates. The projection of the various population figures for 1992 show that the Palestinian population in the OPT ranges between the low Israeli figure of 1,800,000 and a higher Palestinian figure of 2,149,000. The Palestinian figure takes into consideration the total number of Palestinians who hold Israeli identity cards including those staying temporarily abroad either for work or study and those living in East Jerusalem. The low figure usually only recognizes those currently residing in the West Bank and Gaza Strip, excluding East Jerusalem.

In order to achieve proper planning for the Palestinians' demand for water in the coming 30 years, it is essential to know with a high degree of accuracy the demographic changes that are expected to take place in this area which should include any reliable data on the Palestinian population and the numbers of Palestinians in Arab countries who will have the right of return to Palestine. If a just and lasting peace is to take hold in the area and the utilization of the limited water resources are to be used in a fair and peaceful manner, then the following assumptions must be taken into consideration:

1 - The Palestinians and the Israelis will reach sovereinty over their land and natural resources with mutual respect as well as recognizing each others rights to live safely in a civilized and democratic manner which means the declaration of an independent Palestinian entity (state).

2 - As a result of the contemplated peace agreement, the standards of living for the Palestinians will improve and the average population growth will drop to 3%, 2.5% and 2% in the years 2000, 2010 and 2020 respectively.

3 - The Palestinians who will return and settle in the new Palestinian entity until the year 2000 will range between 650,000 people (The Washington Institute, 1991) to 1,000,000 (Shaath, 1989). A number close to one million seems more likely.

It should be noted that economic development in the Near East and the neighboring countries will always be related to population increase and their educational level. The opportunity for work and the high economic growth in the Arab Gulf countries which encouraged the Palestinians to emmigrate has been halted and the majority of these emmigrants returned to their homes in the West Bank and the Gaza Strip especially when the economic growth and the political state in the Arab Gulf States started affecting these people adversely. This fact has been considered when estimating the population growth and that is why the estimates here are higher than the figures usually mentioned by the Israeli Central Bureau of Statistics.

2.1. Population distribution

The data on geographical distribution of population is crucial for physical planning, provision of services and economic development. According to Palestinian estimates in 1990, around 43 percent of the population lived in urban communities, 5 percent in semi-urban communities, 35 percent in rural communities and 17 percent in refugee communities. Projection of these estimates for the year 1992 is presented in the following table. (Center for Engineering and Planning, 1992).

Table 1
Population distribution, 1992 (thousands)

Type of Community	Percent	Population
Urban	43	924,000
Semi-Urban	5	107,500
Rural	35	752,000
Refugee	17	365,500
TOTAL	100	2,149,000

3. PRESENT WATER RESOURCES

In water resources evaluation, a distinction is usually made between surface and groundwater.

Surface Water:

Surface water is that which flows permanently in rivers or as flood flows in wadis or that which is held in seasonal lakes. Permanent river and spring flows vary monthly and are determined by the quantity and duration of rainfall, also contributing somewhat to the groundwater supply.

The Jordan River flows along the Eastern borders of the West Bank from the north to the Dead Sea in the south. The average annual flow of this river is about 1200 MCM (Abu Faris, 1992). Its water resources originate in Israel, Lebanon and the Syrian Arab Republic and are being used to such an extent, in particular by Israel, that only a small, polluted amount reaches the West Bank. The Palestinians cannot use even this amount because they have no access to the river due to the various military rules and restrictions imposed on them after 1967, especially in the Zhor area of the Jordan Valley next to the river. It is estimated that 180 to 200 MCM/year may be provided by surface runoff and from the Jordan River (U.N., 1992) for Palestinians in the OPT.

Groundwater:

Groundwater is considered the main water resource for the Palestinians in the OPT. The total annual renewable fresh groundwater amounts to some 670 MCM (Al-Khatib, 1989). The system of aquifers in the OPT consists of a number of geological formations extending from the Lower Cretaceous to the recent age. These include limestone, dolomite, marl and sandstone formations. The formations tend to occur in a series of aquifers. The aquifer system in the OPT includes four major basins - the west, the northeast, the east and the coast. (Assaf, 1985; Assaf & Assaf, 1986).

The western aquifer or drainage basin flows towards the Mediterranean Sea and recharges the coastal aquifers. This aquifer has an estimated mean average safe yield of about 335 MCM/year (United Nations, 1992). The northeastern aquifer discharges into the Bisan and Zirien Valley. The average safe yield of this aquifer is about 140 MCM/year. The eastern aquifers belong mainly to the Upper Cenomanian-Turonian and Lower Cenomanian geological formations with a safe yield of about 130 MCM. The coastal aquifer is the only water resource in the Gaza Strip. It mainly consists of sandstone or limey sandstone. The estimated safe yield of this aquifer is about 65 MCM (Shuval, 1992).

Floodwater / Runoff:

Surface runoff in most watersheds of the OPT is intermittent and probably occurs only when the rainfall exceeds 50 mm in one day or 70 mm on two consecutive days (Al-Khatib, 1989). The runoff is estimated at about 66 MCM/year (64 MCM in the West Bank and 2 MCM in the Gaza Strip (Al-Khatib, 1989; Al-Khodary, 1991).

Runoff has not been used or controlled on a large scale in the OPT for any purpose. However, streams flowing to the Jordan Valley contribute recharge to the shallow alluvial aquifer especially Wadi Al-Qilt, Auja and Wadi Faria. This flood flow is a very important source in the future planning of water resources in the OPT. This requires monitoring and control of rainfall runoff over the catchment areas. (Assaf, 1991).

The high costs of investment for storage reservoirs and the Israeli military restrictions imposed on utilizing water resources in the OPT are serious obstacles against efficient use of this resource.

4. WATER CONSUMPTION

Due to Israeli military administration restrictions on any information which may be obtained from the Water Department, obtaining accurate data and exact statistics on water resources and their utilization has been very difficult for us as Palestinians and also to others interested in precisely predicting the future water needs of the people residing in the region. Water scarcity and the corresponding military orders are a function of the deficit between water consumption and water demand. Water consumption in the West Bank and Gaza Strip is mainly confined to drinking water and some agricultural use mostly in the Gaza Strip and the Jordan Valley.

The main water sources in the OPT are boreholes, springs and rainwater catchment. The volume of water consumed by Palestinians in the OPT usually varies with rainfall in the area which affects the spring flow and borehole pumpage capacity. The current domestic water consumption for Palestinians in the West Bank including East Jerusalem and the Gaza Strip is estimated at 53,574 million cubic meters per year (West Bank including East Jerusalem 27,574 MCM per year). (Haddad, 1992; and Al-Khodary, 1991). See Table 2. The current irrigation water supply is estimated at 162 MCM per year (90 MCM in the West Bank and 72 MCM in the Gaza Strip). The total irrigated area is estimated at 204,000 dunoms of which 104,000 dunoms are in the West Bank (One donum is equal to 1/10 hectare). (Assaf, 1985; Al-Khodary, 1991; Haddad, 1992).

Table 2
Domestic water consumption from piped systems in the West Bank
Water Consumption (cubic meters per year)

District or Region	Urban Areas	Rural Areas	Semi-Urban Areas	Refugee Camps	Total
Jerusalem	2,687,138	843,342	843,342	190,377	4,564,199
Nablus	4,031,956	1,158,444	183,318	564,826	5,938,544
Hebron	2,352,790	1,299,180	521,082	177,210	4,350,362
Ramallah	1,415,023	1,419,504	259,616	179,845	3,273,988
Tulkarem	2,008,904	697,512	292,727	243,971	3,243,114
Jenin	968,117	377,316	299,000	126,883	1,771,316
Bethlehem	1,126,607	599,616	311,802	125,191	2,163,216
Jericho	184,157	195,792	-	61,243	441,183
TOTAL	14,774,692	6,590,700	2,710,887	1,669,546	25,745,822

References: Haddad, 1992; Center for Engineering and Planning, 1992.

5. WATER DEMANDS

The lack of surface water for Palestinians has made underground water resources the only viable alternative to meet their needs.

In the last two decades, the deficit between available water resources and the growing water demand in the Gaza Strip has been complicated by over-exploitation of the shallow aquifers and limits placed on development. In the West Bank, increasing demands have been frustrated by freezing the water quantities allocated for agriculture and setting these quantities similar to those which were extracted in 1967. This was done through many Israeli military orders (Orders #92, #158, #498) which restrict the exploitation of the ground water. In the future, if the present situation and military occupation continues, no increase of the water supply will be expected to take place, especially for agriculture, except by the possibility of using small quantities of recycled sewage from some Palestinian cities.

The previously mentioned water consumption rates of the Palestinians are expected to sharply increase if Israeli military occupation is ended and a just peace is attained. The Palestinian water demands per capita are expected to reach those of Israelis by the year 2020. This prediction is based on the following reasons: -

a - The expected increase in population due to normal growth and Palestinians returning to their homeland.

b - Due to their scatter (in the Diaspora) all over the world, the Palestinians have acquired habits, customs and cultural relations from many advanced countries so it is expected that within a very short time, as the Palestinian economy develops, the standard of living and consumption habits will become similar to that of Israelis and other industrialized countries.

c - The long years of occupation have restricted the development of the Palestinian economy and infrastructure. This will spur a high capital and manpower investment from developers and aid agencies in meeting the water needs of the OPT entity or state which is expected to reach the same level as that of Israel.

Assuming a comprehensive and just peace agreement is reached between the Palestinians and Israelis in which both the Israeli occupation and the Palestinian Intifada (Uprising) are phased out, then it would be possible for the Palestinians to build their peaceful state and reach similar standards of living as that of the Israelis by the year 2020. There is also the possibility of wealthy Palestinians returning and investing in the area, which is a hidden factor not well explored.

The future forecast of water needs and useage is subject to wide uncertainties due to having only estimates of future demographic, political as well as economic trends.

5.1. Domestic water demand

The water demand for domestic purposes depends on the population growth. It depends also on the future development of the standards of living. Our predictions of the projected demands take into consideration low and high population figures and are as follows:

Table 3
Water demand projections with population growth in the OPT

Expected Year	Population including returnees Low	High	Per Capita Consumption cum/yr *	Consumption increase %	Total Domestic Demand (MCM) Low	High
1992	1,800,000	2,149,000	67	-	121	144
2000 n*	2,930,000	3,722,000	84 b	3.0	246	313
2010 n*	3,750,000	4,765,000	110	2.75	415	524
2020 n*	4,571,000	5,809,000	125	1.25	571	726

* Includes 25 cubic meters per year for house farming (gardens, vegetables, etc.)

n* Population projections include natural increase plus expected returnees 650,00-1,000,000 up the the year 2000.

b Tahal projections for the Bethlehem and Hebron areas were 70 cum/c/yr for pure domestic purposes without allocated agricultural water. Note the 84 cum/c/yr is well below 95 cum/c/yr. References: City of Hebron Master Plan for Water Supply and Cities of Bethlehem, Beit Sahour and Beit Jala Master Plan for Water Supply, Tahal Consulting Engineers, Ltd., Tel Aviv.

5.2. Agricultural water demand

Agriculture has been always the major productive sector in the Palestinian economy. This sector will become more important when a peace agreement is reached with Israel and the Palestinians in the diaspora start to return to Palestine. The fact is that it will be easy to create jobs in agriculture for these returnees to produce enough food to feed them and at the same time the existing population. The small population density in the Jordan Valley encourages absorbing investment by these returnees as well as the development of profitable, irrigated agriculture in this area. The agricultural water demands has already many years ago surpassed the available amount of allocated water. Total water consumption for irrigation is currently estimated at around 162 million cubic meters annually (72 million in the Gaza Strip).

This existing agricultural water consumption by Palestinians (162 million cubic meters per year) does not reflect the real demands. There is a big gap between the agricultural water demand and the existing consumption. This gap is mainly due to the water policy adopted by the occupation authorities after 1967 which has frozen the water supply to agriculture and lack of large investments in water utilization due to insecurity of returnees under a military occupation.

In the future, it is expected that in a very short time agricultural water consumption would dramatically increase immediately after the military orders concerning the water exploitatiation are cancelled. In addition to this, the Palestinian planning policies for developing agriculture will be reflected on the water demand and potential use in an area without occupation.

The potential irrigable land area is estimated to be 712,000 donums (personal communication, 1992). Based on this and assuming that an average of 700 cubic meters per annum are needed for irrigating one dunom of land, then the agricultural water demand will be 500 MCM per year. This figure really coincides with other estimates (304 MCM per year for the West Bank and 150 MCM per annum for the Gaza Strip) (Bruins etal, 1991).

6. WATER SUPPLY ENHANCEMENT

The very limited water quantity, its unequal and unfair distribution and the poor quality of water resources mainly in the Gaza Strip and Jordan Valley has affected the quality of life in the OPT. To improve and enhance the availability of water supplies for the Palestinian people, more water must be generated and extracted from national Palstinian resources. To achieve this, the Palestinians must gain control over their land and national resources as well as their share in the international water courses mainly the Jordan and Yarmouk Rivers. To improve and enhance the Palestinian water supplies and their distribution for the Palestinian people, two scenarios will have their impact on this goal. These scenarios are:

1 - Enhancement of water supplies under a transitional peace period.
2 - Enhancement of water supplies under an independent state which might have confederation relations with Jordan.

6.1. Enhancement of water supplies under a transitional period

The first scenario assumes that the Palestinians in the OPT have to go through a transitional period of three to five years before a final real peace agreement can take place. During this period most of the water supplies must be considered for the immediate and urgent needs to develop the existing national water supplies and upgrading the existing systems. At the same time, during this period, the following developments can be considered.

6.1.1. Improvement of water resource and water demand management.

This can be achieved by establishing a Palestinian National Water Authority. The powers of this authority should extend to the following:

a - Declaration that all non-private water resources in the OPT are under the new Palestinian Water Authority.

b - Establishment of district water companies. Nine local Palestinian water companies can be established, eight in the West Bank including Jerusalem and another one in the Gaza Strip.

c - Establishing at the national level a Water Planning Center. The district water companies can be responsible for the management of the district water systems while the National Authority can plan the large scale water projects and coordinate with other national authorities on further research and studies regarding the enhancement of water resources.

d - Setting the water standards for the various uses and control of the water quality in the OPT.

The water demand must not be treated as an independent or uncontrollable factor. On the contrary, the level of service must be chosen in accordance with the means available to provide each service. It may be possible in the long term to avoid, delay or reduce investments in future water supply extensions while improving the existing level of service all round by measures that manage water demand and produce economies in water use.

The demand on a water supply in the OPT may be reduced without a fall in the standard of service by the following methods:

a - Leakage reduction.

In many cities and towns of the West Bank and the Gaza Strip more than 50 percent of the water entering the system may be lost as leakage. This high proportion of losses should be cut down to the normal situation (15 percent) by the rehabilitation of the distribution networks and by improvements in the metering system. Any cut down percentage of leakage means more water supply to the consumers.

b - Tariff policy.

Although water meters are used in the West Bank, the standard of meter maintainance is still poor and many meters are often not read. Accurate water meters must be installed and a maintainance policy on a regular basis must be adopted.

A nominal charge should be levied for a minimal amount of water to enable the poor people to obtain water for their basic needs, while water tariffs would increase progressively for larger volumes.

c - Water-saving taps and fittings.

The enormous volumes of 10 to 20 liters used to flush conventional cistern-flush toilets are unnecessary for efficient operation. Devices that restrict flow to a fixed amount irrespective of the pressure in the mains must be installed. The introduction of such fittings can be assured by building regulations and by-laws.

d - Consumer education and information.

Publicity campaigns to reduce water wastage and unnecessary consumption must be carried out. Information on water supply systems coupled with health education at schools, factories and clinics, focusing on the inter-relation between health, water and excreta and wastewater disposal can help to improve the water supply with respect to demand.

6.1.2. Development of irrigation methods

In countries where water is very scarce and agriculture is a major sector in the national economy, water must be used very wisely. Sprinkling and drip irrigation methods which can save water must be used wherever possible and flood irrigation has to be avoided. At the same time, since the evaporation rate is very high, open channels must be covered or replaced by pipes, and water channels should be lined or cemented in order to stop any unwanted infiltration.

6.1.3. Wastewater reuse

Every community produces both liquid and solid wastes. The liquid portion - wastewater - is essentially the water supply of the community after it has been fouled by a variety of uses. If the wastewater is allowed to accumulate without treatment, then it can harm the environment, infiltrate to the ground and pollute the groundwater resources. In addition, untreated wastewater usually contains numerous chemicals as well as pathogenic or disease-causing microorganisms that can affect the health of people. For all these reasons, wastewater treatment and disposal is not only desirable but also necessary. Wastewater treatment can be of more importance in semi-arid areas like the West Bank since it can create a major potential for new and cheap water resources.

Wastewater treatment plants can be located near the urban areas and refugee camps of the West Bank and Gaza Strip. The traditional urban centers and their surrounding sub-urban communities where efficient wastewater collection and disposal and treatment are of major importance are the cities of Jerusalem, Nablus, Hebron, Ramallah, Al-Bireh, Bethlehem, Jenin, Tulkarem, Qalqilya, Jericho, Gaza, Khan Yunis and Rafah. The population density and the standards of living in these urban areas implies the necessary of building such systems.

Construction of domestic sewage collection systems and treatment facilities amounts to a per capita investment in the order of $300 US Dollars in the West Bank and $220 US Dollars in the Gaza Strip (see Table 4).

Table 4
Per captia costs for sewerage systems

Task	In West Bank	In Gaza Strip
Collection and Disposal	$220	$180
Treatment	$ 80	$ 40

Source: Personnal Communications, 1992.

Hence, the total cost for implementation of sewerage schemes in the urban areas and refugee camps of the West Bank and Gaza Strip mentioned below amounts to 387 million US Dollars for the year 1992. This does not include the construction of domestic water supply and distribution systems or the agricultural irrigation systems. The following table shows the investment costs needed for constructing sewage systems at various stages.

Table 5
Investment needed for wastewater reuse infrastructure

Urban Population and Refugees			Accumulative Cost Million Dollars	
Low	High	YEAR	Low	High
1,080,000	1,280,000	1992	324	387
1,758,000	2,233,000	2000	527	670
2,250,000	2,859,000	2010	675	658
2,743,000	3,485,000	2020	823	1037

Estimated from previous figures.

Sewage treatment should not only aim to improve water quality so that it will not cause any harm or create any danger when exposed to the environment but should also aim to use the effluent for agriculture. Treated sewage for reuse in agriculture must always fulfill the standards recommended by the WHO.*

* Planting industrial agro-crops, such as jojoba trees which produce an expensive industrial oil for lubrication, cosmetics and other uses, could be done near the lands sewage treatment plants. These dwarf olive-looking trees use little water and can withstand even salty water as has been shown in Peru and in the Negev of Israel where jojoba trees thrive on wastewater.

Over 80,000 jojoba trees have been successfully planted in the West Bank and Gaza Strip as well as in Jordan over the past ten years. In the West Bank, jojoba plots are all dry-farmed with no supplemental water, except in Jericho.

The infrastructure needed to collect and treat the sewage for agricultural purposes in the West Bank and Gaza Strip is still very poor and inefficient. A lot of investment is still needed. Full scale implementation of wastewater systems will provide a substantial amount of purified water suitable for agricultural use. Such implementation should also consider that proper education of farmers is still needed to reuse wastewater and advanced agricultural technologies are essential. The following table reflects the wastewater quantities that can be reclaimed.

Table 6
Quantities of wastewater potentially available in the West Bank and Gaza Strip

Year	Population of Urban and Refugee Camps		Domestic Consumption cm/c/yr	Wastewater Generated 65% of domestic consumption CUM	Potential Wastewater million CUM	
	Low	High			Low	High
1992	1,080,000	1,289,000	67	43.55	47	56
2000	1,758000	2,233,000	84	54.60	96	122
2010	2,250,000	2,859,000	110	71.50	161	204
2020	2,743,000	3,485,000	125	81.25	223	283

Source: Estimated by the authors based on previous mentioned tables.

The above table shows that full reclamation of wastewater can contribute up to 24% of the irrigation water requirements in the years 2000 and up to 56% in the year 2020.

6.1.4. Rain harvesting and flood water storage

Runoff water from ground catchments or from house roofs or greenhouses and its storage in containers is a potential source of water for domestic purposes which can be used for drinking water or garden agriculture around the house.

A catchment area of 100 square meters with a runoff efficiency of 80% might produce more than 48,000 liters of water per year in the hilly mountainous areas of the West Bank. These are quantities that cannot be neglected in view of the current water shortage in the OPT. Rain harvesting is thus a potential water resource for domestic use and for agriculture mainly where drip irrigation is used.

There are many valleys in the OPT which concentrate runoff water that could enhance agriculture if this runoff is stored behind small earth dams or even concrete dams where possible. However, the main obstacles against daming such water flow is the lack of funding and the difficulty to get permits for such projects from the Israelis. (Assaf, 1991).

6.2. Enhancement of water supplies under an independent state which might have confederation relations with Jordan.

Under the second scenario, it is assumed that the Palestinians in the OPT will have absolute rights to control and utilize all their water resources including the joint aquifers and recover their rights from the Jordan and Yarmouk Rivers. All these resources will be the main water supply to improve the existing water shortages. Under this scenario, it is expected that major developments will be taken to expand the water projects mentioned under the first scenario, in addition to implementation of new large scale water developments which will consider the following:

6.2.1. Construction of the West Ghor Canal

The Jordan River flows along the eastern boundaries of the West Bank where the water is much needed for agriculture in the Jordan Valley, especially in the Zhor area. Obtaining full West Bank rights in the well known Palestinian share from the Jordan and Yarmouk Rivers will encourage the Palestinians to construct the West Ghor Canal to fulfill objectives and water needs as that in the Eastern Ghor Canal of Jordan.

6.2.2. Implementation of a national water system similar to the Israeli National Water Carrier.

This system will enable the Palestinians to increase the water supply to the Gaza Strip from cheap Palestinian resources as well as transferring the surplus water from the north to the south or from the West to the East. This system of "fair taking and sharing" should also include the drilling of new boreholes in the region to tap the groundwater from the various water aquifers in the summer and recharge them in the winter.

6.2.3. Improving and protecting the water quality of the Lower Jordan River.

The Palestinians should reach an agreement with Israel as an upstream country to prevent the diversion of the saline water near Lake Tiberias to the Jordan River. This might be possible by laying a main line or constructing a channel to carry the saline water to the Dead Sea. At the same time more water should be allowed to flow from Lake Tiberias to the river.

6.2.4. Other schemes

Some projects which currently have uncertainties and projected high cost can only be justified in the future if they become politically and economically feasible. Such projects include brackish or sea water desalination and transfer of water from outside the region.

7. CONCLUSION

The Occupied Palestinian Territories (OPT), i.e., the West Bank and Gaza Strip including East Jerusalem, have their main water resources from two sources, (1) the portion of the Jordan and Yarmouk Rivers which represent surface water supplies in which the Palestinians have a legitimate share, and (2) the West Bank and Gaza Strip aquifers which represent the main national water supply for these areas.

The Palestinians in the OPT who are about two million now and increasing at an annual rate of 3%, do not receive more than 15% of the water used by the Israelis. Palestinian water demands exceed the quantities allocated by the Israeli authorities themselves. The various Israeli military laws and regulations imposed after 1967 prevent full utilization of Palestinian water resources, while the existing water utilization by Palestinians now for all uses is about 215 MCM per year, the demand is expected to exceed 800 MCM by the year 2000.

The limited water resources of the OPT necessitates a great need for enhancement and development of water resources. The authors proposed that this can be achieved not only through the improvements in the water resources but also by water demand management and various methods of water conservation including development of appropriate irrigation methods, waste water reuse, rain harvesting systems and recharge of existing wells and aquifers. Great enhancement of the Palestinian water supply can be achieved through the construction of the suspended West Ghor Canal to serve Palestinians in the West Bank and adoption of a Palestinian national water system using some of the Syrian water rights in Lake Tiberias in which the Syrian part of that lake was occupied by Israel in 1967, and that may be done through exchange of the Yarmouk waters to the Syrians.

We have calculated that the enhancement and development of water resources through waste water reuse only requires about 400 million dollars in 1992 but 1000 million dollars by the year 2020. Development of all Palestinian water resources including recharge will require multiples of this amount.

Money alone cannot accomplish the required objective of complete development of Palestinian water supplies as this cannot be done in the absence of an independent Palestinian water authority with a pure political Palestinian backing.

Note: This paper is part of a study currently being conducted for IPRCI, the Israeli-Palestinian Research Center for Information, Jerusalem, 1992.

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Management of Israel's water resources

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ABSTRACT

The demand for water in Israel does not coincide, temporally or spatially, with the natural availability of the resource. Water supply must therefore rely on a national system that conveys surface water from the north to the south, in conjunction with groundwater storage. Demand in Israel and the territories is in growing disproportion to the renewable resources, and legal and administrative measures have been instituted to control groundwater use and prevent damage to the overexploited resources. All natural water resources have been utilized to their maximum sustainable yield. Marginal sources, such as recycled domestic wastewater, flash floods and saline water, are being exploited to an increasing degree. In addition, plans exist for future use of additional sources, such as importation of water or sea water desalination.

1. WATER RESOURCES

Situated in the eastern Mediterranean between the sea and deserts, Israel, with an area of 22,000 sq.km, possesses a variety of physiographic conditions and a highly variable climate.

The low narrow coastal plain stretching from north to south is followed by a central mountain range, which then gives way to the deep Jordan Rift Valley, with its continuation to the Red Sea.

The mean annual rainfall decreases from above 1,000 mm in the upper Jordan Basin to less than 200 mm near Be'er Sheva and 50 mm in Elat, in the south. The seasonal variations are also high, with seven completely dry months.

Annual variations are still higher: replenishment of the three main water sources (Lake Kinneret, the Coastal Aquifer, and the central mountain Yarqon-Tanninim Aquifer - see Fig. 1) varies considerably from year to year. Total replenishment of the three sources during the past 60 year period reached a maximum of 2,370 MCM and a minimum of 600 MCM, with a mean of 1,340 MCM. The seven rainy years average is 2,000 MCM while the seven dry years average is 770 MCM only. The three main sources supply about three-quarters (1,200 MCM/yr) of the total national supply of fresh water (1,600 MCM/yr).

Lake Kinneret drains the upper Jordan Basin. The Coastal Aquifer is composed of sand and sandstone formations along the Mediterranean coast, replenished directly by rain on its surface. The impacts of pumping in this aquifer are local, being felt in particular with respect to seawater intrusion. The data cited for the Coastal Aquifer (see Fig. 2) are specific to certain locations only, and are not representative of the aquifer as a whole. Hence data on the Gaza Aquifer, similar to the Coastal Aquifer in geological structure but local in nature, are not included herein.

The Yarqon-Tanninim Aquifer is composed of karstic limestone formations with widely developed caves and cracks. With very high hydraulic transmissivities, it is operated as a single reservoir along a distance of 150 km, from Be'er Sheva to Mount Carmel near Haifa. Replenishment of the aquifer is in the mountain ranges of Judea and Samaria; from there groundwater flows westward to the foothills, where the flow direction shifts northward. The natural drainage outlets prior to 1948 were two springs: Yarqon near Tel-Aviv and Tanninim south of Haifa, with an average total flow of 330 MCM. The aquifer is exploited at present by means of a series of pumping wells in the foothills.

Limitations on the use of this aquifer are imposed by saline water bodies underlying, overlying and bordering the main fresh water aquifer. Under undisturbed flow and pressure patterns these saline water bodies were stagnant. Their boundaries were flushed by fresh water flowing towards the outlets, resulting in an increase in salinity from 30 ppm chlorides in the replenishment area to about 1,000 ppm at the Tanninim outlet in the North.

Lowering of water tables below certain critical levels may reverse the flow pattern (as shown in Fig. 3), with encroachment of saline water in pumping wells.

2. WATER SUPPLY SYSTEMS

Development of the country in the 1950s was based solely on groundwater. The Yarqon-Negev pipelines were constructed with their headworks at the Yarqon springs. The National Water Carrier was constructed in the early 1960s (Fig. 4). It is composed of pumping stations, a canal section and a 108" dia. pipeline, 110 km long, connecting many secondary regional branches, in particular the Yarqon-Negev pipelines in the south.

The objectives of the system were to solve the problems arising from the climatic, hydrologic and physiographic characteristics of the country by:

- Conveying water from the rainy north to the dry south;
- Raising water from the low Jordan Rift Valley (200 m below sea level) to the coastal plain (100 m above sea level), and
- Conjunctive use of the resources: storage of surface water underground by artificial recharge; and temporary replacement of supply from groundwater by surface water or vice versa.

3. GROUNDWATER RESOURCES MANAGEMENT

The National Water System was completed in 1964, when groundwater resources in the country attained full utilization. In 1965 water levels reached a new equilibrium: outflows and spills were reduced to a minimum, and in Yarqon-Tanninim, the unutilized flow of springs peaking in winter was replaced by pumping wells operating according to seasonal demand variations.

Lowering of water levels is constrained by salinization hazards: seawater intrusion and setting in motion of stagnant saline water bodies. The limit of exploitation was reached in 1965, and lowering of water levels was stopped by means of legal and administrative arrangements, set up to control water abstraction and consumption (see Fig. 5). Water supply allocations for irrigation were frozen at the end of the 1960s (Fig. 6), and subsequent increase in agricultural production was achieved primarily due to improved agrotechnologies (selection of cropping patterns with low consumptive use of water), and improved irrigation technologies (moving from surface irrigation to sprinkler irrigation, and later to drip irrigation). As a result of these improvements, irrigation duties decreased from 9,000 m^3/ha to 5,500 m^3/ha in 1985.

4. PRESENT SITUATION

The population has increased steadily since 1960, together with the standard of living and water consumption. Overexploitation of water resources continued unabated, reaching 1,500 MCM in 1985, a quantity equivalent to the annual supply. Although the phenomenon was most evident in the Coastal Aquifer (Fig. 2), Lake Kinneret and the Yarqon-Tanninim aquifer also reached their critical levels.

During the period 1985-90, water allocations were curtailed in order to stop overexploitation and restore reserves to their previous levels. The result was that water levels stabilized (Figs. 5 and 2). Water levels in 1991/1992 regained their 1970 values owing to the exceptional winter, with rains breaking all meteorological records.

5. MASTER PLAN OF 1988

A new master plan was prepared in 1988 against the backdrop of the following data and forecasts:

- Water demand was expected to grow with increasing population and standard of living.
- Reliable future supply required restoration of groundwater stocks.
- Intensive human activities in water catchments endangered the quality of water sources.

Population forecasts are highly variable. The present population of 5.0 million is now expected to grow by the year 2010 (Fig. 7) to 6.9 (low) or 9.0 million (high); this is in contrast to the Master Plan of 1988, which envisaged a modest growth rate and a population of only 6.6 million in 2010.

Average per capita consumption of water in Israel grew from 75 cu.m/yr in 1960 to 100 cu.m/yr in 1990 (Fig. 8). The Master Plan of 1988 assumed a freeze at the level of 100 cu.m/yr by application of conservation measures.

The population in Judea and Samaria (not including Jewish settlements) was expected to grow at a higher rate, from 880,000 in 1990 to 1,300,000 in 2010. Per capita consumption there, estimated at the relatively low figure of 35 cu.m/yr in 1988, was expected to increase to 60 cu.m/yr in 2010. The population of Gaza was expected to grow from 580,000 to 960,000, with an increase in per capita consumption similar to that of Judea and Samaria.

It is worth mentioning that a population of 15 million in Israel, including Judea and Samaria, is expected to consume all fresh water resources, generating 900 MCM of sewage, which may be reclaimed for irrigation.

The Master Plan includes the following activities:

- Recycling of domestic wastewater for irrigation (Fig. 9).

- Desalination of saline groundwater for domestic uses.

- Additional use of winter floods.

- Protection of the major water sources, used mostly for drinking, from contamination. These are in particular the coastal plain and Yarqon-Tanninim catchments; the latter are karstic, without the buffer effect of overlying clays and sands, resulting in short travel times.

- Control of demand to meet the available resources, and replacement of fresh water for irrigation by recycled water.

- Establishment of multi-quality supply systems to handle the various available resources and uses: potable water, water for irrigation and recycled sewage.

- Reduction of outflows such as floods, spills from Lake Kinneret and groundwater seepage to the Mediterranean Sea.

Plans for Gaza were not included in the Israel Master Plan and were prepared separately. As stated, the Gaza Aquifer has distinctly local characteristics, so that the water resources of the Gaza area are considered to be independent of those of Israel. With sandstone formations, the interference of groundwater pumping is felt only to a limited distance. The situation of groundwater in Gaza was critical prior to 1967, and limitations on exploitation were only partially successful in stopping deterioration. With deteriorating groundwater, only new external resources, such as sea water desalination and water importation, can solve the problems of sustaining agriculture and meeting domestic demand.

6. ADDITIONAL SOURCES

Additional sources were not included in the Master Plan due to economic criteria that limited the cost of new water resources to U.S.$ 0.35/m^3. However, this limit no longer appears to be critical, in particular for domestic water supply. Two types of projects to increase the resource base are now being considered:

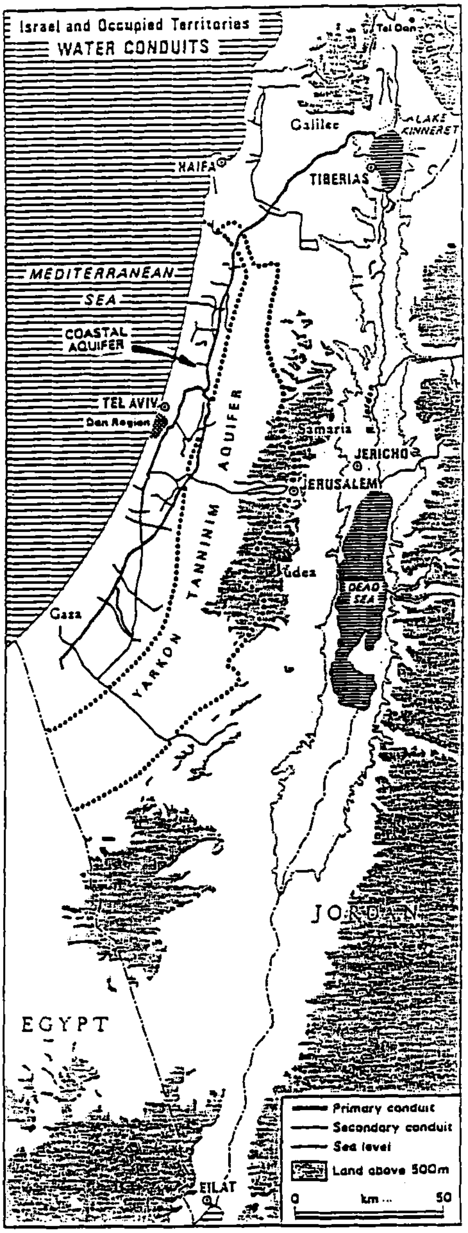
- Sea water desalination based on a variety of methods, combinations and locations.

- Importation of water from countries with relatively abundant water, e.g.:

* The Nile River: surpluses may become available once irrigation efficiency is increased but their use is questionable due to political constraints.

* The Litani River: part of the flow is used only for power production, after which it is discharged to the sea. Exchange of water for energy supplied from Israel may be a solution to the water scarcity in Israel and Judea, particularly in drought years.

* Turkey: water surpluses exist in Anatolia in southern Turkey. A project for transport of water by sea (in medusa bags) is being studied.



Source: Atlas of Israel, 1985

Fig. 1 Water Resources

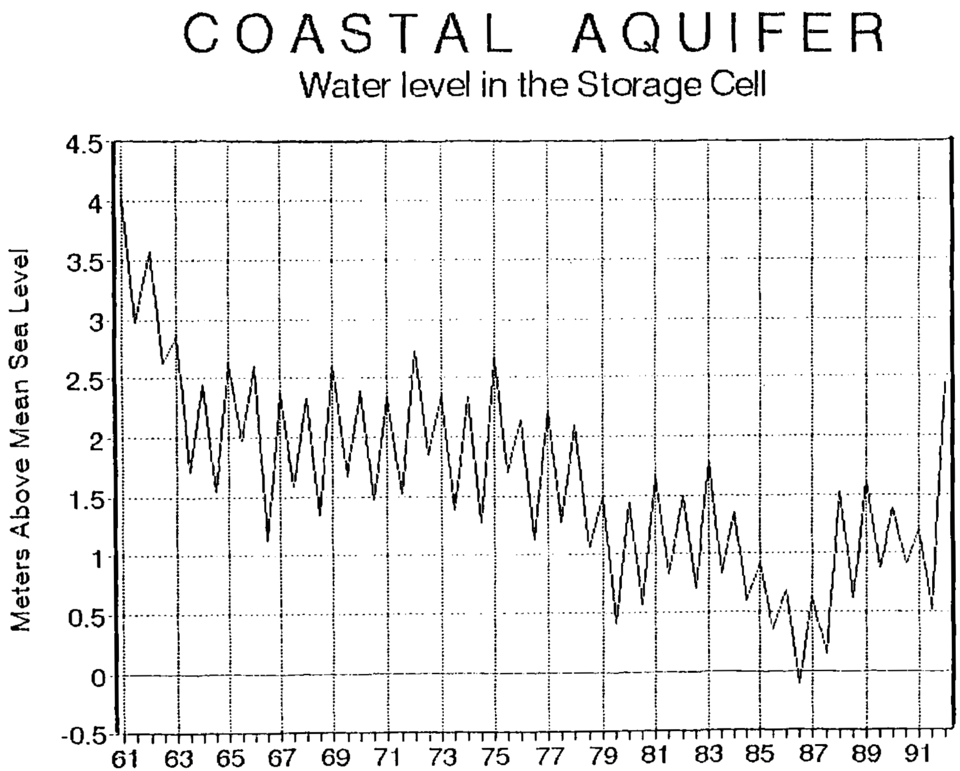


Fig. 2 Water Level in the Coastal Aquifer

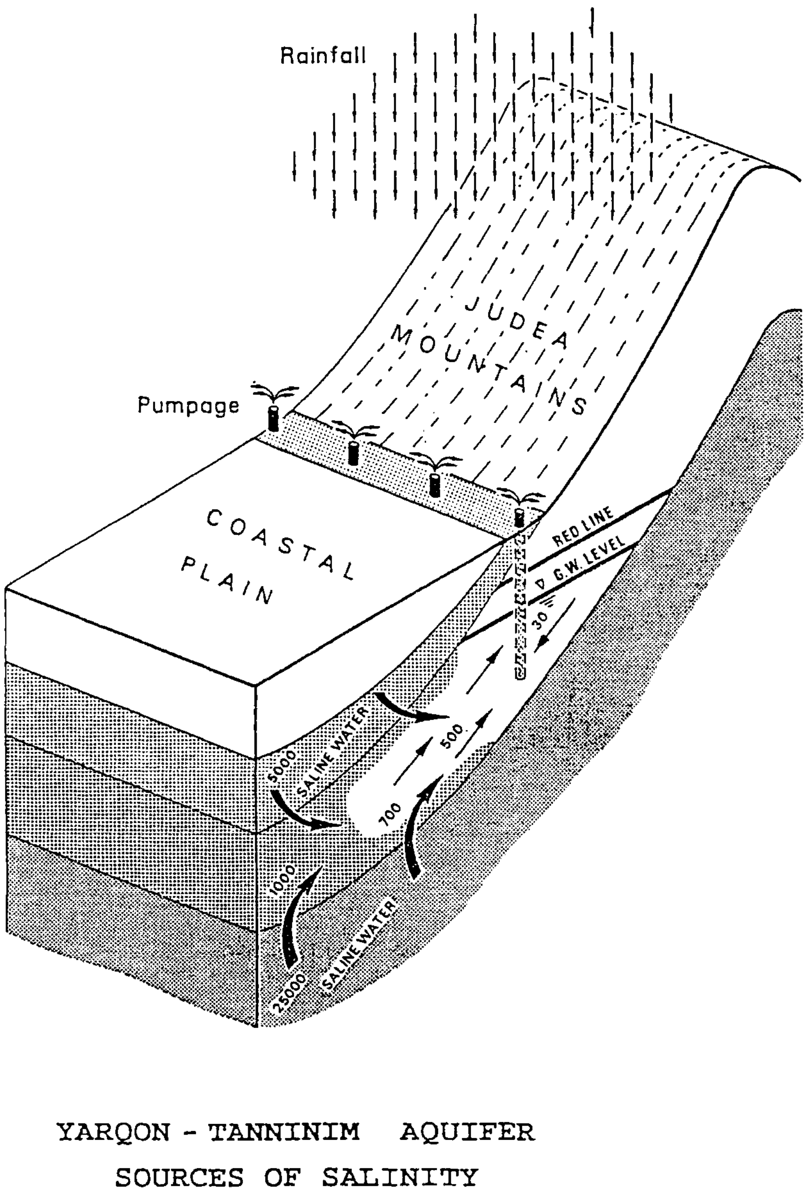


Fig. 3 Yarqon Tanninin Aquifer Sources of Salinity

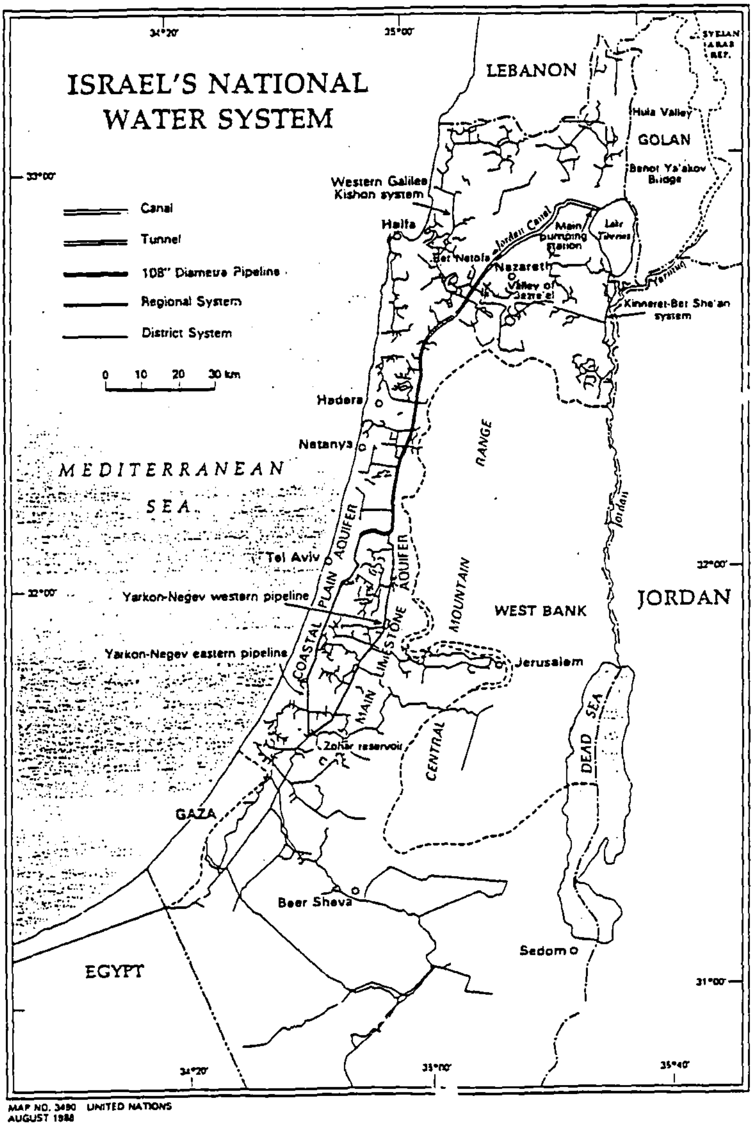


Fig. 4 Israel's National Water System

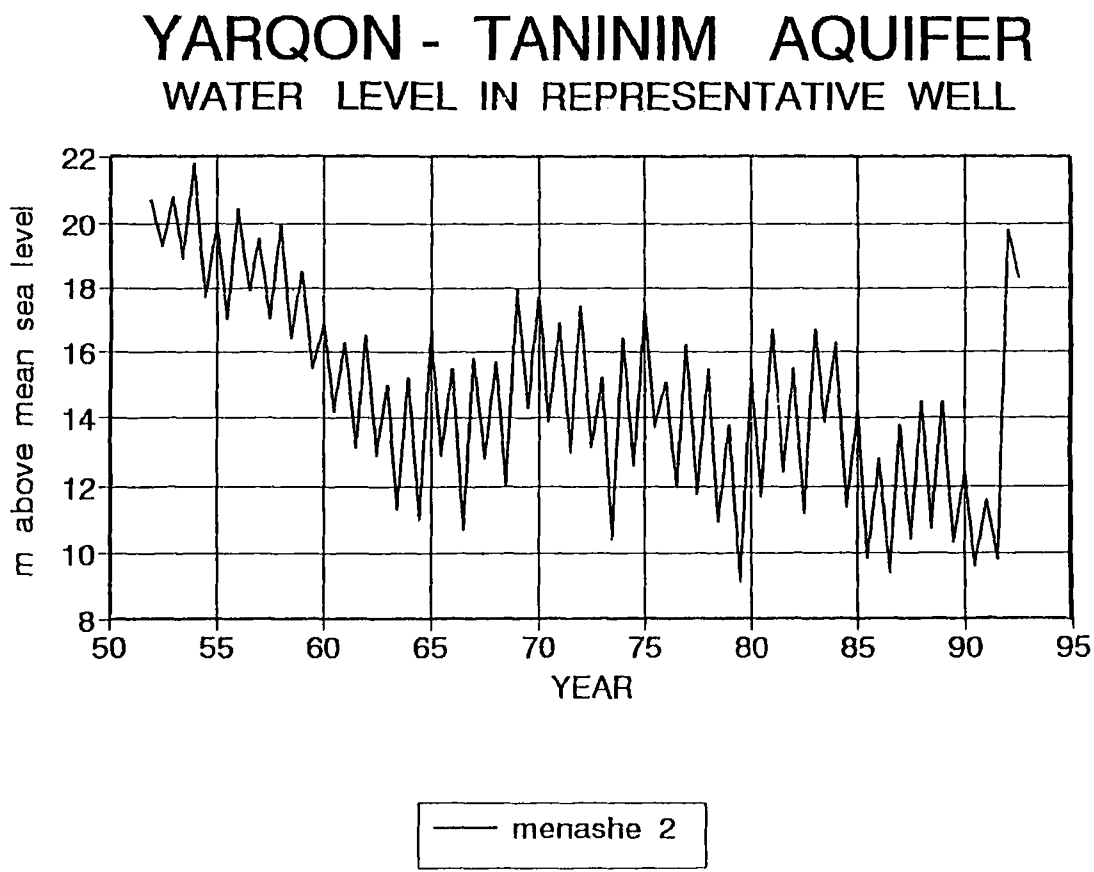


Fig. 5 **Water Level in the Yarqon Tanninin Aquifer**

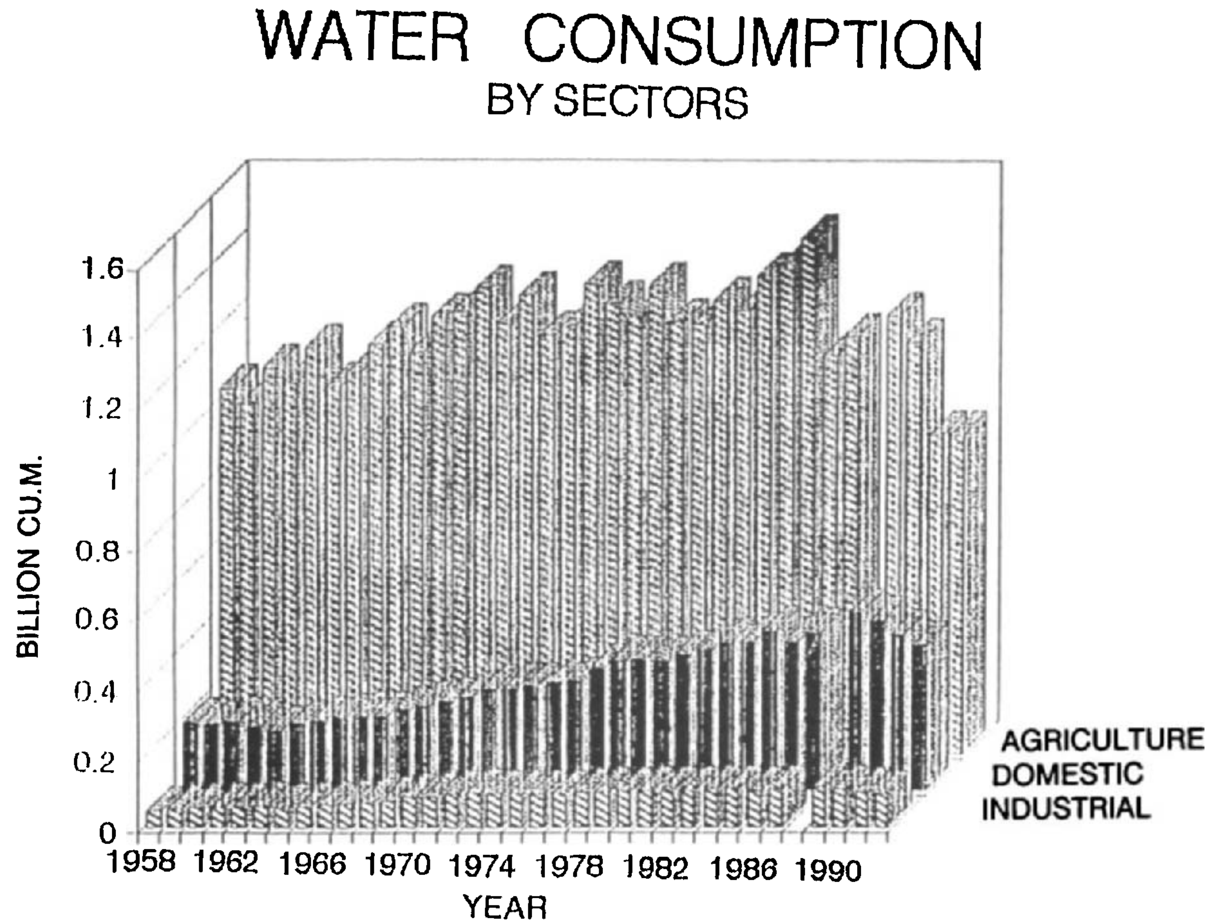


Fig. 6 Water Consumption by Sectors

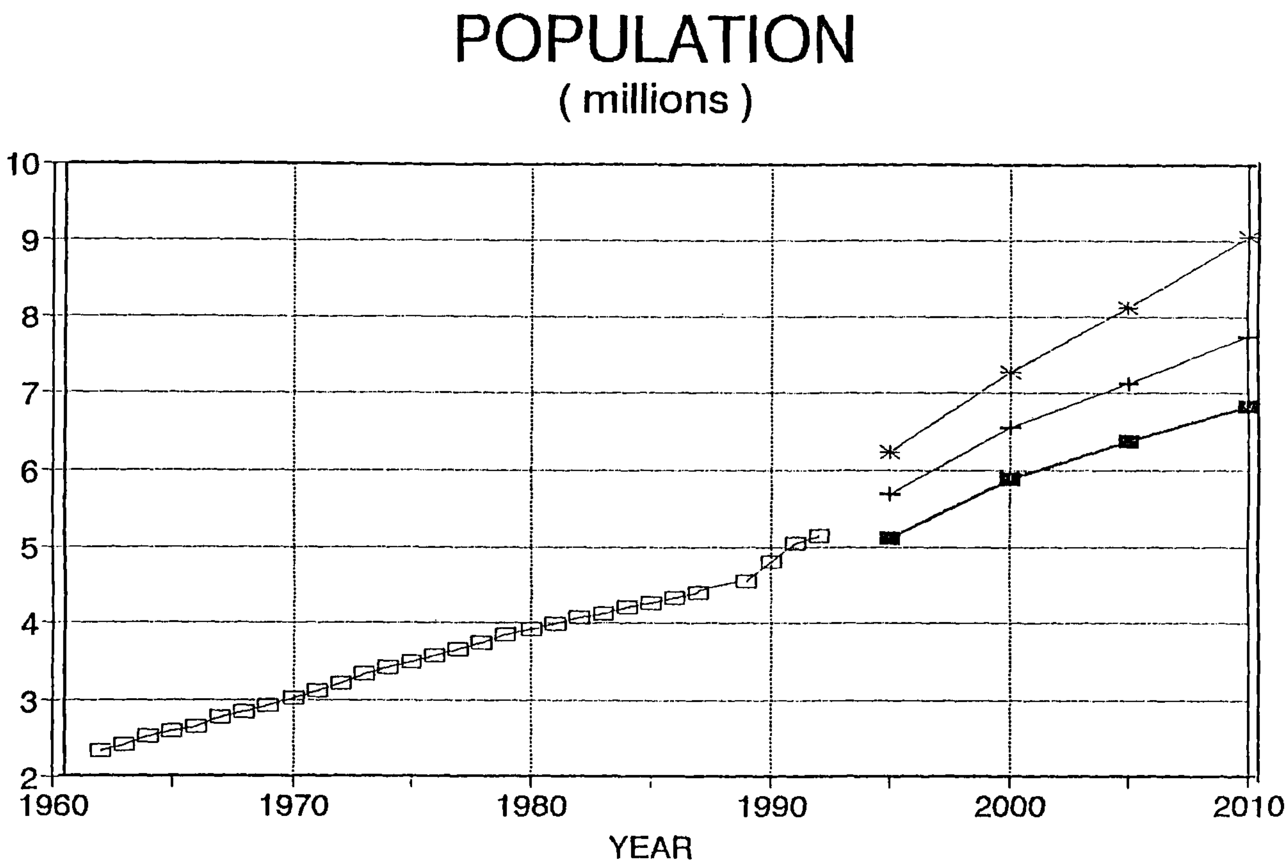


Fig. 7 Population

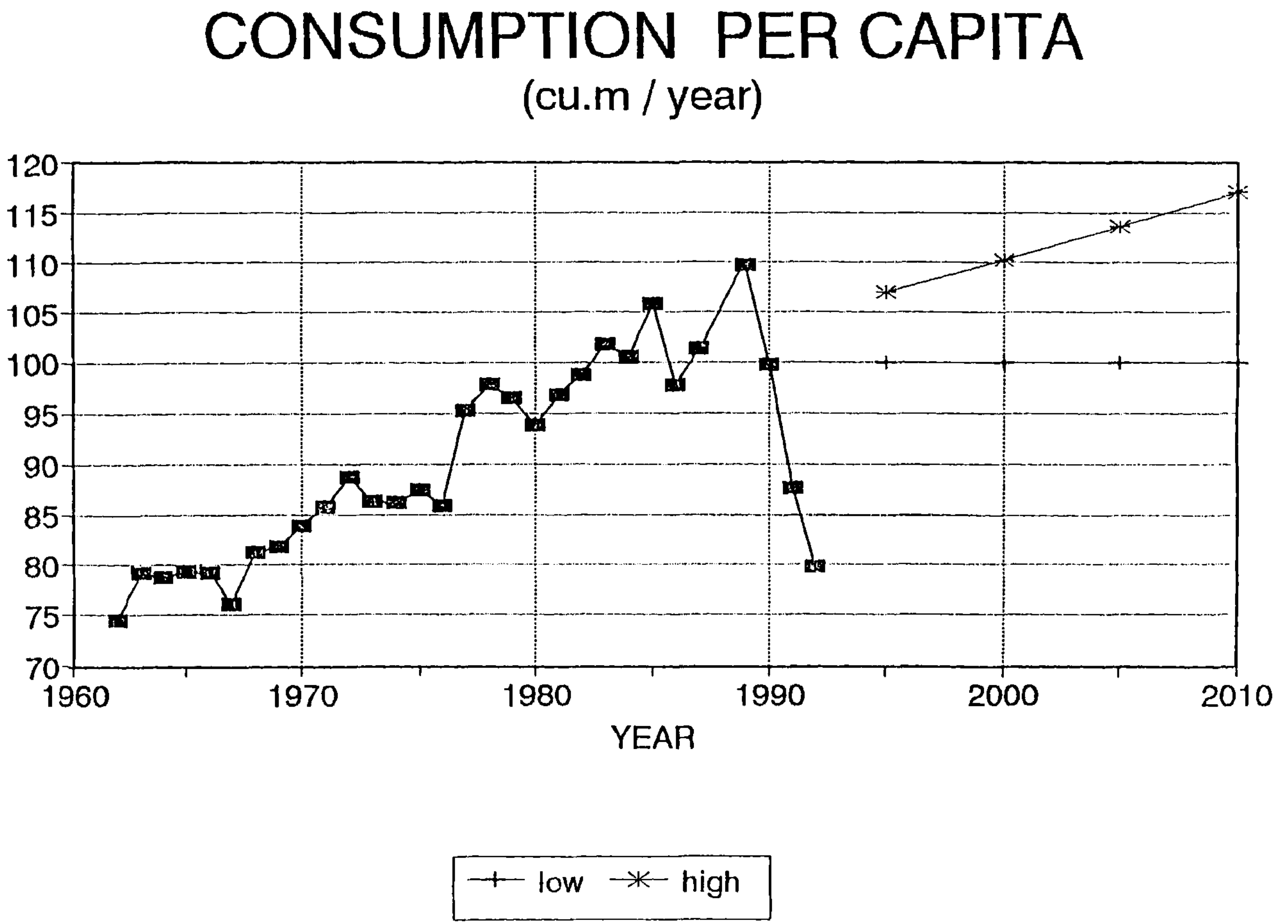


Fig. 8 Consumption per Capita

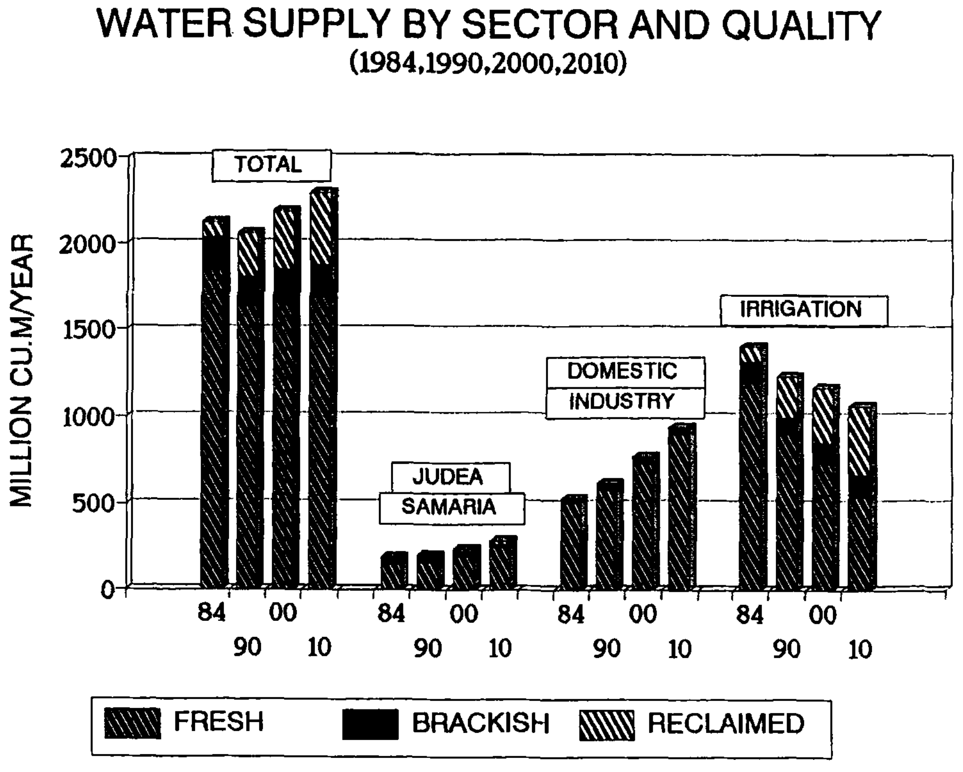


Fig. 9 Water Supply by Sector and Quality - 1988 Master Plan

Isaac/Shuval (Eds), Water and Peace in the Middle East

A Case for Demand-Side Water Management

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Abstract: It is axiomatic that because water is such a complex, pervasive issue, solutions to its problem must be commensurate with its complexity. The key to dealing effectively with the layered intracacies of water is to pay attention to the interlinkages, e.g., approaches that *combine* supply and demand-side policies. Controlling problems of water scarcity and maldistribution in hydrologically marginal regions such as the Middle East require policies that emphasize managing demand and need rather than focussing on increasingly difficult efforts to increase supplies.

When economic and societal development coincide with resource scarcity, particularly scarcity of a shared vital natural resource such as fresh water—as is the case in several arid and semi-arid regions of the Middle East—governing authorities typically behave in ways that tend to deplete the resource, degrade the environment and produce consequent domestic and international tensions. Their perceptions are characteristically—and understandably—anthropocentric, a fact which is reflected in their approach to dealing with development problems, particulary where water is concerned. They often behave in ways analogous to authorities in water-rich countries: their hydro-policies tend to be incremental or inconsistent, and short-term; they treat water as a technical commodity related only to food, agriculture and human settlements; and the emphasis is on increasing supply when problems arise. Such perceptions and strategies, so prevalent among developing and industrialized countries alike, make controlling their harmful impacts on the environment difficult.

Malin Falkenmark put the matter cogently in this way: "In Summary, man is not really capable at the present time to manage or control the environmental impacts of his activities in a broad and consistent way. Problems continue to be approached by decisions makers who address one problem at a time, from a short-term perspective, often in direct response to strong public pressure." [1] The results are often scarcity and evironmental degredation. Jack Goldstone has demonstrated that the consequences of resource depletion can be severe: the legitimacy and stability of governments can be undermined because they would no longer be able to deliver essential services or cope with the social and economic dislocations caused by extreme scarcity.[2]

Water development projects are always an integral part of a nation's larger pattern of social and economic activity and necessitate systemic and coordinated approaches. For example, a water system involves such interlinked elements as chemical treatment plants, equipment together with spare parts, a system of operations and maintenance, training programs for specialized personnel, relevant bureaucratic agencies, a safe and affordable energy supply, a pumping system, cash crops, a transport system, and a ready market; combined with these factors are such ambient components as a stable political system, a functioning economy, sanitation, public health, education, and social acceptance of any given project.[3] To this set of factors must be joined another which may collectively be labeled the "psychological environment" of decision-making. This notion is neither easily measured nor defined. Broadly speaking, the psychological environment is composed of all those elements that go into a decision-maker's conception and evaluation of a given situation that requires action, involving such integrals as power, attitudes, ideology, population, geography, climate, and the resource itself.[4] Associated with the psychological factor is another that I believe must also be taken into account: the "perception gap." This gap reflects the differences in the perceptions of a given issue or problem among the public, the experts, and the policy makers. When perception gaps are wide, as is often the case where issues of resource scarcity are concerned, good policy making or change of policy becomes difficult—particularly if there is a lack of public confidence toward the policy makers and/or experts.

Even this brief litany of factors highlights the complexity of water. It is axiomatic that because water is such a complex, pervasive issue, solutions to its problems must be commensurate with its complexity, and the key to dealing effectively with the multi-layered intracacies of water is to recognize and pay due attention to the constituent interlinkages; this means, to be precise, approaches that *combine* supply and demand-side policies. To attack problems of acute water scarcity chiefly or soley by means of a supply-side policy is not unlike trying to drink out of a seive. I aim to argue here that controlling problems of water scarcity and maldistribution, especially in hydrologically marginal regions such as the Middle East, require an approach that emphasizes managing demand and need rather than focussing on increasingly fruitless efforts to increase supplies.

But, it must be acknowledged that however desireable or necessary managing demand is, the process is very complex and difficult because it involves many actions in combination with other activities that are aimed at increasing supply. Even measuring and forecasting demand accurately is made highly problematic by many difficult-to-control variables: lack of reliable detailed data (characteristic of many parts of the region), high rates of leakage from the distribution system, unmetered supplies or meter cheating, price variations (complicated by subsidies), changes in patterns of water useage, etc. Data is a particularly vexing problem owing to a combination of factors, primary among them being the natural variations in flow and climate. When these are linked to lower riparian position, inability to control source and flow, and the treatment of data as security and political matters, accuracy and accessibility invariably suffer. Thus, planners generally do not have available any truly dependable models for forecasting demand, and must rely on such means as trend extrapolation, component analysis, multiple regression models, or even adapted econometric models, none of which usually yield more than rough approximations.[5]

Managing demand effectively requires such actions as accurate assessments of demand and true need, controlling population growth, economic restructuring, redistribution of supplies, managerial and on-site efficiency, conservation, etc. All of these activities represent very dangerous ideological, symbolic, political, and economic shoals for policy makers. How, then, can political leaders safely adopt a demand management/need based approach to water problems, even if they are inclined to do so? Attitudes towards water—like those towards its cognate, agriculture—are culturally embedded and hard to change. Is it feasible to expect demand management policies to work quickly enough in the midst of a crisis, or, for that matter to expect the necessary courage and will for change from political leaders whose cardinal purpose is, normally, to hold on to power? But, given the realities of water scarcity, maldistribution, population growth, and the requirements of rapid economic development, is there a better alternative?

On the other hand, chronic scarcity of so vital a resource as water, whatever its causes, always begets distress across all economic and social sectors: regions become highly vulnerable to climatic events with diminished capacity to prepare or respond to them effectively, states are weakened, people are often displaced with attendant social dislocations, governments tend to adopt short-term remedial policies that cause capital to be diverted into unproductive activities which then constrict economic growth. Given the harsh consequences of water scarcity, maldistribution, unsustainable population growth, and the requirements of rapid economic development, is there a better alternative than greater stress on the management of demand?

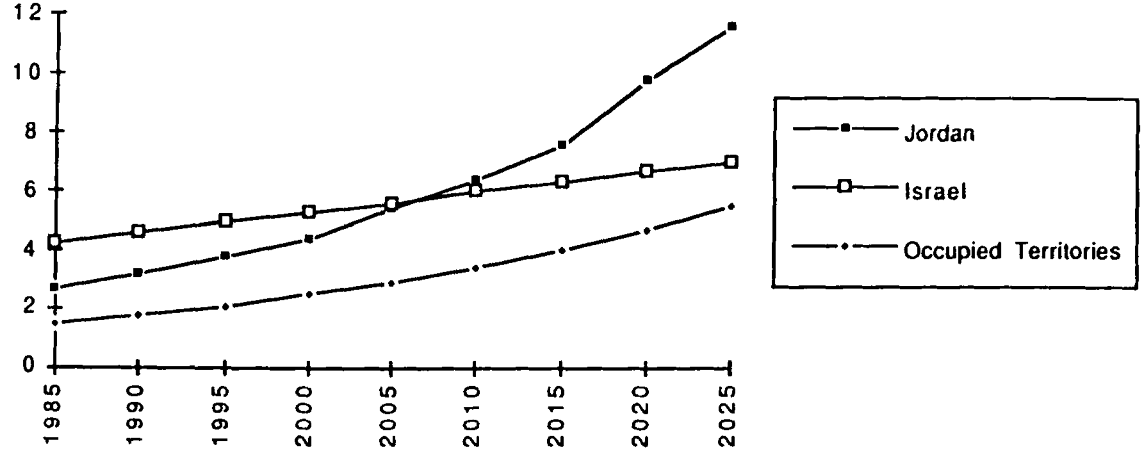
In pivotal, water-scarce areas of the Middle East, such as the Jordan basin, the water supplies of future generations are already being consumed to satisfy current needs. Israel and Jordan have been routinely using more than 100%—some years as much as 108-110%—of their safe yield, and there are no known significant natural sources of new water in the basin. John Waterbury has estimated that under certain conditions, within thirty years the entire flow of the Nile River could become inadequate to satisfy the needs of the projected population of Egypt. Moreover, there is no known water technology or combinations of technology currently available or due to come on line by the end of the century that will produce enough new supplies of water at an affordable cost to avoid the looming crisis.[6]

Consider the implications when the rigid climatic limitations on supply are added to the burgeoning demographic factor in a basin like the Jordan: Jordan's population and that of the Occupied Territories are increasing by about 3.6% annually—at this rate the doubling time is only 18 years (in 1992, unconfirmed reports indicate that the growth rate in Gaza reached an incredible 5.8%). The Israelis are increasing at an annual rate of about 2% but anticipate an absolute increment of three quarters to a million emigres from the former Soviet Union by the end of the decade. Using medium, non-linear projections, and allowing for a projected leveling off by the year 2000 to an average of about 3%/-3.2%/yr, Jordan's population will increase from 2.7 million to 7 million, Israel's will rise from 4.6 million to 7 million (including the Russian emigres), and the Palestinians in the Territories will jump from 1.75 million to 4.2 million.

At these rates, sometime between 2015-2020 the Jordan basin's population (excluding Syria and Lebanon) will reach 16-18 million. The basin's known water resources will support a population of between 12.5-14 million.[7] All the commonly proposed solutions to this problem have serious deficiencies. Large-scale out-of-basin transfers involve too many security, political, and legal complications to be sufficiently reliable as an answer; raising the enormous

Population Projections for Jordan, Israel, and Occupied Territories*

(population in millions)



* Soviet immigration not included

Projections on Israel based on *UN World Population Prospects 1989*
Projections on the Occupied Territories and Jordan are based on in-country data obtained by author

Water Supply and Demand in Jordan Basin
(in Mcm/yr)

	1987-1991 Average Supply Non-Drought Conditions	Average Supply Current Drought Conditions	1987-1991 Average Total Demand	1987-1991 Average Deficits Non-Drought Conditions	Average Deficits Current Drought Conditions	Projected Demand 2015–2020
Israel	1950	1600	2100*	150–200	200	2500–2800
Jordan	900	700–750	800	100–125	100	1600–1800
Occupied Territories	650	450–550	600–650	75–125	100	**

* Includes settlements in Occupied Territories and Golan Heights
** Future status indeterminate

funds necessary to build a sufficient number of desalination plants in time to relieve the crisis is very unlikely owing to the condition of the international financial market and to the exponential increase of new demands on that market from the newly created states following the fragmentation of the eastern bloc—not to mention the vulnerability of desalination facilities to acts of sabotage or hostility; moreover, because desalination requires high inputs of energy, new money and means must be found to create additional energy sources to run the plants. However, there are some imaginative hydropower schemes such as the Dead-Red Canal and more conventional nuclear power proposals for the generation of electrical energy, but problems of inter-riparian cooperation, cost, safety, and time make these somewhat distant solutions.

All basin-wide and cooperative solutions, technical and otherwise, which are essential to solving the basin's scarcity problem, depend on a resolution of the Israeli-Palestinian issue, one of the world's most atavistic, intractable political and ideological problems, whose prospects for a settlement in time to avoid a major water-driven crisis, while improved, do not appear certain in the foreseeable future. In the circumstances, what, then, is to be done with the two or three million additional inhabitants who will need to be provided with water? A strategy of increasing supply alone is patently impractable and could not succeed if attempted. Obviously, solution of the region's water problems require optimal combinations of technology, management, conservation, and efficiency.

The hydrological problems of scarcity and maldistribution in such basins as the Jordan and Euphrates are not unique—they are replicated with local variation in other parts of the globe. Taken together, overall scarcity (assuming water quality to be an integral of scarcity) and maldistribution are the major factors underlying the world's water problems. Only two percent of the world's entire water resources is available as fresh water. When one scans the earth's tiny consumable water resources (exluding oceans, salt seas, frozen glaciers, and ice fields), the poor match-up among supplies, distribution, and population, in most parts of the world becomes apparent, particularly in the Middle East where relatively acute water shortages are common.

Historically, patterns of consumption in this century indicate that the highest annual per capita withdrawals from water resources are associated with nations where both irrigated agriculture and industry are large scale and very advanced (e.g., the U.S. at about 2500 cubic meters). However, it does not follow that the opposite would be true for developing nations where industrialization is low, populations are high, soil quality is poor, and water is scarce. In those countries where need for food production from irrigated agriculture is substantial, the tendency is for proportionately higher per capita withdrawal as, for example, in Egypt at 1852 cubic meters per year. Over the past two decades, the trend has been a rising per capita withdrawal rate globally.[8]

Despite a moderate leveling off among some countries in the late 1960s, the withdrawal rate resumed an upward climb even in those countries where per capita consumption was already high or had overtaken supply, as in the Jordan basin. Furthermore, the world-wide phenomenon of peoples migrating to cities has had a dramatic impact on water supply, use, and quality in urban centers as well. In the last half century, the massive shift of population from rural areas to urban centers, occuring at incredible speed, has resulted in a surge of city water usage as population densities have increased and water uses have multiplied. All of these patterns of behavior typify the Middle East and have been intensifying over the last quarter century.

John Holdren has defined a renewable resource as one that is useable without depletion or its renewal is significantly greater than its depletion, and a non-renewable resource as one that is used in a significantly greater quantity than its renewability or it is not renewable at all; its use is thus a cumulative process.[9] In the Middle East, water stocks in many areas are being depleted faster than they can be replenished; in such diverse places as Jordan, Egypt, and Saudi Arabia, even non-renewable fossil water supplies, which should be held as a strategic reserve, are being used up. Because coping with scarcity by means of technology, social engineering, economics, and education, are inherently lengthy processes requiring considerable lead time, time itself may be running out for the policy makers even faster than the water supply. The supply-side approach, if not a cause of domestic and international tensions and potential conflicts, certainly contributes significantly to their existence and maintenance.

Until now, when water shortages have loomed, the near-Pavlovian response of government authorities has been to try to solve the problem by expanding supply somehow, but without commensurate reductions in demand. This approach remains prevalent. However, as water budgets have dwindled and costs of supply have risen in many countries, particularly where diminishing supply cannot be readily restored and new stocks are very difficult to generate in sufficient quantity—as in the Middle East—the focus of planners must be shifted away from the supply-side to controlling demand. Water management must be directed toward the *needs* of people and managing *demand* rather than on water itself, that is, rather than on finding ways to increase supply.

As stated, the management of demand involves many actions in combination with other activities that are aimed at increasing supply (a major reason why authorities respond to shortages first with efforts to augment supply). Four assumptions underpin the following recommendations: The *will* and gumption for change among the political leadership is the primary requisite; that priority in planning and policy would be given to demand management; that whenever full-scale demand and need management are undertaken by developing countries, considerable outside financial and expert assistance will be required to cushion the attendant hardships; and that whenever possible, basin-wide or region-wide approaches are best. With these qualifications, I would like to offer a few salient steps—proposals I have put forth before on other occasions—that would be necessary for instituting a demand-side strategy; most do not absolutely require a prior settlement of the Palestinian-Israeli-Arab dispute. (Many of these proposals, it will be noted, are reciprocals of one another).

1) Foremost, population growth must be brought to and maintained at sustainable levels.
2) An assiduous, on-going effort to instill in the public consciousness not only the need for reducing demand, but ways

in which this can be done, with a view to changing perceptions, attitudes, and behavior.

3) Economies should be restructured away from heavily irrigated agriculture toward other sectors, such as electronics, service, and industry—a difficult but not impossible task given proper incentives and strictly dedicated financial assistance. The contribution of light industry to GNP is about 30 times greater per unit of water used than the contribution of agriculture.

4) The developed world—the U.S., EC, Japan, the UN, the World Bank, etc.—should make a concerted effort to provide incentives for the transition to demand management together with the necessary assistance.

5) The adoption of appropriate available water-related technologies should be strongly encouraged as should be investments in the development of new technologies while continuously and systematically seeking and selecting useful innovations that come on line, especially in the fields of purification and recycling.

6) Improve the efficiency of the water system in all sectors and, equally, of the bureacracy that administers it.

7) Reduce subsidies and allow the cost of water to rise gradually to its true economic level. The use of market mechanisms for the regulation of water supply and demand should be seriously investigated. In this regard, as Shawki Barghouti of the World Bank has argued, serious thought should be given to making water a commercial commodity to be used profitably, with water banks for storage and later use (as, for example, in California and the Columbia River basin in the U.S.), and to exploring new investment policies, improved management techniques, inter-basin transfers, and the creation of an international water market. (But, the question then arises to what degree can water be treated as a commercial and technical commodity, separated from its ideological, symbolic, and cultural linkages?)

8) Improve data collection and record keeping, and invest in ways to improve on determining and forecasting demand.

9) The shift from farming to industry will be difficult because agriculture is culturally embedded, highly symbolic, political, and militarily significant. Therefore, investment in research and practices oriented toward encouraging the smooth transition would be essential and would yield high dividends.

10) Do all possible to promote inter-and-intrabasin cooperation, coordination, data production and sharing.

11) Since it is unlikely that cooperation can be coerced or induced at the highest political levels, the most promising approach would be to encourage cooperation at a lower but still significant level, among officials and technical experts. If officials and scientists in a given region communicate

sufficiently to develop shared understanding of the water situation, of available technologies, and potential solutions, they could constitute a community of informed specialists throughout the region, and become a strong force for cooperation by pressing for and guiding effective water policies, that emphasize demand management.

12) Promote economic restructuring by making it possible for one country to act as a demonstration model for others—in the Middle East, Jordan would probably be the best candidate for that role. The program would be implemented gradually, with rigorous periodic evaluations, flexible planning, and built-in measures for easing transitional hardships. The undertaking would lend itself to collective endeavor, so many governments and agencies could act jointly thereby spreading the risks.

13) Create a technical infrastructure for hydropolicy that addresses problems at basin and regional levels by creating two types of interrelated water institutes: one for river basins and another for comprehensive regional hydrological issues. These institutes, comprising staff, fellows, trainees, and other personnel from the world's major basins, would perform several functions: provide the expertise, research, educational opportunities, and data necessary to develop entrepreneurial, human, and technical resources presently lacking; generate databases and hydrologic, economic, and other social scientific analytical tools; act as conference settings; serve as centers for accurate record keeping and information dissemination; and foster interaction among basin and regional specialists.

The supply-side approach to solving problems of scarcity and distribution has been the predominant policy of choice because it has traditionally been perceived by decision makers as being less politically painful andcostly than the requirements of demand-side policies, even though the real economic and political costs are often exorbitant. Hence, the consistent preference for short-term resource and environmental planning by political leaders. What politician would willingly choose to tell a group of constituent farmers that in order to reduce demand and conserve water for the nation they must give up profitable but high water consuming crops, or switch over to entirely new cropping patterns, or perhaps even cease farming altogether and try to enter into new a mode of livlihood? What national leader relishes the opportunity to announce that the government is abandoning its ideologically grounded policy of food-self sufficiency and security for the sake of avoiding hydrological bankruptcy and preserving an adequate supply for future generations?

The answers to such questions distinguish the petty politician and demagogue from the statesman. But how they are acted on will in large measure determine whether key nations of the Middle East—and of other parts of the world—will face a future that is stable enough and with enough vital resources to allow their leaders to cope with the environmental and socio-economic problems bearing inexorably down on them; or whether they will be caught up in the vortex of a downward spiral of resource degredation, depletion, environmental disasters, accompanied by inevitable tensions and conflicts.

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1 Malin Falkenmark, "Fresh Water—Time for a Modified Approach," *Ambio* , v. 15, no. 4, 1986, 194.

2 Jack A. Goldstone, "Resource Depletion and the State," unpublished paper delivered at the Academy of Arts and Sciences Conference on the environment, resources depletion, and conflict, Washington, D.C., May 11-12, 1992; and *Revolution and Rebellion in the Early Modern World*, University of California, 1991, Introduction and Chapters 1 and 2.

3 Falkenmark, "Fresh Water," 196.

4 Harold and Margaret Sprout, "Environmental Factors in the Study of International Politics," *International Politics and Foreign Policy*, ed. James N. Rosenau, New York, 1969, 41-56; Elizabeth J. Kirk, "The Greening of Security," *New Perspectives for a Changing World Order*, ed. Eric H. Arnett, AAAS, Washington, D.C., 1991, 50-51.

5 G.G. Archibald, "Forecasting Water Demand—A Disaggregated Approach," *Journal of Forecasting*, Vol. 2, 1983, 189-92.

6 John Keenan, *Water Issues in the Middle East: Review of Technology, Parts I and II, 1987, 1989*, unpublished reports of the AMER Middle East Water Issues Project.

7 Some Israeli scholars have calculated a maximum supportable population of 14 million; my own calculation is that the maximum falls between 12.5-13.5 million.

8 Peter Gleick, "Water and Conflict," paper prepared for the Workshop on Water Resources and International Conflict, American Academy of Arts and Sciences, June 15-16, 1991, 1-29, and "Climate Change and International Politics: Problems Facing Developing Countries," *Ambio*, 18, no. 6, 1989, Table 3; Frederick Frey, "The Political Context of Conflict and Cooperation Over International River Basins," unpublished paper, courtesy of the author.

9 John Holdren, "Resources, the Environment, and Conflict," unpublished paper delivered at the American Academy of Arts and Sciences conference on the environment, resources depletion, and conflict, Washington, D.C., May 11-12, 1992.

SECTION II
The Jordan river basin

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Water Utilization in the Yarmuk-Jordan, 1192 - 1992

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Abstract

In 1992, for the first time in 800 years, all the peoples who live within the Yarmuk-Jordan River Basin are negotiating over water allocation. A mutually acceptable agreement achieved voluntarily through negotiation will require at a minimum that each side can be made unambiguously better off by sharing the waters than through current unilateral self development.

1. INTRODUCTION

Not only is 1992 the 500th anniversary of the landing of Columbus in the Western Hemisphere, but it is also the 800th anniversary of the last stable peace treaty between distinct religious and ethnic entities in Yarmuk-Jordan River Basin (the Basin). For most of eight centuries, water resources in the Basin were managed primarily by persons not residing within it. What is promising about the current Madrid round of negotiations is that persons living in the region are talking, and even agreeing on the value of concurring with one another. This paper describes the evolution of water resources infrastructure in the Basin. Its conclusion is that the prospects for a stable water resources-sharing agreement that enhances the lives of people who live in the region are better today than they have been for many years.

2. THE PRE-INFRASTRUCTURE PERIOD: 1192 - 1898

In ancient times, Palestine was the site of an advanced level of technology in water management, as indicated by the Biblical record and the remains of terraces and viaducts. Over time these installations were allowed to deteriorate. In Europe, as well as in Palestine, the decline in the quality of life of ordinary people was influenced by the Crusaders who ravished the local infrastructure and population along their path.

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Salah al-Din is revered by many Arabs because he forced the Crusaders to leave most of the country; in 1192 Richard the Lion-Hearted accepted terms to evacuate Jerusalem and all of the Holy Land except for a small strip along the shore between Jaffa and Tyre. Salah al-Din also deserves to be remembered for his ecumenical attitude when inviting settlers to Jerusalem and other parts of the Holy Land, which was under-populated as a result of the Crusades. Some contemporary Palestinians can trace their ancestry from Saudi Arabia and Egypt to forefathers who heeded Salah al-Din's call. Among them were Jews, who had been driven out by the Crusaders.

For about seven hundred and twenty-five years, foreign Muslim potentates ruled Palestine with only a short period of interruption. Arabs and Jews who resided in the Basin co-existed in Palestine, but never exercised sovereignty. Their land was administered either as an appendage of southern Syria or of northern Egypt, with control shifting frequently among warlords. Few of these rulers paid much attention to the water resources or any other improvement of Palestine's infrastructure, as they were interested in recruiting soldiers and raising taxes from the local population. In Palestine, as in most of the world, the main function of government was to maintain the ruling elite's extravagant life-style.

During the nineteenth century, as more Western travelers came to explore the Holy Land, they found a population most of whom were living in abject poverty. The land was neglected, including its water resources. Much of the Jordan valley, as well as the shores of small streams which flow into the Mediterranean, had been allowed to become malaria infested swamps. The only recorded effort to promote water infrastructure was made by Mr. Georges Franghia, Director of Public Works in Palestine just before the Ottoman Empire lost control over the territory [1], who proposed a plan for irrigation and hydroelectric exploration.

Just before the British conquered Palestine in 1917, its population was down to about 600,000, less than one tenth of the number of residents in 1992. Foreign Christian missions and Jewish institutions financed from abroad began to send physicians, teachers, and agricultural experts. There rarely was a water shortage, but urban residents had to rely on cisterns filled during the rainy season and communal wells; few had water piped into their homes. Sewage disposal was primitive and human wastes polluted the environment. The acreage of irrigated land was small.

3. THE PERIOD OF EXTERNAL ADVISORS: 1898-1948

In 1917 the British conquered Palestine with the help of both an Arab Legion and a Jewish Legion. Although the League of Nations delegated trusteeship to Great Britain, it never acquired sovereignty. Great Britain sought to improve the educational level, standard of living, and self-government capabilities of the local population, with an expectation of turning over sovereignty to the people living in the region. Although both Arab and Jewish residents of Palestine attained a considerable degree of local autonomy after 1917, the British Government was often in conflict with both the Arab and the Zionist national movements.

In the field of water resources development, Palestine under British trusteeship led other nations in the region in adopting technical improvements in irrigation, modern agricultural techniques, and sewage disposal. These achievements, as well as some of the related problems, are summarized in a two volume report prepared for the use of the Anglo-American Committee of Inquiry in 1946-47 [2].

In 1919 a Norwegian consortium (headed by the engineer Mr. Moltke-Hansen) proposed to use the surface water supply of the Jordan River to expand irrigation. The Norwegian plan also proposed the transfer of sea water to the Dead Sea via tunnel, creating an 800 foot drop in elevation to produce hydroelectricity. Preliminary calculations indicated that the cost of this electricity would compare favorably with "water power developments anywhere in the world." The British military authorities rejected the plan. They informed the Norwegians that His Majesty's Government was not yet in a position to act "as the future of Palestine was still uncertain." British archives indicate that the Colonial Office was also under high-level instructions to give preference to similar plans of the Zionist Organization [3].

The borders of Palestine were still under dispute between the British and French governments. The Zionist delegation to the Peace Conference in Versailles actively lobbied in favor of including the entire watershed of the Jordan and Yarmuk Rivers within the borders of Palestine; they also wanted to incorporate the lower section of the Litani River. Its waters, which flowed into the Mediterranean, were proposed to be diverted into the Hasbani River through a short tunnel to supplement Palestine's limited supply of fresh water.

The French and British colonial negotiators did not accept this Zionist proposal and the Litani River was placed under exclusive French jurisdiction. The Yarmuk-Jordan watershed was divided between the French and British, but the French agreed that they would not divert any of the tributaries from their traditional flow into Palestine and Transjordan. For the Zionist movement, the exclusion of the Jordan-Yarmuk river watershed area from the borders of Palestine restricted their economic and social development plans. In retrospect, it also has hampered the Government of Jordan, while providing both Lebanon and Syria with additional surface water supplies which have yet to be utilized [4].

However, the Jewish Agency was able to obtain a concession to implement a detailed plan for "Waterpower and Irrigation Installations in Palestine" as first proposed around the turn of the 20th century by a Swiss Engineer Abraham Bourcart to Theodor Herzl [5]. The plan was updated under the leadership of Pinhas Rutenberg. After overcoming heated opposition in the British House of Lords, the British Crown Agents For The Colonies signed an agreement with Palestine Electric Corporation [6].

Two memoranda (signed by Jamal Husseini as General Secretary of the Executive Committee of the Palestine Arab Congress) indicated the opposition of Palestinian Arabs to infrastructure development projects (the Rutenberg concession, Zionist land purchases, and swamp drainage), the separation of Palestine from Syria, and the League of Nation's endorsement of a Jewish National Home [7]. This opposition to infrastructure built by the Jews was part of a policy established by the first Palestinian Arab Congress held in Jerusalem in

1919. They resolved that "We consider Palestine nothing but part of Arab Syria." [8] The Palestinian leadership generated many memoranda to the British Government protesting against the equal status of Hebrew and English with Arabic as official languages, Jewish immigration, and land purchase. They also organized violent protests which brought them into conflict with both the Jewish self-defense forces and the British army.

Water problems were low in the order of priorities of the Moslem or Christian residents of Palestine, who never formulated an Arab alternative plan for the utilization of the country's water resources or for sewage disposal. Improving the lot of Fellahin, Bedouins, or the urban Arab poor was of concern only to a small minority of Palestinian political leaders [9].

By contrast, the Zionists concentrated on the expansion of Jewish agricultural settlement in areas with access to water. As a result, when the United Nations adopted Resolution 181, partitioning Palestine in 1947 between an Arab and a Jewish state, the upper part of the Jordan River watershed was heavily populated by cooperative farms. These settlements were incorporated within the projected boundaries of the Jewish state, including Lakes Hulah, the Lake of Galilee, the Jezreel Valley, and most of the fertile coastal strip. Many settlements relied on groundwater, by which they established a right-of-usage of this relatively stable, high quality water source fed by wells or springs from the aquifer in the hills on the western bank of the Jordan.

4. THE PERIOD OF SOVEREIGNTY: 1949 TO THE PRESENT

After Israel, Lebanon, Syria, Jordan, and Egypt attained sovereignty over their territory, decisions about water could no longer be made by outsiders in Istanbul, London, Paris, or at United Nations headquarters in New York. The Yarmuk-Jordan watershed was now shared by four sovereign nations. Their officials began to become concerned about future shortages of their sweet water supply due to two irreversible trends: *natural population growth and immigration*. The net reproduction rate in all of these countries increased as health conditions improved in the entire Middle East, especially in Palestine. This change helped to trigger a significant decrease in infant mortality and an increase in life expectancy. For example, Palestinians and Jordanians currently enjoy one of the highest natural population growth rates in the entire world. Israel concentrated a significant part of its resources to encourage and absorb Jewish immigrants under its "Law of Return." The Arab nations bordering Israel, especially Jordan, admitted large number of Palestinian refugees.

The war following Israel's Declaration of Independence was fought by its Arab neighbors in the hope of driving the Jews into the sea or of forcing their evacuation. In the effort to avoid fighting on their own territory, the Israeli Defense forces took risks to push into areas allocated by the United Nations to the Palestinian State. When the mutually exhausted armies agreed to an armistice, Israel was in control of all of the 53 percent of the land which had been allocated to it by the United Nations partition resolution. In addition, Israeli troops had conquered another 12 percent originally allocated to the Palestinian Arab State. Israel's territorial gain was equivalent to an Arab loss.

With sovereignty came the power to control water resources. Israel asserted state ownership of all natural resources under its control, consistent with a legal precedent that had been asserted previously by the Ottomon and British regimes. When the British Government enforced its rights to public ownership or control of the country's water resources, it argued that the position was in line with the *Mejelle* provisions of the Ottoman civil code. The latter was claimed to be consistent with Muslim law. This legislation abolished *de facto* ownership and control by landowners or villages over local wells. It reads:

> The waters of all rivers, streams and springs and all lakes and other natural collections of still water in Palestine shall be vested in the High Commissioner for the time being in trust for the Government of Palestine [10].

The distribution of water between stakeholders in every country tends to be controversial. In Israel, agricultural users enjoy a high priority. In Jordan, this is true of the residents of Amman. Syria is diverting an increasing volume of water from the Yarmuk River for the use of its citizens, reducing the volume available downstream to Jordan and Israel.

Palestinian, Jordanian, and Israeli scholars agree that the people who reside within the Yarmuk-Jordan River live with water shortage. For several years many of the people in the region have had to accept water rationing, especially during the dry season and during drought years. Within a generation, the current volume of available fresh water resources may have to be used entirely for domestic purposes, leaving reclaimed sewage or new water supplies as the source for irrigated agriculture. Lebanon and Syria, however, may have more water than they require for current beneficial uses, at least for the next few decades. Water, like any other natural resource, could in theory be sold to a regional market of Palestinians, Jordanians, and Israelis. The issue that all participants in the Madrid-round of negotiations now face is whether to treat these water resources as a so-called "zero-sum game" or as a means to make all parties much better off.

5. THE ZERO SUM GAME DILEMMA

It would be convenient if some rules could be used to allocate water fairly between the parties, but no single clear cut international standard of water allocation fairness exists. For example, Table 1 lists the diverse factors that the International Law Association associates with equitable water use [11]. For good or ill, the resolution of differences has to be a political process, as it is among all nations which share a common watershed, like Turkey, Iraq, and Syria in the Tigris River Basin.

A conflict orientation makes it hard to negotiate a voluntary and mutually acceptable agreement. Zero-sum game negotiations --"If it is good for them, it is not good for us"-- rarely work in the voluntary settlement of such international disputes. The exceptions involve inconsequential matters, like a damage payment by a state to someone who was victimized by one of its agents.

Table 1
Factors which determine equitable water use

According to the Helsinki Rules, factors include but are not limited to:

- the geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;
- the hydrology of the basin, including in particular the contribution of water by each basin State;
- the climate affecting the basin;
- the past utilization of the waters of the basin, including in particular existing utilization;
- the economic and social needs of each basin State;
- the population dependent on the waters of the basin in each basin State;
- the comparative costs of alternative means of satisfying the economic and social needs of each basin State;
- the availability of other resources;
- the avoidance of unnecessary waste in the utilization of waters of the basin;
- the practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses; and
- the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.

Source: International Law Association, "The Helsinki Rules on the Uses of the Waters of International Rivers," Chapter 2, Article V.

The current Palestinian perspective appears to favor a zero-sum negotiation position. Many Palestinian leaders continue to assert that they are in a permanent state of war, in spite of armistice agreements signed by all Arab governments and the Palestinian Liberation Organization's (PLO) declaration to accept Israel's right to exist. Hisham Zarour and Jad Isaac explain that:

> "Palestinians insist first on setting a credible distribution deed, which would define their national rights in the region's waters, before looking outward for additional supplies. Palestinians find it difficult to understand why they should give what they believe to be their own water to Israel to get Turkish or Egyptian water in return." [12]

Palestinians in the Westbank and Gaza have a lower per-capita water consumption than Israelis. However, unless the total supply of fresh water in the region is increased, equity for the Palestinians can only be met by further and even more drastic reduction of the water available to Israeli consumers, industry, and agriculture. The decision to impose such a sacrifice would be up to the government elected by Israeli voters, not by Palestinians. The Rabin government, which holds its power by the grace of a single-member majority in the Knesset, could probably not impose such a concession, even if it were inclined to do so. The opposition parties claim that Israel is already making too many unilateral concessions to embittered enemies.

Apologists for the current Israeli water distribution pattern make no claim that the *status quo* is equitable. Israelis acknowledge that their farmers buy fresh water at subsidized rates, and no steps have been taken to extend these rates to the Westbank. A few Israelis have reasoned that most Palestinian water users are treated somewhat better by the Israelis than they were when Jordan governed the area, as the Westbank population has been allocated about 20 percent more water for drinking, bathing, laundry, washing cars, and watering gardens. This statistical fact ignores the pertinent reality that the Westbank population increased by 84 percent during the same period. The net effect is that Palestinians live with a much lower per-capita fresh water supply. Palestinians who live in the portion of the Mountain Aquifer that drains toward the Mediterranean are rarely permitted to drill a new or deeper well on land they own and occupy, as they would be tapping into the aquifer which also provides the drinking water supplies for some three million people, including Jerusalem and Tel Aviv. As Professor Hillel Shuval has noted, "This would result in a serious threat to Israel's viability." [13]

The Madrid round of multilateral talks included Jordan, the Palestinians, Israel, Egypt, Turkey, Saudi Arabia, plus many other nations. Syria and Lebanon are not currently participating, although they are negotiating directly with Israel on other territorial and political issues. Israeli negotiators so far have not responded to Palestinian demands for more control over land and water. The Israeli position appears to be that Israel has water rights that pre-date the state and that most prior armistice agreements since 1949 were violated. For example, Arab "Freedom Fighter" factions often have been allowed to fire missiles across the supposedly peaceful borders or to infiltrate into Israel to maim and kill. The record of adherence to agreements freely negotiated between Lebanese factions or between Middle East nations is even worse. The Israeli view appears to be that they first want evidence that an Arab autonomous area can police itself. The Palestinians want independence first. The inter-phasing of concessions is therefore a major issue. The regional deficit of fresh water does not wait for a regional solution. Without more fresh water Israelis, Palestinians, and Jordanians may be forced to reduce agricultural production drastically, as they now do during years of drought.

6. THE WIN-WIN (NON-ZERO SUM GAME) STRATEGY

Should Palestinians be given more control over water resources before or after an agreement to import surplus water from elsewhere? Can Israel afford to withdraw from any occupied territories as a pre-condition for a peace treaty? Should full autonomy or independence be scheduled only after there is evidence over a number of years that Westbank authorities could limit pumping from the common Mountain Aquifer which supplies water to Israelis, including Tel Aviv and Jerusalem? Such questions are likely to be resolved only within the context of a non-zero sum game process. For each side to comply voluntarily each partial agreement must allow all sides to win. Each step can be validated only by demonstrating to each side that it derives concrete benefits.

It is beyond the scope of this paper to discuss the particular negotiating positions of Israelis or Palestinians or to assess the areas of conflict and convergence in those positions. However, in practice it has been possible for Arabs and Israelis to arrive at stable solutions which benefit each side and enhance the stability of all sides - a "non-zero sum game." In at least two cases, the Johnston negotiations and existing unofficial cooperation between Jordan and Israel, such win-win solutions have been acceptable. These historical practices predate the new reality that emerged in Madrid in 1991, where the States in the region ended a forty-three year diplomatic boycott of Israel and welcomed a joint Jordanian-Palestinian delegation. For the first time representatives of all the peoples who live within the Yarmuk-Jordan watershed began to meet in face-to-face sessions.

6.1 The Johnston Negotiations

An example of "non-zero sum game" negotiations was achieved in 1955 over the distribution of the Yarmuk-Jordan River watershed. It involved not only the riparian stakeholders (Jordan, Israel, Syria, and Lebanon) but also included the passive participation of the Arab League, including the Palestinians and Egypt, then led by the charismatic Abdul Nasser. Through patient, multi-sided negotiations as an intermediary, U.S. Ambassador Eric Johnston and his support staff successfully facilitated a *de facto* water-sharing agreement between nations unwilling to let their representatives sit together in the same room. Arab and Israeli technical experts agreed to a number of mutually advantageous gains.

The United States agreed to provide financial assistance to Jordan and Israel to complete water projects vital to their respective economies (the Ghor canal in Jordan and the National Water Carrier in Israel, which diverts water from the Jordan valley to irrigate other regions of the country, including the Negev. In subsequent years financial assistance for water projects was also provided to Jordan by other donor countries. As a result Jordan and Israel were able to construct year-around irrigation facilities which enabled them to expand their agricultural production and export earnings. Jordan also acquired the right to divert 100 million cubic meters through a West Ghor canal to benefit the Palestinians.

Although the Palestinians were not an independent partner in the Johnston negotiation process, each of the Arab negotiators claimed to be concerned with their interest. However, the West Ghor canal was not built between 1955 and 1967, as Jordan had other priorities for development projects. After Israel occupied the Westbank as a result of the Six-Day War, the Jordanian Government asserted an entitlement to the Palestinian water-share because it absorbed Westbank refugees displaced by the war. "They are entitled to take their water quota with them," is the way one senior Jordanian official justified this position [14].

6.2 Jordanian-Israeli "Win-Win" Cooperation

In spite of a formal state of war, Jordan and Israel have unofficially made a number of other mutually advantageous agreements in which both parties have come to trust. Each day, Jordanian and Israeli officials exchange newspapers at the Allenby bridge. The delivery of the *Jerusalem Post* and Hebrew daily newspapers, to be read in the Jordanian Royal Palace and at the Foreign Office, diminish no Hashemite power. Israel gets in return the *Jordan Times* and Arabic papers to be analyzed by their military intelligence and diplomatic services. Although there is no trade and almost no visiting between Syria and Israel, heavy traffic of trucks and people cross between Jordan and Israel over the Allenby and Damia bridges. Both nations derive economic gain from this unofficial trade and tourism exchange.

Jordan and Israel also coordinate their respective rights to the Gulf of Aquaba (Elath). Both have airports in Wadi Araba, whose controllers respect their respective flight arrivals and departures. Both operate a port in very close proximity of each other. For example, when a horse escaped from the Royal Jordanian stables, Israelis fed the animal and returned it.

Despite these positive auguries, the political gulf between Arabs and Israelis cannot be underestimated. For example, until quite recently the Arab League insisted that Israel is an illegal state. The Palestinian leader Ahmad Shukeiry, who represented Saudi Arabia during two "Law of the Sea" international conferences held in 1958 and 1960, asserted the following legal position with respect to Israel rights of access to the Gulf of Aquaba:

> "We have made no mention of Israel as a bordering state on the Gulf of Aquaba, not of political reason. Neither was it a mere forgetful omission. It is with full purpose, and the reason is one of law and not of politics. . . . the States in the region do not recognize Israel, be it the existence, territory or the boundary, if any. Second, Israel's foothold on the Aquaba Gulf, apart from its illegal origin, is based on Armistice Agreement which by their character and express provisions vest no sovereignty whatsoever . . ." [15]

This position was somewhat modified by the Arab League of States in 1991 when most of its members agreed to take part in the U.S.-Russian sponsored Madrid conference, thus involving them in direct negotiations with Israel on all outstanding issues.

7. CONCLUSIONS

There are seven favorable conditions that exist today and have not existed before (see Table 2). For the first time in the Middle East most representatives negotiating to influence the future have close ties to people affected by decisions. The Israeli and Jordanian delegations represent governments responsible to democratically-elected parliaments. To a lesser extent this is also true of the Palestinian delegation which includes persons associated with a variety of factions within their national movement. It includes a water program specialist, Dr. Riyad H. El Khoudery, who works with a team of professionally trained colleagues. The Israelis clear their positions with the government of Jerusalem. The Palestinians go to Tunis for their instructions from the Palestine Liberation Organization [16].

No party at the multilateral meetings is adjusting his or her remarks to conform to preferences transmitted from Washington, Moscow, or the United Nations. Even when negotiations take place in Washington, Vienna, Madrid, or Tokyo, the power to impose peace has moved to the Middle East. Nations such as Egypt, Turkey, the U.S., and U.S.S.R. that once dominated regional decisions now participate in negotiations as observers. They can exert influence to speed implementation of an agreement made by the parties by offering development loans or grants or make off-the-record suggestions to the negotiating parties on how to bridge differences. Both Western and East European diplomats have been careful to avoid being viewed as final arbitrators. For the time being, at least, they assert the positions that Israelis and Palestinians must make peace with each other, not by proxy with the Americans or the French.

Table 2
Favorable conditions for water negotiations

1.	The definition of the affected parties.
2.	The perceived roles of the affected parties.
3.	The perceived role of outside powers.
4.	The multilateral reality of water resource investments.
5.	The relevance of water conservation technology.
6.	Changes in the economies of the parties.
7.	Existence of underutilized water within the region.

Palestinians, Jordanian, and Israeli experts are agreed that within a decade or less the entire available fresh water supply will be needed to provide a minimum quota for domestic use by the rapidly growing population of Israelis, Palestinians, and Jordanians. Agriculture may have to be restricted almost entirely to the use of reclaimed sewage, excess flood water temporarily available after heavy winter rains, or new sources of water. None of these water-short stakeholders can build the economy without either generating new sources of water (purchasing from water-surplus neighbors, desalinating brackish or sea water, or other infrastructure improvements) or shifting water use among users.

Many pertinent and feasible projects must be constructed jointly. The Yarmuk River constitutes the border between Syria and Jordan for much of its length. The Jordan River constitutes the border of Jordan and Israel for its lower portion. Flood control measures in the Wadi Araba also will involve Jordan-Israeli cooperation. Storage dams in the hills west of the Jordan that can reduce erosion and flooding will require joint Palestinian and Israeli action. The same need for cooperative action applies to sewage treatment and water re-use.

The historical pessimism of British colonial social-economic planners has been overtaken by improvements in water resources technology. [Could the British Colonial Service imagine that Jordan would use airplanes to ship fresh vegetables to British markets or that Israel would compete today with Great Britain in the manufacture of computers, medical instruments, or pharmaceuticals!] Drip irrigation, sewage recycling, cloud seeding, flood catchment dams, and saline water use for special crops are illustrative of established off-the-shelf technology improvements. They are sufficiently well developed that they can increase the volume of available usable water for irrigation. Additional water supplies can be made available by conservation and changes in economic structure. Repairing leaky pipe and canal delivery systems, water-use monitoring, and increasing-block pricing can lead to increased yields with reduced water consumption. Change in national economies, such as the shift from agriculture to industrial production, human services, or tourism, may further reduce water consumption.

Water, unlike oil, has not been viewed in the past as a source of income by Middle East nations. Many millions could be earned for a resource now allowed to run off into the oceans. Syria, Lebanon, Turkey, and Egypt have a permanent or an occasional surplus of water. They and their neighbors could invest in pipelines or tankers to export fresh water for profit.

It is unclear whether the peoples within the Basin will seize upon these trends to find a "win-win" solution. There is a supportive international environment, including external financial assistance to support unilateral water resource investment by each party. Israel has agreed to an increasing degree of PLO public involvement in controlling the actions of the Palestinian negotiators. Israel also agreed to halt the construction or expansion of new settlements in Westbank-Gaza area, except of those in the greater Jerusalem area or with security maintenance functions. The United States and Western Europe have rewarded these Israeli concessions by contributing toward a 10 billion dollar plus program of loan guarantees to strengthen Israel's economic capacity to integrate its flood of immigrants. On the other hand it is not clear whether the Palestinians are willing to make parallel concessions without the prior assurance of an independent Palestinian state. There has been no cessation of the Arab boycott or a suspension of the *Intefadeh*.

The road to a comprehensive Middle East appears to be open; agreements on water problems are feasible. Real progress will occur when each of the parties can adopt "Win-Win" non-zero sum game strategies. This may occur if each side believes that any agreement is better than no agreement; has political leaders who have the stature and stability to delivery an agreement; and is willing to express a general sense of agreement before detailed give-and-take through negotiations.

No voluntary agreement is likely as long as negotiators for the Palestinians and Jordanians believe that their shortages can be resolved only by increasing Israel's already excessive water deficit. A stable negotiated settlement will assure that the requirements of each stakeholder be met by coordinated unilateral (as opposed to regional) infrastructural improvements that can either increase total water supplies and/or reduce water demands. The cost of obtaining new water will have to be shared on an ability to pay basis, even if incentives are provided by external parties. These expenditures, however, will come with a peace dividend that for the first time in eight centuries will allow all parties to beat swords into plows.

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THE RELEVANCE OF JOHNSTON PLAN TO THE REALITY OF 1993 AND BEYOND

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ABSTRACT

Out of sixteen plans proposed for the utilization of the Jordan-Yarmuk sources, the Johnson plan (1955) is considered as the defacto accepted for the division of the water. The article analyses the relevance of this plan to the reality of the 90s.

Thirty six years have passed since the Johnson plan was proposed, and many changes have taken place in the countries of the Jordan basin since then. Water needs only become worse, and therefore all the countries cannot compromise in one direction or another on the little water. The only solution lies in water desalination.

1. INTRODUCTION

The Jordan river and its tributary, the Yarmuk, is one of the most volatile international rivers in the World. It combined hydrological and political structure make a peaceful solution very difficult. Sixteen plans were proposed for the utilization of the Jordan-Yarmuk sources, seven plans before the late 40's when Israel and Jordan became independent states and nine plans afterwards. Out of the sixteen plans, the Johnston plan (1955) is considered as the defacto accepted formula for the division of the Jordan-Yarmuk water.

This article analyses the relevance of Johnston plan to the reality of the 90s.

2. THE JORDAN-YARMUK BASIN - HYDROLOGY AND DISCHARGE

The sources of the Jordan, the Dan, the Hasbani and the Banias provides approximately 500 m/m^3 of water. The upper Jordan, including some additional springs and wadis along the rift Valley as well as rains, less evaporation, contributes an average of 500/600 m/m^3 annually to the sea of Galilee (Table 1).

Table 1
Average discharge from the Jordan river (before 1932)

Northern Basin	Average Discharge (m/m^3)	Southern Basin	Average Discharge (m/m^3)
Hasbani	130-150	Yarmuk	475
Dan	250	Eastern Rim	200-220
Banias	110-120	Western Rim	45-55
Western Rim	20		
Eastern Rim	30		
Hula Valley, Sea of Galilee Basin (rain, springs)	300-350	Less evaporation	20
	----------------		----------------
Less evaporation (from Sea of Galilee)	300	Total Southern Basin	700-730
	----------------		----------------
Total Northern Basin	540-620	Total Jordan Discharge	1240-1350

Sources: Khouri, 1981; Gilad, 1988; National Atlas of Jordan, 1984, 1986; Salik, 1988; Soffer, Kliot, 1988.

The Southern drainage basin of the Jordan river includes the Yarmuk and all the tributaries which flow into the Jordan in its eastern and western parts, south of the Sea of Galilee. The average annual discharge from the Southern drainage contributes an average of 700 m/m^3 annually to the system (Table 1). In conclusion, approximately 1300 m/m^3 of water flows into the Dead Sea before the riparian countries use its water (see map 1).

3. RIPARIAN SHARES IN THE JORDAN DISCHARGE

The contribution of the riparian countries to the Jordan discharge is shown in Table 2. The table differentiate between the riparian shares at the present time to their shares before the six days war (1967).

Table 2
Riparian shares of the Jordan discharge

Tribary	Israel	Lebanon	Jordan	Syria
Hasbani	45	85-105		45*
Dan	250			
Banias	110-120			110-120*
Western Rim	20			
Eastern Rim	30			30*
Valley and Lake (less evaporation)	0-50			
Yarmuk			100	375
Eastern Rim (South Yarmuk)			200-220	
Western Rim (South Sea of Galilee)	45-55		40*	
Total (1992)				
1350 m/m^3	570	85-105	300-320	375
%	42.2	6.3	24	27.5
Total (1966)				
1350 m/m^3	335	85-105	340-360	560-570
%	25	6.3	26.5	42.2

*Pre-1967.
Sources: Gilad, 1988; Salik, 1988; Soffer, 1992; Soffer, Kliot, 1988.

4. THE JOHNSTON PLAN AND ITS HISTORICAL BACKGROUND

The establishment of the State of Israel and the aftershocks in the region, in particular the awakening of the question of the Palestinian refugees, led to a number of urgent proposals for exploiting the waters of the Jordan River.

Arab plans left Israel in the cold, Israeli plans gave preference to the new state, while a number of international plans sought a way for regional cooperation and a reasonable division of the waters, taking into account the needs of all the states partner to these waters. (For more detail, see Soffer, 1992, pp. 141-144.)

The United States felt embarrassed at its inability to advance its plans in the region, one in which there was a multiplicity of armed incidents, during 1953, particularly in the Jordan basin.

Upon Eisenhower's election, therefore, the U.S. President appointed Eric Johnston as his personal emissary, with the rank of roving ambassador, to seek a solution to the waters of the Jordan. The appointment was made on 16 October 1953.

His first visit to the region was of two weeks duration (21 October-5 November 1953), during which he met with representatives of all the states of the Jordan basin and also with a representative of Egypt. The various proposals that were presented to him at this time are found in Table 3. This table also shows his initial suggestion for dividing the waters. The considerations that guided Johnston in this division included, among others, the desire to aid in finding a solution for the Palestinian refugees who were living in the Jordan Valley, on both sides of the River; the water needs of Jordan and Israel, in each case taking into consideration the potential land available for irrigation; Syria's effective exploitation of the waters of the Yarmuk and Jordan Rivers; and the assumption that Lebanon was not in need of Jordan River water. The Israeli Cotton plan stressed the need for integrating the Litani River in any plan, and for a long time Israel stood firm on this position, which was utterly rejected by both the Arab states and Johnston himself (Nimrod, 1966, p.48, p.57).

Table 3 also shows the different values of the total water supply of the Jordan. The data range from 1.2 billion to 1.4 billion cubic meters annually.

Table 3
Plans presented to Johnson for exploiting Jordan river waters

	Arab plan (March 1954)	UN Plan (Main-Clapp 1953)	Israeli Plan (Cotton)*	First Johnston Plan
Syria	132	45	30	50
Lebanon	35	-	450.7	-
Jordan	1047	774	575	829
Total Arab States	1214	819	1055.7	879
Israel	182	394	1290	426
Total	1396	1213	*2345.7	1307

* including the Litani River
Source: Doherty, 1965, p.27.

Johnston's second visit to the area took place in June 1954. In the course of this visit, the Arab states agreed to an expanded development plan for the Jordan basin under an international authority that would supervise the division of the waters. The Israeli reaction was cool, from fear that control of the Kinneret (Sea of Galilee) would devolve to a foreign international authority (Rabinowitz, 1983, p. 864).

Johnston's third visit was made in January-February 1955, during which time the Arab states showed flexibility in all aspects of the division of water and Israel gave up its idea of including the Litani in any plan (Nimrod, 1966, p. 57).

In the period between Johnston's third and fourth visits to the region, he hosted Israeli experts, and together they made progress on his revised proposal (Table 4).

Table 4
The Johnston plan (1955) - co-riparian shares

Country	Share (m/m^3)	%
Lebanon	35	3
Jordan	720	56
(Jordan River	100)	
(Yarmuk River	377)	
(Western and Eastern Rim	243)	
Syria	132	10
(Yarmuk River	90)	
(Jordan River near Sea of Galilee	22)	
(Banias	20)	
Israel	400	31
(Jordan River	*375)	
(Yarmuk River	25)	
Total Jordan-Yarmuk	1287	100

Sources: Saliba, 1968; Doherty K.B., 1965; Nimrod, Y. 1966.

Notes: *In 1956, Israel presented to Johnston a masterplan for its exploitation of up to 450 million cubic meters per year of the waters of the Jordan. Johnston approved this plan, and the amount mentioned in 1958 and stated that the Israeli plan was in accord with that proposed by him (Nimrod, 1966, p.61).

In addition to the division of the waters, it was also decided that the Sea of Galilee would serve as the main reservoir for those waters of the Yarmuk and the Jordan not impounded in the Kingdom. Also, that every state would be able to use its water as it saw fit (a hint of the possibility of transferring water from the Jordan to another basin--such as the Negev, as Israeli demanded) (Nimrod 1966, pp.62-66).

From an engineering viewpoint, Johnston detailed several topics: a dam would be constructed on the upper Yarmuk (at Maqaren) and a connecting canal built between the Sea of Galilee and the 'Ghor Canal', through which Israel would transfer 100 million cubic meters of the Jordan waters. One version claims that this would be composed of 85 million cubic meters of sweet water and 15 million of salt water; a second version, 48 million cubic meters of sweet water and 52 million of salt water (Soffer, 1992, p. 145). There was also talk of a siphon for transferring the water of the eastern 'Ghor Canal' to the western section.

His fourth and last visit took place between August and October 1955, with the intention of concluding the details of the plan; but he encountered sharply opposing positions among the Arab states themselves, which in the end rejected his plan (at a meeting in Damascus in August). Among other reasons, the charge was made that ratification of the plan was eagerly sought as recognition of the Palestinian refugees remaining in their present place of residence (Nimrod, 1966, p. 64). A few days afterwards, the Arab states changed their mind and informed Johnston that they were continuing to review the plan. With that, the plan as a whole came to an end, since other events of very great geopolitical significance began to take place in the region, such as America's refusal to aid in the construction of the Aswan Dam and the Sinai Campaign.

Nevertheless, it must be emphasized that Johnston stated upon his return to the United States: "The states of the region (Israel, Lebanon, Syria, and Jordan) are now sold on the Jordan basin plan as the single rational, possible approach to the problem of developing the river" (Daily News Bulletin, Vol. 7, No. 197, 19 October 1957).

In the end, the Johnston Plan gained de facto recognition from the U.S. Administration, which initiated it, and from Israel, which saw it as a basis for the division of the Jordan waters and a green light to start with the 'Jordan-Negev Carrier' (National Water Carrier). Syria and Lebanon, on the other hand, never saw themselves committed to the plan (Golan, 1983, p. 855; Rabinowitz, 1966, p. 864). Jordan indirectly adopted the plan when it received American aid for implementing the 'Ghor Plan'.

The question is, Is this really the single rational, possible plan?

5. CHANGES IN THE JORDAN BASIN SINCE THE JOHNSTON PLAN

Since the presentation of the Johnston Plan toward the end of 1955, every state in the Jordan basin has begun developing its own resources. Israel completed its National Water Carrier project, which brings water from the Sea of Galilee to the South and Central regions of the country. Israel has also carried out a series of projects in the Sea of Galilee basin, among others the irrigation of the eastern lower Galilee, the conveyance of water to the Beit Shean valley, and the impounding of water on the Golan Heights (Sofer, 1992). In addition, Israel has since 1967 been working areas in the Jordan Valley south of the Beit Shean valley (settlements of the Alon Plan).

In recent years, the Kingdom of Jordan completed the eastern part of the 'Ghor Plan and put up dams on part of the eastern tributaries of the Jordan south of the Yarmuk. In all, the Kingdom uses some 250 million cubic meters of Jordan River water (Soffer, 1992, p. 156-8). The State of Israel and the Kingdom of Jordan both benefit from American aid in these projects.

Between 1964 and 1966, the Arab states tried to carry out a diversion of the sources of the Jordan in order to prevent its flow to Israel. These attempts failed after a series of armed incidents along the Syrian-Israel border (Golan, 1983).

Israel's victory in the Six Day War of 1967 completely changed the hydropolitics of the Jordan basin. The tributaries and springs of the Jordan all fell under Israeli control. Israel's share of the Yarmuk alignment grew as did its share of the route of the Jordan River from south of the Beit Shean valley to the Dead Sea. This advantage has been exploited, and the use of water from the Jordan river in Israel increased, amounting to 550-600 million cubic meters annually, in contrast to the Johnston Plan's allotment of 400-450 million (Soffer, 1992).

One of the reasons given for the increased use of water by Israel is the fact that it now rules over the areas of Judea and Samaria, and the waters intended in the Johnston Plan for this section now belong to Israel.

The Syrians in the past two decades have begun an independent project for capturing the overflow waters of the Yarmuk in its territory (see Map 2). The plan includes the building of 25 dams on the Yarmuk tributaries with a collection capacity totaling 200-250 million cubic meters. In 1992, this capacity came to 153 million cubic meters (Soffer, 1992, p. 153-6). In such a situation, the Kingdom of Jordan will be left with 225 million cubic meters of the Yarmuk of the 377 million that had been promised according to the Johnston Plan. (Table 5) A more detailed analysis of the plan for the El-Wahda dam shows that the Kingdom will be left with but 120-160 million cubic meters of this water (Soffer, 1992, p. 147-150).

The Kingdom of Jordan fears that the Syrian project will leave it without any water at all, and therefore Jordan was quick to sign an agreement with Syria for the construction of the El-Wahda dam (on the site of the Maqaren Dam). Construction has been delayed, meanwhile, because -- among other reasons--of Israel's refusal to permit the dam from going up so long as Israeli interests in the Yarmuk basin are not assured, something that Syria firmly refuses to do (Soffer, 1992). Another change in the Israel-Jordan-Syria border meeting point took place in the 1980s, when Israel received permission to transfer surplus Yarmuk water to the Sea of Galilee during the winter flood season, so long as Jordan could not make use of these waters. (Table 5)

Table 5
The Jordan River - Johnston Plan and Present Use (90's)

Country		According to Johnston Plan	Present Use
Lebanon		35	1-5 app.
Jordan	Jordan River	100	10 app.
	Yarmuk	377	120-130 app.
Western and Eastern Rim		243	125-150
Syria	Yarmuk R.	90	153
	Jordan R. and Banias	42	-
Israel	Jordan R.	375-(450)	650*
	Yarmuk	25	25-50
	Total Use		1063 app.
	To the Dead Sea		152-203
	Total discharge	1287	1287-1350

*Including water for the West Bank
Sources: Table 4 and Soffer 1992.

6. WHY HAS THE JOHNSTON PLAN RETURNED TO THE HEADLINES?

In 1992, the peace talks began between Israel and its neighbors and, among other subjects, separate discussions are being held on the issue of water, with the United States navigating these talks as the world's only superpower. It may be assumed that for the U.S.A., the Johnston Plan is the only existing one and that in it are to be found the principles for dividing the water jointly among the countries concerned.

The Kingdom of Jordan views this plan as its only hope for forcing Israel and Syria to allot it more water than it has and than it receives from the two of them today (Haddadin, 1992, p.15).

7. IS THE JOHNSTON PLAN RELEVANT IN 1992?

First, there have been political changes in the region, and in addition to the four states--(Israel, Syria, Lebanon, and Jordan)--there will be need to allot water, too, to the residents of Judea and Samaria (and the Gaza Strip) as independent entities, separate from Jordan (and Egypt). In other words, the division will have to relate not only to the Jordan basin, it will also have to subsume in it the other parts of the Land of Israel and its population. In such a case, water that was allotted to Jordan will have to be deducted in favor of the Palestinians in Judea and Samaria. Estimates of the quantity that will be transferred to these territories range from 150 million to 220 million cubic meters annually (Al Qasem, 1992 p.2; Soffer, 1992, p.179).

The Palestinians are insistent in their demand to benefit from the Jordan waters as well as from all the aquifiers of the West Bank mountain. Any attempt to respond positively to their demands will harm both Israel and the Kingdom of Jordan in the present situation.

Second, the Johnston Plan took into consideration basic population and agricultural land data of the early 1950s. The current picture is completely different.

Third, among other things, one must consider today the possibility of desalination, something that was not at all on the agenda in the 1950's.

Fourth, at present the waters of the Jordan basin are being exploited to their fullest. Even according to the minimalist forecasts to the year 2000, the states of the basin will be short hundreds of millions of cubic meters of water a year.

Fifth, more practicably, the Syrian plan in the upper Yarmuk basin completely changed the allotment percentage for Syria, and no one can suppose that the clock can be turned back and that this project will be reduced or cancelled altogether.

Furthermore, the forecast of population growth in Syria is not encouraging, and a shortage of drinking water in the Damascus basin and southward may already be expected this decade.

In Israel, the situation is similar to that of Syria because of population growth, the salting of the soil, and the need to supply food for the growing urban population.

Seventh, there is the Kingdom of Jordan, which receives much less water than guaranteed it. If Israel were to transfer to it from the Sea of Galilee the water in the Johnston Plan, of 100 million cubic meters, this still would not solve the Kingdom's present or future problems. Jordan needed in 1992 some 700 million cubic meters of water, which in effect is the quantity promised the Kingdom by the Johnston Plan; by the year 2000, it will need 1.120 billion cubic meters of water (Jordan Times, 7.2.1991), or 300-400 million cubic meters more than it requires today. No reorganization of the division of the Jordan waters, whether according to the Johnston Plan or any other method, will aid the country, given the existing water in the basin.

For all of the aforementioned reasons, it appears that the Johnston Plan is no longer relevant to the present water situation, not to speak of the future situation, of this region.

8. SUMMARY AND CONCLUSIONS

The total water needs that are of immediate necessity in the Jordan basin are far greater than is the total discharge of the Jordan.

The Kingdom of Jordan is lacking 200-300 million cubic meters today and will be short double this quantity in the coming decade.

In Israel, there is talk of adjusting consumption to existing supply while increasing the use of recycled water and realloting water from agriculture to household use. Such a situation cannot continue much longer (State Comptroller, 1990).

In Syria, the shortage grows worse, and there is the chance that Syria will increase its exploitation of the water of the upper Yarmuk for southern Syria and perhaps even Damascus (involving additional quantities of 120-125 million cubic meters) (Soffer, 1992. p.149).

In Judea and Samaria, some 150 million cubic meters are being used, and there will be need to transfer at least another 200 million cubic meters for the needs of the population by the end of the decade.

In the Gaza Strip, the situation is particularly serious, and there is need for at least another 200 million cubic meters of water within the present decade.

In all, the states of the Jordan basin will in the coming decade have need for an additional one billion cubic meters of waters from the Jordan River.

In the light of this reality, use of the present waters by the states of the region must be viewed as a given and additional sources of water must be sought.

The possibilities that have been raised by various parties--governmental, academic, economic--over the past five years are, for the most part unrealistic (Soffer, 1992, pp.212-225). Thus, there has been talk of a Turkish peace pipeline, which seems impractical; transfer of water from the Euphrates to the Jordan, but it may not be assumed that the Iraqis will be left with surplus water for this purpose when there is a fear that Turkey will permit little water of the Euphrates for the needs of Syria and Iraq. One may also not assume that the water of the Nile can be conveyed to Sinai, the Gaza Strip, and Judea and Samaria, since the Egyptians are thirsty for water in their present economic and social condition.

Transfer of the Litani to the Jordan basin is not realistic for both economic and political reasons. The possibility has also been raised of importing water in tankers, just as oil is imported. At the present stage, this idea, too, is impractical (Soffer, 1992).

The only solution that appears reasonable technologically, economically, and politically is that of desalination plants in the Jordan basin. A desalination facility having a capacity of 200-250 million cubic meters a year on the Israeli coastal plain would answer Israel's needs for the coming decade. A second such plant of the same capacity inside the Gaza Strip would solve the shortage of water there beyond the year 2000.

In order to enable the Jordanians and the residents of Judea and Samaria to benefit from their desalinated water, there would be need to transfer Mediterranean water to reservoirs in their territories. This recommendation was made by S. Gur. Transference of sea water to reservoirs in the Jordan Valley in the area of Beit Shean, and if needs be also further south, would enable the Jordanians to desalinate on the eastern side and the residents of Judea/Samaria on the western side. In order to assure a continuous flow of water, there is room for international supervision, which would also remove the fear of Israeli blackmail (Gur, 1992, pp.1-15).

Financing of four such facilities must come from international financial sources or from the economic superpowers. (A desalination plant for 100,000 people is equal to the cost of a Mig 29, and a facility with a capacity of 250 million cubic meters is equal to the cost of one day's modern warfare; i.e., one billion dollars.)

Theoretically other alternatives to the above solution may be proposed, such as use of the Sea of Galilee for the needs of Jordan, Judea/Samaria, and even Syria, while Israel would receive as compensation many more desalination plants on its coastal plain. This idea would certainly reduce setting-up costs and save on building canals, reservoirs, and the lifting of Sea of Galilee water to the Negev. But the idea would severely impinge on Israeli sovereignty and threaten national security, and so must be rejected out of hand.

Thirty-six years have passed since the Johnston Plan was proposed, and many changes have taken place in the countries of the Jordan basin since then--geopolitical, hydropolitical, demographic, economic, and technological changes.

Water needs only become worse, and therefore all the countries of the region are in need of more water and cannot compromise one way or another on the little water supplied by the Jordan River and its tributaries. The ecological damage that over use of the Jordan waters have caused obligate radical correction. All this cannot be carried out by a redivision according to the Johnston Plan, but by bringing additional water to the basin. The only solution lies in water desalination.

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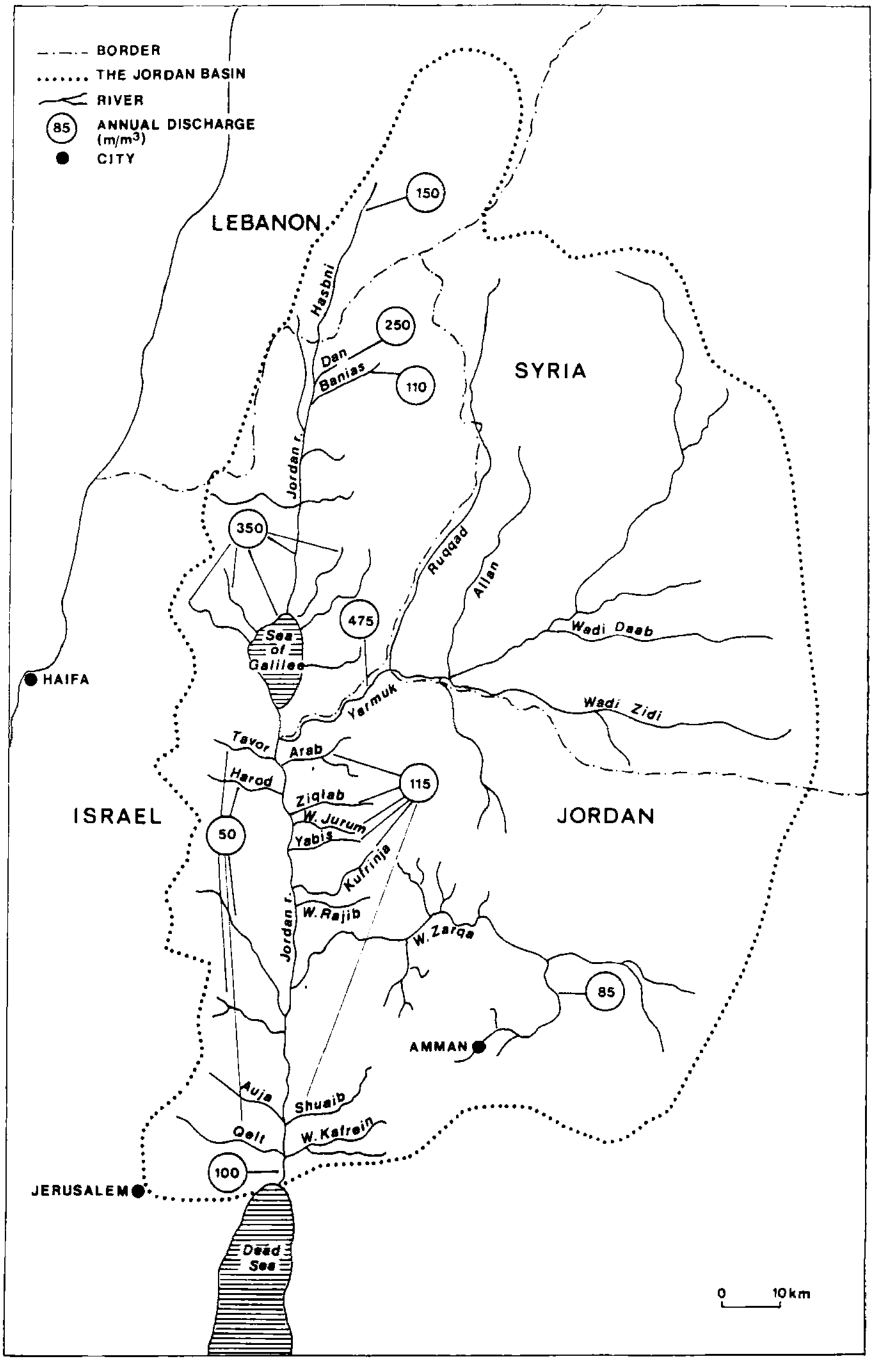
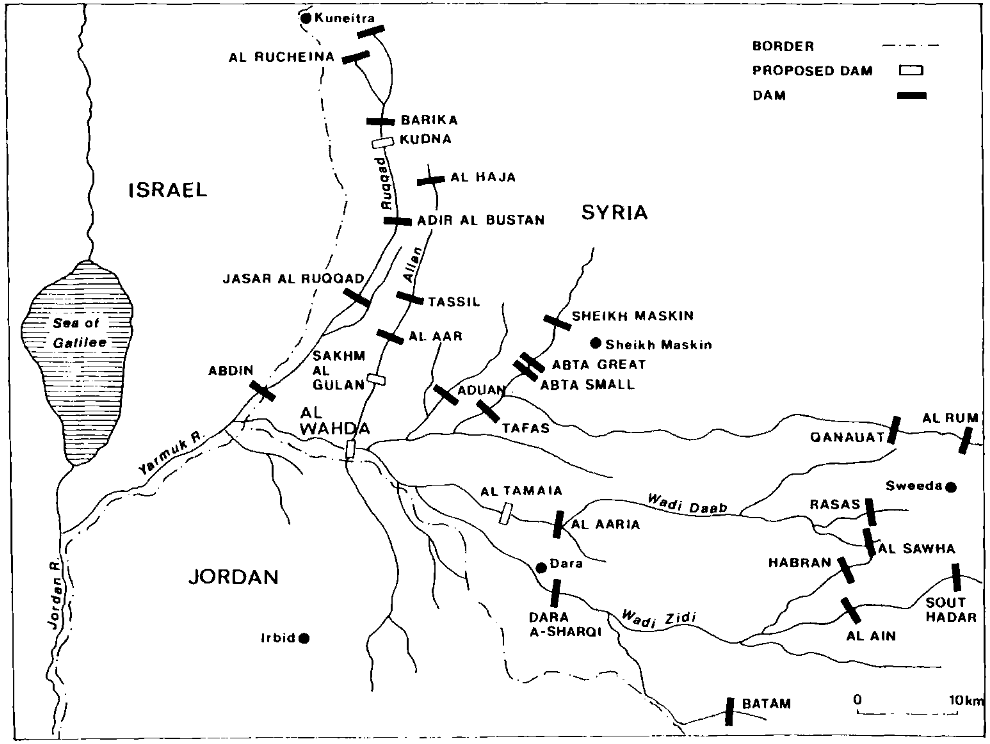
Map 1: The Jordan River Basin



Map 2: Syrian Water Projects on the Yarmuk River



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The Arab - Israeli Conflict Over Water Resources

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Abstract
The particular focus of this paper is on those countries which border Israel- Lebanon, Syria, Jordan and Palestine. The main source of the water supply is from the rainwater and consequent surface and groundwater of these countries. This has created the two-fold conflict about land and water. Water is scarce in these countries and has been of paramount importance in the past and will be in the future . This is especially the case with respect of water security and water as an essential resource for food production. Water is the major concern for the very survival of these nations. This paper draws attention to the problems concerning the waters of the rivers Jordan, Yarmouk and Litani, with their tributaries, as well as the underground water of the West Bank and the Gaza Strip, as a means of seeking a just and peaceful settlement of this regional water conflict.

INTRODUCTION

Conflict over water resources is an age-old question which leads to war and colonization. Although Competition over water- resources is a world-wide phenomenon, it is especially true of the Middle East, and no where so dramatically than about Israel-Palestine, and between Israel and adjacent Arab States. The struggle for the possession of land and water is the two fold aspect of the Arab-Israeli Conflict.

Water is such precious commodity for the Arabs (Jordanians, Palestinians, Syrians and Lebanese) as well as for Israel. It is and integral part of the life and survival of these nations. The fact that the climate tends to be moderate and dry with fluctuating average rainfall makes agriculture vulnerable which necessiates seeking to other means of irrigation such as rivers. This cause ever increasing demands for river water in the region.

Taking into account the natural population growth, the rising standards of living and the expanding influx of new Jewish immigrants to Israel from diaspora, as for example Jews from the former Soviet Union, water has become more sensitive issue, a condition which forced Israel to exhaust Arab river waters at the expense of the neighboring Arab nations, thus making the region tense, dangerous and volatile.

CONFLICT OVER RIVER WATERS

This conflict began with the rise of early Zionism and its intentions to take Arab river waters, the Jordan, the Yarmouk and Litani, all of which either start or flow through Arab-Israeli borders. Arab, Israeli and American projects have been tried to allocate these water supplies.

THE JORDAN RIVER

The Jordan River rises in the east part of the upper Galilee,the Hermon slopes and the Golan heights. The main tributaries of this river (also considered as its sources) are Hasbani, Dan and Banias. The average annual quantity of water resulting from the meeting of the three tributaries is 500 million cubic metres, half of which (about 240 million cubic metres) is supplied by Dan, and the rest (about 260 million cubic metres) by Banias and Hasbani. Through the Jordan River's course in the Hula Plain till it empties into the See of Galilee, an additional 300 million cubic metres of water reaches the Sea of Galilee. Therefore, it receives an average about 800 million cubic metres from the Jordan River. This water is used for drinking, irrigation and other purposes. The Israeli settlements north of the Galilee Sea draw off the water that they need directly from the Jordan River before such water reaches the Sea of Galilee.

In addition, the Jordan River receives another quantity of water from the Yarmouk River and the other valleys east and west of it. Thus, the total quantity of water which runs in the Jordan River (starting at its sources and ending at the Dead Sea where it last empties) amounts to 1.25 billion cubic metres of water annually.

The distance from the source of the River Jordan to where it emplies into the Dead Sea is 105 km. Meandering gives total length for the river of 500 km.

THE CONFLICT OVER THE JORDAN RIVER WATER

Since the Zionist movement started to plan for settling in Palestine in the 19th century, it has shown utmost interest in water. This isuue passed through three stages:

1) 1918-1948

Soon after the First World War in 1918 , and following Balfour's Promise of the national home for the Jews in Palestine, the Zionist Movement demanded that the allied countries alter some of the borders mentioned in Sykes-Picot accord, so that Hermon Mount (which is the main source of water for Palestine) would be included as part of Palestine. The Jews then sought to extend their borders by annexing the Litani River and the water springs in the Hermon Mount (i.e Horan Plain and the Golan) so that such areas would be included within Palestine. (Abu-Arafa 1981)

Raising this issue in his letter to the British Foreign Office following the San-Remo accord, Weissman said, "The accord draft France proposed not only separates Palestine from the Litani River, but also deprives Palestine from the Jordan River sources, the east coast of the Sea of Galilee and all the Yarmouk valley north of the Sykes-Pico line. I am quite sure you are fully aware of the expected bad future the Jewish national home would face when that proposal is carried out. You also know the great importance of the Litani River, Jordan River with its tributaries, and the Yarmouk River for Palestine".

In 1944, the American engineer LowderMilk wrote a book entitled, "Palestine, land of Promise". It included a water scheme for the Jordan valley based on the following proposals: A) Seizing the Jordan River water (including the tributaries in Dan and Banias rivers in Syria and the Hasbani River in Lebanon);

B) Draining the Hula Lake and digging wide canals in which the water of the Jordan River flows so that it could be used to irrigate the land in the Beit-Shean area and then be carried to southern Palestine to irrigate the Negev desert.

C) Seizing the Litani River in Lebanon and tranferring its water into an artificial lake in Palestine (to be made in the plain of Al-Batouf north of Nazareth), from which the water could be carried to the Negev.

The Jews welcomed LowderMilk's plan and considered it as " their water constitution" though many other studies had been made concerning water in Palestine, as Ionides report in 1939, Hayes report in the same year, the Klab study in 1949, and McDonald's in 1950.

2) 1948-1967

The Zionist Movement tried hard to overrule the Northern parts of Palestine through the Partition plan of 1948. Some studies and schemes concerning water schemes followed in succession like Banger's, Johnston's, Baker-Herza's, the Arab scheme, and finally the most significant one referred to as Kontone's Israeli scheme.

The Israelis indirectly rejected the Arab and American schemes because they were looking forward to obtaining the utmost benefit from the water resources, disregarding the neighbouring countries interests and rights.

3) 1968-1992

After 1967, Israel occupied the water resources in Golan heights, south Lebanon and part of the Yarmouk cource, violating henceforth Johnstons Project and its share from the Jordan and Yarmouk water. The conflict has then strongly ascalated after 1967 as a result of extensive use of these waters neglecting the Arab interests.

In 1954, the Israeli Agriculture Minister proposed his scheme (known as Kotonoe's Israeli Scheme for Irrigation) to the Prime Minister. This project was expected to irrigate 2,598,000 dunums of land; 1,790,000 dunums of which were in Israel and irrigated by 1,290 cubic meters of water annually from the Litani and the Jordan water areas. The cost of that project was estimated to be about 597.5 million dollars.

Some of the main goals of this project were:

1) Transferring the Jordan springs to the north of Israel where the water would be stored in the Al-Batouf plain;

2) Transferring the water of the Yarmouk River to the Galilee Sea, which would be used as a reservoir to supply the lower Jordan valley with water;

3) Transferring more than half of the Litani water to Israel to be stored at the Al-Batouf plain reservoir to irrigate southern Israel;

4) Constructing 17 generating stations which could produce 226,500 kilowatts of electricity.

Following Johnston's scheme, which the Arabs rejected, and during the well known water crisis of 1964 , the Israelis proposed a new plan. This scheme of the American engineer

Huzes Tosh, aimed to make use of the Jordan River water and other water resources and called for the transfer of the Litani River water to Palestine. Accordingly, what was left for Lebanon was just 1/8th of the quantity of water of that river.

It was quite clear that the Negev desert reclamation could not be achieved without the water of the Jordan River and the Litani. Indeed Ben Gurion once asserted that "Jews and the Arabs battle over water and the consequences of the battle will determine the future of Palestine". (Middle Eastern Affairs, 1955).

THE YARMOUK RIVER

The Yarmouk is 42 km. long, rising in Syria (80% of its source lies there) and flows south westerly, to form part of the joint Syrian-Jordanian-Palestinian borders. It empties into the Jordan River to the south of the Sea of Galilee. In fact, Johnston's water scheme for Jordan, Syria and Israel included utilizing the Yarmouk River water. However, after occupying the Golan Heights, Israel enforced its authority on this river and started to steal its water, depriving Jordan of one of its main sources it needs to irrigate its land.

On the Yarmouk River, 'Mukheiba Dam" has been built for water storage for irrigation. A canal has also been dug to connect the Yarmouk River to the Ghor Land in Jordan.

PROJECTS TO UTILIZE THE JORDAN RIVER WATER

1. Johnston's

In the Period 1953-1955 the US deputy, Johnston was commissioned by his government to lay the foundation for a plan to use the waters in the region in such away as to prevent any "bloody conflicts" between Israel on the one hand and Syria, Jordan and Lebanon on the other. According to this plan, the annual 1.25 billion m3 (Al-Safadi 1989) of the Jordan and the Yarmouk waters were to be distributed as follows:
- 35 million m3 for Lebanon from the Hasbani.(Tameer 1992);
- 132 million m3 for Syria (42 million m3 from the Jordan and 90 million m3 from the Yarmouk). (Shefinar 1992);
- 720 million m3 for Jordan (377 million m3 from Yarmouk and 343 million m3 from the Jordan);¶ 360 million m3 for Israel (320 million m3 from the Jordan and 40 million m3 from the Yarmouk).

Johnston's plan thus allocates only 887 million m3 for the Arabs compared with the 360 million m3 for Israel. Today, Israel uses 545 million m3 while Jordan and Syria uses 255 million m3.

Another point of conflict is the 150 million m3 (Mustafa 1990) those amounts of water flowing south of lake Tiberias that Israel takes away illegally by force, as well as 75 million m3 of flood waters of which Israel claims the right to half on the assumption that supplying the West Bank with water has become the responsibility of Israel and not Jordan since 1967.

With regard to Syria, the point is the Yarmouk water, as Banias and the Golan are under Israeli Occupation.

2. The Arab Plan for Transferring the Jordan River water using the Yarmouk water:

This plan aims to transfer 230 million m3 from the Jordan tributaries to the Mukheibah Dam in Jordan, at the time when 320 million m3 are being transferred by Israel according to its national plan. The Arab project started in 1964, with an eye to building several dams to transfer Hasbani and Banias to the Syrian land and then to channel the surplus waters through special cannals that would flow into the Yarmouk where the surplus water would be stored in a 10-km man-made lake to be built behind Mukheibah Dam in Jordan.

Arab Project to Distribute Jordan River Water

State	Water quantity (million m3)	Source	Irrigated land (Dunums)	Irrigated area
Lebanon	350	Hasbani R.	35000	Hasbani B.
Syria	20	Banias R.	20000	Banias B.
	22	Jordan R.	22000	Al-Botma B.
	80	Yarmouk R.	18000	Al-Yarmouk
Jordan	295	Jordan R.	Unknown	Eastern Ghor
	305	Yarmouk R.	Unknown	Western Ghor

Through this lake, a tunnel would be dug to carry water to the Eastern Ghor cannal. The idea behind such a project is to irrigate about 430,000 dunums of land in Lebanon, Syria, Jordan and the West Bank. This project was set aside after the 1967 war when Israel occupied the West Bank, the Golan,and took control of the Hasbani and Banias rivers. Furthermore, the U.S.A stopped funding the project. The project did not survive and the idea was then limited to built the "Alwahda Dam", near the Jordanian village Almakarin on the Yarmouk in coordination with Syria in 1987. The dam holds back 220 million m3 of the Yarmouk, which is considered vital to Jordan, in order to double the area of irrigated land and to supply the East Ghor canal with water. Syria was to make use of 75% of the electrical energy produced from the dam, but this plan also failed as there was no agreement concerning water allocation among Syria, Jordan and Israel. Israel pressurized the World Bank and the US aid which were to fund the project, linking funding with the agreement on allocation.

In short, Israel is annually extorting a total of 660 million m3 of water from upper Jordan river and storing it in Lake Tiberias, thus reducing the water flow into the Jordna. In fact, whatever water reaches the Jordan is either saline or polluted because of the transfer of salty spring waters and hot springs into the Jordan river through canals without going through Lake Tiberias. Fishery waste is also dumpd into the Jordan south of the lake.

The East Ghor canal project aims to transfer part of the Yarmouk waters (before it meets the Jordan river) to East Jordan valley through a 78 kilometer cannal which will then branch off into several irrigation canals.

The Litani River

The Litani river is considered a major water resource which Israel has always tried to seize. In fact the Litani was on the list of demands submitted to Johnston in the aftermath of the 1964 water crisis. Israel asked for 400 million m3 of this river's flow, a figure which comprises 25% of the Israeli water consumption. Taking into account that Israel now controls the southern border strip, the river is not far from Israel.

3. The Israeli projects to utilize the water of the Jordan and its tributaries.

Israel is greatly interested in water for agricultural settlements. Many Israeli projects have aim to transfer water to the Negev for land reclamation and cultivation in preparation for immigrants. Israel has set up several projects through which large quantities of water were pumped from the upper Jordan River (north of Lake Tiberias) through giant pipes to the Negev to supply the newly-established communities with water. The project in its entirety implemented in 1964. Certain of the Israeli projects follow:

1- Yarqon-Negev project

This was started in 1952 and completed in 1955 to supply the north Negev which now accommodates a large number of settlements. The project aims to bring water (Amir) from the Auja (Yarqon) river which have their sources in the West Bank. This project and other local porjects seek to supply the Western Negev with water.

2- The National water carrier project

Israel over exhausted local water resources as the Yarkon especially after the Jewish immigration during the period 1949-1952. Then Israel decided to establish a comprehensive project in 1956 to transfer the Jordan River water to the southern parts of Israel and in 1964 the project was completed. Water from Lake Tiberias was drawn through a huge 130 km pipeline through Rosh Haayn to the Negev. At present, efforts are being made to transfer the Jordan River waters directly to the Israeli national water network by circumventing Lake Tiberias through an open canal and large pipeline (Tsor, 1990).

Israel has set up a plan to link the local projects with the Yarkone and the national projects within a central unified regional network.

WATERS AND ISRAELI FUTURE PROSPECTS

After the Law of Return (which allows world Jewry permanent residence in Israel) was passed in 1950 and with the surge of Jewish immigrants since 1880 to reach 3 million by the end of this century, the expected overpopulation requires massive water resources to meet the rising water demand for agricultrual, domestic and industrial purposes. Given water scarcity and the high costs of sea water distillation, sewage treatment plants and man made rain together with the pollution of surface and ground waters, Israel will look for other natural water resources from neighboring areas.

A case in point is the Jordan River which is now exhausted by Israel where the water is transferred to central and south Israel. Israel is asking a further one hundred million m3 of the river water, that is more than twice the allocation alloted for Israel under the Johnston project). As for the Litani, Israel seeks to pump 400 million m3 of its water to Lake Tiberias to irrigate the agricultural land north of the lake.

Israel also seeks to maintain the Golan Heights as an abundant source of water and to control the springs of the rivers in south Lebanon. With regards to the occupied West Bank, with its moutain aquifers reserves (1/3 of water resources in Israel). Israel used 30-40% of its needs from it by controling the ground water through military and civil acts that limit the Palestinian consumption of water, but at the same time support the settlements in this respect.

In order to supply the increasing numbers of immigrants, Israel is now thinking of drawing water from the Nile Delta via the Suez Canal to the Negev through Sinai, after signing the

Camp David Accords with Egypt. The Israeli researcher Joseph Dor'el and the engineer Elisha Kali and others spelled out various projects to this effect but these projects are still on paper due to Egyptian urgent need for water. Also Egypt only shares the use of Nile waters by a group of countries - parties of the 1959 agreement.

In 1973 a water transfer scheme was proposed to dig a canal between the Dead Sea and the Mediterranean. This would utilize the difference in elevation to generate electricity and to make up for the loss of water flowing into the Dead Sea. Topographical maps and blue prints were drawn up for this purpose , but the project has not been carried out yet.

Finally, Sholmo Ghor, the Israeli engineer came up with a plan to use the energy produced from the flow of the Mediterranean water into the Jordan river near Bet Shean to distill over a billion m3 of water each year as a solution to the water problem in Israel and the neigbouirng countries.

JORDANIAN FUTURE OUTLOOK CONCERNING WATER

In the light of natural increase in the population of Jordan and the return of massive numbers of Jordanians, and Palestinians from Kuwait and the Gulf States to live permanently in Jordan, and with the Jordanian strategy of switching to irrigated agriculture to overcome the fluctuaton and unpredictability of rainfall, the droughts and the scanty rain that Jordan has witnessed lately, Jordan is on the threshold of a serious water crisis by the end of the decade, which will challange the water and food sufficiency of the country if the present water resources are not augmented to respond to steady increase in demand.

In response to the alarming predictions of formidable water shortage by 1995, Jordan has signed an agreement (Jordan University 1990) with Syria in 1987 to build a dam on the Yarmouk, viz, Sad Al-Wihdah near Maqarin east of Sad El- Mkheibeh. This dam was supposed to compensate for the sheer lack of water, but Israel pushed so hard that the World Bank and the USA stopped funding the project, thus leaving Jordan high and dry, but Syria managed to erect about 28 dams on the Yarmouk and thus reserved enough water. Israel exceeded the apportionment alloted to her by the Johnston project and her extensive use of the Jordan River waters north and south of the Sea of Galilee fill the gap. The Yarmouk is the lifeline for Jordan because it doubles the Jordanian irrigated land and feeds the East Ghor Canal which is the life blood of the Jordan valley. In the year 2000 the water deficit in Jordan is estimated to be 170-200 million m3 (Naff, 1990) with an increase in demand from 870 million m3 to a billion. What adds insult to injury is the shrinkage of underground water in the Jordan Valley, salinity in some water resources, pollution of the Jordan River waters and the depression of the water flow in the Yarmouk as a result of the Syrian dams, hence appeared the rationing of irrigation in the Jordan Valley and the restraints on water consumption in Amman and other areas especially in the summer, when there was running water for home use only twice a week sometimes.

As Jordan is a desert country, it has no water options. In order to find substitutes. It has started small projects to increase its water supplies, but the population growth and the wide gap between renewable supply of water resources and demand for water, offset the reserve. Well overpumping has led to salinity in the water of the Azraq Oasis which supplies Amman with water.

Other water resources have become polluted as a result of some recent industries. Jordan is trying to increase the area of farmed rain water land irrigated by rain, to repair old water networks to make up for the loss, to build dams on some valleys to collect rain water, and to sensitize its citizens to the water problem. Studies are being conducted on water recycling by sewage treatment for agricultural purposes. Other studies are being made to distill the Red Sea water in Aqaba. Above all is a proposal, (now under discussion) to import water from Iraq and other places whereby Jordan can make available 140 million m3 of water a year.

Keeping in mind that Jordan views the Jordan and the Yarmouk rivers as "do or die matters", the conflict over these rivers will determine security in the region especially after the Israeli occupation of the Syrian Golan and the 12 K of the Yarmouk cource, taken more than its share of water and the waves of Soviet immigrants to Israel on one side and the flow of Jordanian returnees on the other side of the river heightens the need for water.

THE LEBANESE FUTURE PROSPECTS

Lebanon is the only desert-free country, rich in springs and rivers and good annual rainfall. The major trouble however,(Jordan University 1990) is that Israel need for water has increased thus, it continually tries to make the Litani, the biggest and richest Lebanese river, its northern border. Israeli need for water makes her tighten her grip on south Lebanon to remain close to the river which is meant to supply Israel with 400 million m3 of water after it has made use of the tributaries, (Wazani, Hasbani and Banias) and transfered their waters for the Negev. This will force Lebanon to join Jordan, Syria and Palestine in their conflict with Israel over water resources.

THE SYRIAN PERSPECTIVE ON THE WATER PROBLEMS

Syria, located in the northern levant, has a considerably coastline along the Mediterranean and a quite plentiful rainfall. Compared with Jordan, Syria has few water problems as there ae big rivers such as the Euphrates the Asi and the Yarmouk; with dams and man-made lakes built on each. Yet the Israeli occupation of the Golan Heights in 1967 dispossessed Syria of part of these water resources, Israel has begun to monopolize these waters and springs and transfer such water to the Israeli settlements. Israel has aslo seized lake "Ram" in Masa'ada which holds some 2 - 3 million m3 and part of mount Hermon with its waters, thus causing Syria to lose a large portion of its abundant supply of water.

Syria faces two particular major problems. First; Turkey has established 22 dams on the Euphrates, the largest being the Ataturk Dam. Thus reduces the Euphrates flow to Syria by 1/3 resulting in major damage to agriculture. Second, Syria has witnessed almost 10 years of marked drought. Also river waters has increase in salinity as the water level of these rivers dropped. To counteract this, Syria built more dams on these rivers in particular the Yarmouk. Jordan has suffered as aresult of this and, as yet is unable to make up for this loss.

THE PALESTINIANS AND THEIR FUTURE OUTLOOKS

Israel was partially using Gazan and West Bank waters prior to 1967. Israel linked these water sources into the Israeli central water network . Since then has developed a special policy towards those territories and its waters. Following are the main features of this policy:

1. Severe restrictions on Palestinian consumption of water, regarding to Military Order No. 158, order Amending the Water Supervision Law of October 1967 (Rowley,1990);
2. Encouraging the Jewish settlements in the territories to utilize the water reserve of those areas;
3. Causing West Bank surface and undergroud water to seep to the Israeli coastland, this seepage comprises one third of the underground water in Israel (Benvenisti 1986);

Out of the 600 million m3 (Benvenisti, 1986) of West Bank water, the Palestinians (over one million). Use 137 million m3 while the Jewish settlers (about 100,000) use 100 million m3. The annual average per-capita consumption is 38 m3 for Palestinians and 90m3 for settlers. Gaza Strip faces a water crisis due to lack of rain and a drop in the water level of artesian wells caused by the settlers' heavy water consumption. Further more, Mediterranean sea water, which seeps through to the underground water, increases water salinity . Among the factors that heightened the water crisis in Gaza, quantitatively and qualitatively, is the fact that Israel has dug many artesian wells along the borders between Gaza and Israel to stop the flow of underground water to Gaza.Gazan water is also laken by Israel to supply the Israeli colorial settlements further east in the Negev desert. In short, the water problems in Palestine come from Israeli control of the underground water in the West Bank and Gaza, restrictions on water consumption, deprivation of the Palestinians from the Jordan and the Yarmouk river waters especially after 1967 under the pretext of security. Israel now belives that she has the right to those waters. This is the major obstacle to the solution of the water problem. Eventually, it is water that determines the future of the Occupied Territories and there upon will determine peace and security.

PROPOSED SOLUTIONS TO THE WATER PROBLEM

From the above discussion, one can conclude that neither surface nor underground water can be compartmentalized according to political borders and thus is apt to cause conflicts. In other words, the Arab-Israeli conflict is both over land and water as the two are inseparable and for any solution to be successful, it has to address both issues: Land and Water. The question is who will manage the distribution and allocation of water, taking into consideration that Israel gets two thirds of its water from the Occupied Territories. It is also a historical fact that through cooperation and peaceful settlements of disputes, contestant parties can use water for mutual benefits. For Israel, the only condition to make peace with its Arab neighbors, is to pull out of their land and then to work with them on mutual projects such as water resources.

Thus the Johnston project (based on pre-1967 borders) seems to be the basis to settle the conflicts over the Jordan, the Yarmouk and the Litani waters. The Palestinian share of water resources (from the Jordan, the Yarmouk as well as surface and underground waters) should be clearly defined.

The Turkish peace pipes project to bring water through a huge ipe to the region which cost 24 billion dollars,was refused by the Arab States especially the Gulf States because they considered it strategically, politically and economically impossible. At the same time, this project was welcomed by Israel.

Another project was the Lebanese project (Shateela 1992) to bring water from Lebanon (which is considered a country that is rich in water) to carry water through a pipe line of 1500km long passing Syria, Jordan to the Arab Gulf States and which supplied 750 million m3 of water a year, Syria and Jordan, which suffered from water shortage can benefit from this project. This line which was planned to parallel the Tabline oil pipe cost 7 billion dollars (1/3 of the Turkish project cost). This project was more realistic than the Turkish project because Lebanon is a small country and did not have any covetous actions in the region, in the case of a peace condition between Arab States and Israel, Israel may be interested in this project through regional cooperation.

Once peace has been established, such projects as that of Shlomo Ghour, which plans to draw Mediterranean water to the Jordan River through Beit-Shan to the Dead Sea and then to distill the Dead Sea water, will be worked on by all parties concerned.

In the end, all the parties have to realize that just peace and joint water projects is the surest way and the shortest cut to security and peace. On the other hand, individual isolated projects for each country to use whatever amounts of water regardless of her neighbors is the road to war which nations shun, especially with the advent of the new world order.

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A budget of the surface and underground water in northern Jordan

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Abstract

The motivation for this study is the great requirement for water expected in the future to satisfy the increasing demands of accelerated growth, and development programs in Jordan. This fact, in addition to the recent migration of hundreds of thousands of people after the Gulf War, should encourage more intensive studies of the quality and quantity of water resources in Jordan.

The aim of this study is to carry out a comprehensive assessment and evaluation of the water resources-potential of the northern area of Jordan. This work required hydrological, hydrogeological, hydrodynamical and hydrochemical analyses and interpretations. The rates of precipitation, evaporation, surface runoff and infiltration were calculated. The regional recharge sources and directions of the groundwater movements were mapped.

Netto the recharge-discharge mechanisms should provide an improved understanding of the water resources in the study area, which covers about 6000 km of northern Jordan.

INTRODUCTION

The study area covering about 6000 km in northern Jordan is one of the most intensely developed regions in the country (location map is given in Salem, 1984). It extends between (Palestinian) Grid Coordinates of N 160 to 240, and E 200 to 300, and includes the Yarmouk Basin, Wadi Zerqa Province and the northern part of the Jordan River. Dams, industries, farms, irrigation projects and municipal schemes are being implemented in the area. Some of the dams constructed in the area are: the king Talal Dam, the Yarmouk Dam and the Arab Dam. To the north the area is bordered by the Yarmouk River, to the south, Wadi Shueib and the southern part of Wadi Zerqa Catchment areas from the southern end of the area. It is bordered by the Jordan River from west, and by the Azraq Basin from East. The altitude of the ranges between 300 m (below sea level) to 1200 m (above sea level).

The area has been geological surveyed by many researchers (Queenly, 1951; Masri, 1963, the German Geological Mission under the supervision of Bender in the period from 1961 to 1967). These studies yielded a variety of geological maps with different scales. The most comprehensive study of the geology of Jordan was published in German by Bender in 1968, and translated to English in 1974. The earliest hydrogeological study of the area was in 1939, carried out by Ionides and Black as part of their survey on East Jordan. McDonald and Partners (1965) conducted a hydrogeological survey of several regions of East Jordan. Other hydrogeological and drilling investigations were carried out in the period between 1965 and 1970 by the United Nations Drilling Program (UNDP). The Natural Resources Authority (RNA) of Jordan and its Water Resources Division made several investigations since 1960 and produced many reports. Several research projects for academic purposes were also completed (Mudallal, 1973: Abdul-Jaber, 1982 and Salem, 1984). The most important detailed work was carried out through the Natural Water Master Plan of Jordan prepared by the German Agency for Technical Cooperation, Ltd. (GTZ). The results from their work in 1976 and 1977 were published in eight volumes.

This study is part of a Master thesis, which was submitted in partial fulfillment of the requirements of the Master degree from the University of Jordan in 1984. The aim of the study is a numerical analysis of available rainfall and well data, to establish a surface-underground water budget as well as to evaluate the potential water resources in northern Jordan. The available hydrogeological data were employed to calculate the rates of precipitation, evaporation, surface runoff, and infiltration. These results were uww to construct hydrological, hydrogeological, hydrochemical maps, and to determine some petrophysical parameters which control the transport of water in aquifers. Some of the parameters determined are: permeability, transmissivity, hydraulic gradient, and flow velocities. Also, the age of the groundwater was estimated. In addition, the recharge-discharge areas were recognized, and the aquifer systems and aquitards were identified. Net flow maps of the aquifer system were derived.

GEOLOGY AND STRUCTURE

The study area is mainly covered by Cretaceous, Tertiary and Quaternary rocks and sediments. In a few locations Triassic and Jurassic rocks crop out. Triassic outcrops are recorded at Ramtha and Khaldiya. At Zerqa River, Triassic rocks form a series of sandstones, shales and marls. Crystalline and argillaceous marly limestone, massive gypsum, and ferrogeneous sandstone and oolites also occur as intercalations.

The Jurassic rocks crop out at Zerqa River, and consist of thick-bedded limestone overlain by sandstone and calcareous sandstone, sandy marls and shales. Quennell (1951) named the Triassic-Jurassic succession the Zerqa Group. Towards the north in the Syrian region, the Jurassic sequence exhibits a thickness of 1450 m (Bender, 1974).

The Cretaceous rocks are divided into lower and upper formations. At Zerqa River, the lower Cretaceous sequence consists of basal conglomerate intercalated with sandstone, marl, shale and gypsum with a total thickness of 140 m. The Upper Cretaceous sequence in addition to the basaltic flows and some of the Tertiary-Quaternary sediments are considered the main groungwater-bearing formations in north Jordan. Generally, the basaltic intrusions are of Oligocene age. As will be seen later, the basalt in northern Jordan forms one of the shallow aquifer systems of high to very potential, with very good water quality.

The Upper cretaceous sequence consists of thick-bedded and intercalated sandstone, limestone and dolomite. The Upper Cretaceous, recent sediments and the basaltic flows are divided, as will be seen later, into several hydrogeological units.

Concerning the Tertiary and Quaternary sediments, the lower syntectonic conglomerate is present on the eastern side of the Jordan Rift, about 20 km WSW of Irbid City. These sediments comprise a succession of 40 m of glauconitic marl and limestone considered to be of Oligocene age (Wetzel and Morton, 1959). The Pleistocene and Holocene deposits occur in the course of Yarmouk and Zerqa Rivers and in different valleys in the study area. These unconsolidated Quaternary sediments consist of Wadi-fill deposits. In some parts of the study area they have a thickness of about 10 m. Calcrete rocks, known as caliche, exist in the Ajlun and Baqa' areas (Abed, 1982). These rocks, of Tertiary age, occur as a calcareous crust in areas of annual rainfall exceeds 50 mm.

The main folds, faults and flexures in the study area are elements of the regional structural features and patterns in Jordan. In general, the area is affected by three types of structures; minor, major, and other structures.

The minor structures include small anticlines and faults. Many folds exist at this small scale, and generally plunge in NW-SE. The central and western parts of the area are affected by many abrupt flexures and faults. Some of these structures are: an important fault exists near Wadi Nau'm in the Wadi Sir Formation, and a small graben is present in the Kurnub Formation between Wadi El-Azziya and Zerqa River. More details about these structural elements are given in Salem (1984). The most important major structures in the study area are: Zerqa River Valley, Suweilih Flexure and Ajlun Dome. Within the Zerqa River Valley a fault Zone exists where a rotation of about 20 occurred between the two blocks north and south of the fault. This rotation is thought to have happened in Quaternary times. This movement is explained as a relative rotation of the blocks related to regional tectonic forcewwffecting the area (Mikbel and Atallah, 1982). The Suweilih Flexure, a symmetric anticline striking 240 (Wetzel and Morton, 1959), was developed in incompetent sedimentary beds and is related to faults in the underlying basement. It appears to be a continuation of the Dead Sea fault (Burdon, 1959) passing east of Salt City and then spilting to die away some 15 km further to the NE. Salameh (1980) suggested that this structure is marked to the west by the uplifted margins of the Jordan Graben, and to the east it gradually merges into the Jordanian Plateau. In the southern part of the flexure, the Upper Cretaceous beds are vertical, and locally overturned. The core of this structure is affected by erosion to form the Baqa' Basin. Different ideas concerning the origin of this structure are cited in Salem (1984). The Ajlun Dome axis strikes NNE-SSW and extends for more than 50 km (Bender, 1974). Ajlun Dome is flat, wide and upwarped, and is affected by extensive faulting in its crustal area. The uplifting effects on the Ajlun Dome lead to erosion in the limestone of the Belqa Group. The other structures include the Ramtha Syncline, which strikes WNW-ESE. Also, major fault Zones exist in the Jebel Druze Plateau (Burdon, 1959).

ROCK UNIT CLARIFICATION

Based on hydrogeological consideration, the study area is classified into various hydrogeological categories (Table 1), namely:

SANDSTONE GROUP (K-Z)

The Triassic-Jurassic-lower Cretaceous rocks are known as the Kurnub-Zerqa Group (K-Z). This group underlies almost the whole study area, and crops out along the lower reaches of Zerqa River. It mainly consists of sandstone and shale. In the Jeresh District, the lower part of this group has groundwater potential as it contains very few argillaceous horizons than the upper part which has shown disappointing results due to the limited permeability of the intercalated sandy and shaly horizons.

AJLUN GROUP (A)

The Upper Cretaceous and lower Tertiary sedimentswre classified into different units, or aquifer-aquiclude systems. Quennell (1951) applied the term Ajlun Group (A) to the lower part of the Upper Cretaceous, and Belqa group (B) to the upper part.

This group embraces all the marine sediments of Cenomanian-Toronian age. It overlies the Kurnub sandstone and consists of intercalations of limestone, dolomite, marl, shale and sometimes sandstone. In the Ajlun District, this group reaches its maximum thickness of more than 500 m. It gradually thins towards Zerqa River and Suweilih Flexure. McDonald and Partners (1965) subdivided this group, in the central part of Jordan, into three main units; (A1-A2), (A3-A6) and (A7). The Ajlun Group (A) can be classified as follows:

NODULAR LIMESTONE UNIT [A1-A2 AND A3]

This unit is particulary well-exposed in the area between Zerqa River and Arda Road. It mainly consists of alternating hard dolomite and nodular limestone. This unit includes the Nau'r (A1-A2) and Fuheis (A3) Formations. The Nau'r Formation (A1-A2) has a maximum thickness between 200 and 230 m. It is composed of sandy marl, shale, dolomitic limestone and limestone, and is characterized as an aquifer of low to medium potential. The Fuheis Formation (A3) is exposed in north Jordan with a thickness of 70 to 90 m, and is composed of intercalations of marl, limestone and chalk. Because of the presence of considerable amounts of chalk and marl, this formation has low potential and is considered as aquiclude. The total thickness of the aquifer and aquiclude [(A1-A2) and (A3)] is between 70 and 80m.

ECHINOIDAL LIMESTONE UNIT [A4 AND A5-A6]

This unit overlies the Nodular limestone unit, and mainly consists of alternating thick-and thin bedded limestone, dolomite marly limestone. It exhibits a thickness of about 250 m. It can be subdivided into two sub-units; the Hummar Formation (A4) and Shueib Formation(A5-A6). The Hummar Formation (A4) crops out in northwest Jordan, and consists of dolomitic limestone. It thins eastwards towards the basaltic plateau. It exhibits$x thickness of about 40 m. This formation is considered one of the best groundwater-bearing formations with a medium to high potential. The Shueib Formation (A5-A6) consists of thin-bedded grey limestone (A5), and of white to crystalline massive limestone (A6). Generally the thickness of (A5-A6) Formation is between 50 and 100 m. The Shueib Formation (A5-A6) is classified as an aquiclude of very low potential.

MASSIVE LIMESTONE UNIT [A7]

This unit overlies the Echinoidal limestone unit, and exhibits a local thickness in the study area of about 60 m. Its regional thickness widely varies from north to south, where it exhibits a thickness of 185 m as penetrated in the Qumein well (E 220.0, N 219.0). It

TABLE (1): ROCK UNIT CLASSIFÍCATION AND GROUNDWATER POTENTIAL

Period	Epoch	Group	Symbol	Wolfart (1968) Irbid Area	Masri (1963) Amman/Zerqa	McDonald (1965) North Jordan	German Geological Mission (1951-86)	Sandstone Aquifer Project (1969-70)	Thickness of Unit (m)	National Water Master Plan (GTZ) (1976-77) Potential of Aquifer	National Water Master Plan (GTZ) (1976-77) Hydraulic Complex	Thickness of Aquifer (m)
QUATERNARY	Holocene		R	Fluviatile: coarse and fine clastics Wadi Fill. Lacustrine: carbonates, sandy clay with finely distributed rock salt and gypsum					up to 120	low to medium to high	Shallow Aquifer Hydraulic Complex	up to 120
	Pleistocene Oligocene		BA	absent	absent	Basalt: different flow separated by silt and gravel			250	high to very high		up to 200
TERTIARY	Eocene	BELQA GROUP	B5	chalk	absent	chalk formation	chalky limestone, bitum. marly limestone of Yarmouk area	Wadi Shallala Formation	200-220	Medium		30-50
	Paleocene		B4	chalk and chert	absent	chert-limestone formation	Chert-Limestone Unit: thin bedded limestone interc. of chert	Rijam Formation	20-40	aquiclude		20-40
UPPER CRETACEOUS	Maastrichtian		B3	chalk and marl	Muwaqqar Formation	chalk-marl formation	Chalk-Marl Unit: chalky marl and marly limestone	Muwaqqar Formation	50	aquiclude	Upper Cretaceous Aquifer Hydraulic Complex	50
	Campanian		B2	limestone, chalk and chert	Amman Formation (B1-B2)	silicified limestone	Phosphorite Limestone Unit	Amman Formation (B2)	50	high		50
	Santonian						Silicified Limestone Unit		up to 90			up to 90
			B1 b	limestone		(B2) Formation	Massive Limestone Unit: thick bedded karstic limestone beds overlain with a 10-15 m thick marlstone bed		55-60	very low		40-45
			B1 a	chalky marl		chalky marl formation		Wadi Ghudran Formation (B1)		aquiclude		
	Turonian	AJLUN GROUP	A7	limestone, dolomite	Wadi Sir Formation	limestone formation		Wadi Sir Formation		high		
	Cenomanian		A6	marl, limestone	Shueib Formation (A5-A6)	marly limestone formation	Echinoidal Limestone Unit: cavernous, dense thick bedded limestone, overlain by dense chalky limestone	Shueib Formation	250	aquiclude		40-60
			A5	limestone								
			A4	limestone, marl	Hummar Formation	limestone formation		Hummar Formation		medium		
			A3	marly limestone	Fuheis Formation	marl formation	Nodular Limestone Unit: marly dolomitic and nodular limestone; the middle part forms the aquifer	Fuheis Formation	300	low		70-80
			A2	marly nodular limestone	Nau'r Formation (A1-A2)	limestone formation		Nau'r Formation (A1-2)		low to medium		
			A1	chalk, marl, limestone and dolomite		marl formation						
LOWER CRETACEOUS	Albian	KURNUB GROUP	K2		Subeihi Formation		Kurnub Sandstone Unit		330	low	Deep Sandstone Aquifer Hydraulic Complex	300
	Aptian-Neocomian		K1		Arda Formation					medium		
JURASSIC		ZERQA GROUP	Z2		Azab Formation		Zerqa Sandstone Unit		up to 500	medium		205
TRIASSIC			Z1		Ma'in Formation					medium		

consists of several meters of thick-bedded limestone separated by thin layers of marl. Also, it is overlain by 10 to 15 m of beds of soft marl. This unit is subdivided into Wadi Sir Formation (A7) and Wadi Ghudran Formation (B1). The Wadi Sir Formation (A7) is composed of hard massive limestone in its lower part, and of white soft chalk and marl in the upper part. The (A7) Formation, due to its high potential, is penetrated by numerous wells in the study area. It is classified as one of the best yielding aquifers. The Wadi Ghudran Formation (B1) is considered to be, as will be seen later, a part of the Belqa Group (B).

BELQA GROUP (B)

The Belqa Group (B) conformably overlies the Ajlun Group (A), and embraces all the sediments from the end of Turonian to Oligocene (Bender, 1974). This group mainly consists of chert and carbonate rocks. The total thickness of this unit reaches up to 550 m. This group is subdivided into Silicified limestone Unit-Phosphorite limestone Unit, Chalk-Marl Unit and Chert-Limestone Unit. These units are further subdivided into five formations; Wadi Ghudran Formation (B1), Amman Formation (B2), Muwaqqar Formation (B3), Rijam Formation (B4), and Wadi Shallala Formation (B5).

SILICIFIED LIMESTONE UNIT-PHOSPHORITE LIMESTONE UNIT [B1-B2]

The Silicified Limestone Unit is characterization by massive chert intercalated by limestone. This unit is easily recognized in the field because of its spectacular undulations. In southern Jordan (Wadi Mujeb area), it attains a maximum thickness of about 100 m. The Phosphorite Limestone Unit overlies the Silicified Limestone Unit, and is characterized, in comparison with the underlain unit, by a distinct increase in the limestone and phosphate contents and by a decrease in its chert content. This unit shows considerable variations in its thickness within short distances, exhibiting a range of thickness from one meter to more than 20 m. Both units can be together subdivided into Wadi Ghudran Formation (B1) and Amman Formation (B2). The Wadi Ghudran Formation (B1) is composed of a sequence ofchalk and marl forming the lower part of Belqa Group (B), and directly overlies the Wadi Sir Formation (A7), which is considered, as previously seen, the last member of the Ajlun Group (A). Therefore, some researchers consider (B1) as the uppermost part of the Massive Limestone Unit terminating the Ajlun Group (A), and others consider it as the lower part of the Silicified Unit at the base of the Belqa Group (B), (see Bender, 1974). This formation (B1) can only be recognized in northern Jordan with a widely variable thickness between 10 and 60 m. This formation, due to its high content of chalk and marl, is considered an aquiclude with very low potential. The Amman Formation (B2) mainly consists of chalk, limestone, chert and phosphatic beds with a total thickness of about 50 m. The undulations, fractures and joints in the chert beds are the characteristic features of this formation. These features cause the formation to be highly porous and permeable. Therefore, this formation (B2) combined with the Wadi Sir Formation (A7), known as (A7-B2), is considered a very good aquifer penetrated by numerous wells, with high productivity.

CHALK-MARL UNIT [B3]

This unit is partly bituminous and consists of chalky marl and marly limestone. In somwlocations it contains thin beds of gypsum and concretions of chert. Although the thickness of this unit in some places (Yarmouk River and Wadi Shallala) is more than

300m, the average thickness is generally about 50 m. The Muwaqqar Formation (B3) is considered the only formation in this unit, and can be easily recognized. It consists of chalk, marl, chalky limestone and chert nodules. The recorded thickness of (B3) varies from place to place and generally ranges between 60 and 320 m (Masri, 1963; McDonald and Partners, 1965; and Wolfart, 1968). The wide variation in thickness may be due to facies changes. Regardless of its thickness, this formation has very poor potential and is considered as an aquiclude.

CHERT-LIMESTONE UNIT [B4 AND B5]

This unit crops out in the northern and northeastern parts of the study area (Wadi Shallala, north of Irbid City, and in the eastern areas of Jebel Druze). It consists of thin-bedded limestone with some intercalations of chert beds. It exhibits a total thickness of 200 to 220 m with a general thickness of 30 to 50 m (Wiesemann and Abdullatif, 1963). This unit contains two formations; the Rijam Formation (B4) and the Wadi Shallala Formation (B5). This name, Rijam Formation, was first introduced during the implementation of the Sandstone Aquifer Project (UNDP) in 1956 for a sequence of alternating beds of chert, limestone and chalk, which conformably overlies the Muwaqqar Formation (B3). A thickness of about 40 m in the northern part of Jordan was recorded by McDonald and partners (1965). The Rijam Formation forms the base of the shallow aquifer hydraulic complex. In the central parts of the Azraq and Jafr Basins, this formation is considered an aquiclude of very low to low potential. The Wadi Shallala Formation (B5) was first named by UNDP. It overlies unconformably the (B4), and consists of chalky limestone and bituminous marly limestone intercalated by some beds of chert. Its total thickness is between 200 and 220 m, with aquifer thickness of 30 to 50 m. It is considered a shallow aquifer of medium potential.

UPPER TERTIARY AND QUATERNARY SEDIMENTS (R)

The Upper Tertiary and Quaternary sediments generally attain a maximum thickness of 120 m, which is also the thickness of the aquifer. They are mainly composed of wadi-fill of coarse and fine clastic and lacustrine deposits of carbonates, sandy clay with finely distributed rock salt and gypsum. Because of their lithological heterogeneity, they have a widely variable groundwater potential ranging from high to low.

VOLCANIC ROCKS (BA)

In addition to the previously mentioned Upper Cretaceous, Tertiary and Quaternary sediments, which are considered as shallow and medium-depth aquifer hydraulic complexes, the Upper Tertiary and Quaternary basalts of Jebel Druze and Hauran areas (covering about 11,000 km in Jordan; Bender, 1974) are considered one of the major producing aquifers in Jordan. Six phases of basalt emission were distinguished (Boom and Suwwan, 1966). In Jordan, the basalt flows of the lower three phases were only known from the groundwater drilling in west Dhuleil area (Hunting Geology and Geophysics Ltd., 1966). They are separated from each other by about 5 m thick of soil layers and red clays, and have a total thickness of about 150 m. The lava flows of phases one to four can be placed in a time interval from Upper Eocene to Miocene (Bender, 1974). The fifth phases of basalt flows exposed in the northeastern part of the study area, with a thickness of 25 m, can be placed in the interval between Miocene and Pleistocene.

HYDROLOGY

It this part of the study four items will be discussed; precipitation, evaporation, surface runoff, and infiltration. Solving the equation of hydrologic equilibrium requires a comprehensive collection of basic hydrological data.

PRECIPITATION

It is well known that precipitation is the primary source of fresh water. Its record forms the basic of most studies that deal with water supply in all its forms. The amount of precipitation depends on the moisture available in the atmosphere. Cooling of the moist air masses leads to precipitation, and orographic barriers can lead to very large amounts of precipitation. Four main mechanisms cause cooling and then precipitation: Orographic uplift; when a mountain range deflects moist air upward, the air is cooled and then precipitated as rain, snow or both. Convection currents; when differential heating causes air to become locally more buoyant, the air mass may then rise to levels where it becomes saturated to form clouds and precipitation. Convergence; the wind fields may converge and force air to rise. Fronts; low pressure areas usually have frontal systems causing interfaces between large moving masses of warm and cool air.

Jordan is located at the southeastern corner of the Mediterranean Sea, with an area of approximately 95,000 km. About 80% of Jordan's area belongs to the arid Zone with desert basins of restricted drainage. The rainfall in Jordan is caused by the Eastern Europe and Western Mediterranean cold fronts, which are drawn by the Eastern Mediterranean low pressure system. Rainfall in Jordan occurs in the wet season that begins in October/November and ends in April/ May. Jordan can be divided into five topographic units (National Master Plan of Jordan, GTZ, 1977) with different climatic patterns affected by the geographical setting of the regions: West Bank Hills, Rift Valley, the Eastern Bank Hills, the Eastern Palateau, and Southern Desert. The study area is affected by the general climatic conditions of the Rift Valley, the Eastern Bank Hills, and the Eastern Plateau. The Rift Valley is characterized by its low altitude and subtropical climatic conditions. The average annual total precipitation is around 300 mm. The Eastern Bank Hills have a modified Mediterranean or semi-arid climate with an average annual rainfall between 400 and 600 mm. The Eastern Plateau is generally affected by arid climate and average annual rainfall less than 150 mm. Generally, the study area is affected by moderate humidity and average temperatures of 25 C in the dry season, and 10 C in the wet season.

The drainage basins and river catchment areas in Jordan can be classified as follows (GTZ, 1977): Jordan River Basin (A), Mediterranean Sea Basin (B), Dead Sea Basin (C), Wadi Arab (North) Basin (D), Wadi Arab (South) Basin (E), Azraq Basin/Northern Desert (F), Qa' El-Jafr Basin/Central Desert (G), Wadi Hammad Basin/North-Eastern Desert (H), Wadi Sirhan Basin/South-Eastern Desert (J), and Southern Desert Basin (K). The Jordan River Basin (A) and, partially, the Azraq Basin/Northern Desert (F) are the basins included in the study area. A map of the basins and catchment areas is given in Salem (1984).

The catchment rainfall can be approximated by averaging the rainfall measured at the gauge stations, or from the isohyetal maps, or by the Polygon methods. The Thiessen Polygons-map constructed of the study area is given in Salem (1984). However, because the Polygon method assumes linear variations between stations, and makes no allowance for the topographic variations, the rainfall calculations were not made by this method. Precipitation data of the study area were collected for the period from 1937/38 to 1980/81. These data were used to construct an isohyetal map, given in Salem (1984), and to calculate a long-term annual average precipitation of the thirty three gauge stations distributed all over the study area. The average annual rainfall for a certain period was calculated using the following statistical formula:

$X = (1/N)\ \Sigma X$, for i from 1 to N, where

X = arithmetic average annual rainfall (in mm)

N = number of available years

X_i = annual rainfall (in mm) of year i.

Because of the absence of rainfall data for some years, the average rainfall for the period between 1937/38 and 1974/75 was calculated according to the following formula for each Station:

$X3 = [(N2 \times X2) + (N1 \times X1)]/N3$, where

$X1$ = average annual rainfall (in mm) for the period of 1975/76-1980/81

$N1$ = number of available years for the same period

$X2$ = average annual rainfall (in mm) for the period 1937/38 - 1974/75

$N2$ = number of available years for the same period

$X3$ = average annual rainfall (in mm) for the period of 1937/38 - 1980/81

$N3$ = number of available years for the same period.

The results obtained are regarded as the best that can be extracted. These results of the mean annual rainfall were used to construct the isohyetal map (Salem, 1984) of the study area. The monthly distribution of rainfall in an average year for 12 selected stations (Table 2) was calculated. The results obtained show that the highest average rainfall of 195.4 mm was recorded in January at Ras Muneif Station for the period of 1966-1980. The lowest average rainfall, of 1.8 mm, was recorded by Jeresh Station in October for the period 1972-1977. Annually, Ajlun Station recorded the highest average rainfall, of 653 mm, in the period of 1938 - 1976, whereas the lowest value of 70 mm was recorded by the Azraq Station in the period of 1966 - 1980. In order to prepare a water balance of the various catchment areas, the rainfall data collected at the different stations were transferred into area-rainfall. From the area-rainfall results, it can be concluded that Wadi Kufrinja Catchment (AJ) shows the highest mean annual rainfall of 633 mm, while Wadi Zerqa Catchment (AL) shows the lowest mean annual of 347 mm (Salem, 1984). Generally, the years 1942, 1944, and 1966 recorded the maximum values, and the years 1959, 1972, and 1978 recorded the minimum values of precipitation.

The area-rainfall values were computed (in MCM) with reference to the areas between the isohyets and the catchment area. These results were obtained by multiplying the area between every two isohyets by the average annual rainfall (in mm) for each drainage area. The results show that the volumes of annual precipitation are mostly governed by the extent of the catchment areas. They also show that the study area with a total extent of 5890 km received an annual precipitation volume of about 1707 MCM. To check these results, another method was used to calculate the annual precipitation volumes. This was done by using the isohyetal lines and the areas between them, without consideration of the drainage areas (Salem, 1984). A comparison of the results shows a difference of 0.9%, indicating good agreement between the two methods.

The average annual precipitation for the study area, as a whole, equal 292.4 mm. It was calculated using the following formula:

$X = \Sigma[XN \times AN]/AN$, where,

X = average annual precipitation (in mm) for the period 1937/38 - 1980/81
XN = average precipitation between every two isohyets (in mm)
AN = area between every two isohyets (in km)
N = number of areas from 1 to 8 (see Salem, 1984).

Table 2. Mean Monthly & Yearly Rainfall (in mm) for Selected Stations in Different Periods.

Station Code#	Station Name	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Tot	Per
AB1	At-Taiyba	21.0	51.0	109.9	108.0	83.2	79.0	32.6	2.9	487.6	1973-1980
AH3	Ras Muneif	16.7	44.2	102.5	195.4	84.4	111.0	35.2	9.2	598.6	66-80
AD3	Kufr Saum	8.7	56.0	90.3	133.3	102.4	84.9	30.4	4.9	510.9	38-76
AD12	Ramtha Sch	8.6	31.5	52.1	71.5	54.5	50.7	18.0	2.4	289.3	38-76
AD16	MafraqPPost	7.3	16.3	31.4	33.9	27.2	33.5	11.8	2.6	164.0	66-80
AE1	Irbid Sch	16.4	40.9	98.6	120.2	76.7	104.7	33.5	4.3	495.3	66-80
AH2	WadiElYabis	13.1	29.6	71.9	65.0	39.3	52.3	17.3	2.2	290.7	66-80
AJ1	Ajlun	15.7	64.8	120.0	164.9	128.0	114.9	36.7	8.1	653.1	38-76
AL4	Jeresh	1.8	24.6	40.3	55.9	79.7	65.3	13.3	2.6	283.5	72-77
	WadiDhuleil	3.7	16.5	24.9	34.5	25.3	27.4	12.4	2.9	147.6	66-80
F3	AzraqPPost	3.0	9.9	11.8	13.0	11.0	11.8	7.0	2.5	70.0	66-80
H1	H4	4.5	10.1	11.8	10.3	13.3	10.4	10.2	5.2	75.8	38-76

In summary, the western highlands are affected by the highest average annual rainfall of 600 mm. Towards the east, the average decreases to between 400 and 200 mm in the middle part of the study area. Further to east, it is between 200 and less than 150 mm. The Jordan Valley slopes have an average annual rainfall between 300 and 150 mm. The northern part of the area received an average between 500 and 400 mm, while the southern part received an average between 400 and 200 mm. A map of the variation in the annual directional precipitation, N-S and E-W, was constructed to show the average precipitation of specific trapezohedrons (Salem, 1984).

EVAPORATION

About 70% of the annual precipitation on the land surface of the earth is returned to the atmosphere by direct evapotranspiration. As will be seen later, about 91% of the annual precipitation in the study area is returned as evapotranspiration (simply evaporation). About 70% of the annual evaporation is recorded in the dry season between May and October. Therefore, evaporation is considered the main mechanism in the hydrological cycle. It plays a major role in the water balance in any area, and is the primary consideration in any design of water resources projects.

Evaporation in Jordan is measured by Piche Atmometer and through Pan observations. Data were collected from different sources to calculate the evaporation rates in the study area. These data include mean monthly records of precipitation, cloudiness, wind speed, atmosphere pessure, temperature, humidity, sunshine hours and solar radiation. In this study, the evaporation rates were calculated according to three main empirical formulas;

Wundt's (1937) method, Turk's (1954) method, and Haude's (1952) method.

WUNDT'S METHOD

$E = X/[0.95 + \{X/f(T)\}]$, where

E = annual potential evaporation (in mm)

X = average annual precipitation (in mm)

T = annual mean temperature in C = (Tmax + Tmin)/2.

This temperature is only for the west seasons where moisture is still available in soil. f(T)=temperature function = 1400 + 170T + 5.5T2 + 0.15T3, where T lies between -5 and 20 C.

Using Eq. (4), the evaporation rates were calculate at 42 stations by using annual temperatures between 11.4 and 18.6 C for the season from October to May. The results obtained show that the highest annual evaporation is 454 mm calculated for the At-Taiyba Station, and the lowest value is 65 mm corresponding to the H5 Station. The evaporation-precipitation ratio exhibits a range between 81 and 100% (Salem, 1984).

TURK'S METHOD

wTurk's method also accounts for the annual precipitation, and temperature. It can be expressed as follows:

$E = X/[(0.9 + \{X/f(T)\}2]$, where

E, X and T as previously defined, and f(T) = temperature function = 300 + 25T + 0.05 T2.

The results obtained are in good agreement with those obtained using Wundt's method with small and negligible deviations of about 2%.

HAUDE'S METHOD

Since Haude's method accounts for other factors than those included in the previous methods, such as air saturation, vapour pressure and relative humidity, it was also used to calculate the evaporation rates in the study area. Haude's Method can be expressed as follows:

$ED = F \times S$, where

ED = daily evaporation (in mm)

F = coefficient for rainy months equal to 0.26 for the months from October to February, 0.33 for March, and 0.39 for the months from April to May

S = saturation deficit in mbar of air at 14.00 O'clock = (A x VP)/0.75, where A = 100 -R, where R is the relative humidity (in %), and A (in %)

VP = vapour pressure (in Tor).

The vapour pressure (VP) was taken from thermodynamic tables. The relative humidity (R) was taken from the Meteorological Department. The available figure of R, as mean annual measurements are between 45 and 68% for the study area (see Salem, 1984). The results obtained using Haude's method do not coincide with those with those obtained with the Wundt and Turk methods. This disagreement is probably due to non-accurate measurements of the variables mentioned in Eq. (6).

Evaporation volumes were calculated as averages of the results obtained from the Wundt

Table 3. Catchment Areas in the Study Area with their Code No. (CN), Areas (A, in km²), and their Annual Volumes (in MCM) of Precipitation (P), Evaporation (E), Runoff (R), and Infiltration (I), and Ratios (in %) of E/P, R/P, and I/P.

River/ Wadi	CN	A	P	E	E/P	R	R/P	I	I/P
Jordan	AB11	35	14.0	12.3	87.5				
	AB12	107	39.1	34.7	88.8				
	AB13	197	49.8	46.1	92.6				
	AB14	70	12.1	11.0	90.5				
	AB21	98	44.1	38.4	87.2				
	AB22	49	21.0	18.0	85.9				
	AB23	27	9.7	9.1	93.8				
	AB24	73	24.9	24.4	98.2				
	AB25	58	14.8	12.2	82.6				
TOTAL	AB	714	229.5	206.2	89.9	3.7	1.6	19.5	8.5
Yarmouk	AD21	98	45.1	36.0	79.8	2.3	5.1	6.8	15.1
	AD23	140	63.8	55.8	87.5	3.3	5.2	4.7	7.4
	AD52	1159	331.4	301.6	91.0	23.3	7.0	6.5	2.0
TOTAL	AD	1397	440.3	393.4	89.3	28.9	6.6	18.0	24.5
Arab	AE	267	124.0	105.7	85.2	3.7	3.0	14.6	11.8
Ziqlab	AF	106	51.2	41.9	81.8	1.4	2.7	7.9	15.4
Jurm	AG	22	8.9	7.9	88.8	0.5	5.6	0.5	5.6
Yabis	AH	124	58.4	48.8	83.6	0.6	1.0	9.0	15.4
Kufrinja	AJ	111	61.6	51.9	84.2	1.0	1.6	8.7	14.1
Rajeb	AK	85	44.8	39.6	88.4	0.7	1.6	4.4	9.8
TOTAL	AE-AK	715	348.9	295.8	84.8	7.9	2.3	45.0	12.9
Zerqa	AL0	90	28.0	24.0	85.7	0.3	1.1	3.7	13.2
	AL11	841	245.6	241.3	98.3	3.7	1.5	?	?
	AL21	40	14.0	11.0	78.6	2.4	17.0	3.0	21.4
	AL22	32	11.2	10.5	93.8	0.4	0.4	0.7	6.3
	AL23	253	105.6	98.6	93.4	0.8	0.8	6.8	6.4
	AL31	26	7.8	6.8	87.2	0.2	2.6	0.8	10.3
	AL32	122	27.4	23.0	83.9	1.1	4.0	3.3	12.0
	AL72	500	65.6	62.5	95.3	0.2	0.3	2.9	4.4
	AL73	1139	176.1	171.2	97.2	0.7	0.4	4.5	2.6
TOTAL	AL	3043	648.9	648.9	95.2	9.4	1.4	25.7	3.8
Shueib	AM	21	6.9	5.3	76.8	.007	0.1	1.6	23.2
TOTAL OF TOTALS		5890	1707	1550	90.8	49.9	2.9	110	6.4

and Turk methods for the different stations. These volumes were calculated for each catchment area, using the isohyetal evaporation map (Salem, 1984). This was achieved by multiplying the area between every two isohyets by the mean annual evaporation. The annual evaporation volume corresponding to the large catchment areas ranges between 206 and about 650 MCM. These volumes amount to 90-95% of the total precipitation. In general, the study area as a whole received an annual amount of precipitation of 1707 MCM, and about 91% (1550 MCM) of the precipitation evaporates annually (Table 3). By introducing evaporation rates in Eq. (3) instead of precipitation rates, the average annual evaporation was calculated for the area as a whole to be about 1600 MCM.

SURFACE RUNOFF

Surface runoff is the residual water of the hydrological cycle which has not evaporated or infiltrated. The runoff comprises three elements; overland flow as a thin sheet of water, small stream flows, and river flows.

Data collected by the gauge stations were used to make the runoff calculations. The method used to calculate precipitation and evaporation rates was also used to calculate annual rates of runoff for the various catchment areas. In general, the catchments included in the study area exhibit the following ratios of surface runoff in relation to the total annual volume of runoff, which is about 50 MCM: AB = 7%, AD = 58%, AE-AK = 16% and AL = 19% (Table 3).

As shown in the hydrological classification, the study area is underlain by various geological formations. These formations were simplified here into alluvial and wadi-fill deposits (R), lower and upper chalk intercalated with chert, (B3-B5), lower silicified limestone (B1-B2), upper limestone (A7), limestone and marl (A4-A6), lower marl and limestone (A1-A3), sandstone (K-Z), and basalt (B4). Also, the area was divided, as previously seen, into four catchments; AB, AD, AE-AK, and AL. Because of geological, topographic and climate considerations, the Rift Valley catchments (AE-AK) were treated as one region. This area, for example, is mostly covered by the (A7) Formation, which forms about one third of the whole catchment area (AE-AK). The remaining part of the area is covered by the (R, B3-B5, B1-B2, A4-A6, and A1-A3) formations. A descriptive table is given in Salem (1984). The Zerqa River Catchment (AL) consists of 9 drainage areas with a total area of 3043 km, forming about 52% of the study area. It is covered by all the geological formations including the sandstone (K-Z), Ajlun (A1- A7), Belqa (B1-B5), basalt (BA) and alluvial deposits (R). This classification of the study area into hydrogeological formations and drainage catchments, enabled calculation of the specific discharge (Runoff Volume/Specific Area) of the different geological formations of the catchment areas. Equations were developed to be
used in this part of the study (Salem, 1984). The general equations for specific discharge has the following form:

$afA + bfB + cfC + \dots\dots + nfN = Z$, where,

a, b,..,n = percentage of an area covered by a geological formation relative to the total area

A, B,..,N = geological formations, i.e R, B1-B3, A7, etc.

f = specific discharge of a geological formation (in MCM/km2).

Z = specific discharge of a drainage area (in MCM/km2).

By solving up to nine equations for each catchment area, including all the drainage systems and all the geological formations, the specific runoff discharge (f) for every geological formation was obtained. The calculated specific discharge (f) of the different geological formations located in the three main catchments (AD, AE-AK, and AL) are given in Table (4).

Table (4) shows that the specific discharge (f) for the different geological formations in the three catchment areas ranges between 5.0x10-3 and 7.9x10-1 MCM/km2. This range corresponds, respectively, to alluvial and Wadi-fill formation (R), and to the chalk intercalated with chert (B3-B5). Both formations are located in the Zerqa River Catchment (AL). This result indicates that the alluvial formation shows the lowest value of specific discharge. This is due to its recent age, unconsolidation and high porosity,
whereby a large amount of surface water infiltrates the subsurface. At the other extreme,

the chalk-cherty formation has the highest rate, probably due to its older age and lower porosity. So the major part of the runoff flows on the surface. In general, the three catchments, mentioned above, exhibit the following rates of specific discharge (in MCM/km2): AD = 2.07x10-2, AE-AK = 1.12x10-2, and AL = 3.1x10-3. These results indicate that high amounts of runoff infiltrate the subsurface of the (AL) catchment area.

Table 4. Specific Discharge Rates (in MCM/km) of the Geological Formations in Respect to the Catchment Areas.

f of Geol. Form	f_R	f_{B3-B5}	f_{B1-B2}	f_{A7}	f_{A4-A6}	f_{A1-A3}	f_{K-Z}	fBA
Catchment								
AD	2.1×10^{2}	2.4×10^{2}	3.6×10^{2}					
AE-AK	4.8×10^{2}	2.4×10^{2}	6.7×10^{2}	1.3×10^{2}	5.6×10^{2}	4.5×10^{2}		
AL	5.0×10^{-3}	7.9×10^{-1}	8.0×10^{-3}	3.9×10^{-2}	7.5×10^{-3}	6.0×10^{-3}	5.5×10^{-3}	2.5x10-2

INFILTRATION

Infiltration is one of the most difficult elements of the hydrological cycle to quantify. Precipitation, which does not form runoff, either infiltrates the soil and then evaporates, or to join the groundwater storage.

The water table is the upper surface of the completely saturated subsurface soils. Directly above the water table is the capillary fringe where water is held by capillary forces. The height of this rise depends on many factors, such as the pore size and permeability of the soil. The entire zone from the water table to the surface is known as the aeration zone or the zone of suspended water, where destructive chemical actions and physical processes occur. Infiltration is strongly dependent on the moisture content of soils, and whether the soils or rocks are fractured and cracked. Dense vegetal cover promotes high rates of infiltration, where the organic debris forms a sponge-like layer retaining moisture.

The available information on precipitation (P), evaporation (E) and runoff (R) were used in the following simple formula to calculate the annual volumes of infiltration (I, in MCM): $I = P - (E + R)$.

The results obtained are given in Table (3). It can be seen that the total volume of annual infiltration all over the study area is 110 MCM. It only forms about 6% of the total annual volume of rainfall (1707 MCM). Table (3) also shows that the highest percentage of infiltration takes place in the western highlands and the (AE-AK) catchments. The heavily fissured and fractured outcropping rocks allow more surface water to infiltrate into the subsurface. Also, the basaltic rocks in the eastern regions are highly fractured allowing more surface water to recharge the basaltic aquifer underneath.

SURFACE-SUBSURFACE WATER BUDGET

Within the study area, four major water balance regions were recognized. They were defined by their groundwater divides and limits of aquifers. These regions are:
Northern Escarpment to the Jordan Valley (AB); Yarmouk Basin (AD); Rift Side Catchments (AE-AK) and Zerqa River Catchment (AL). These regions were further subdivided into various drainage areas with more definite boundaries (Table 3). Some of these regions and drainage areas can be considered as groundwater basins, where the

groundwater is recharged and discharged within their boundaries. But due to the presence of at least two different hydraulic complexes; shallow and deep, the boundaries of a groundwater basin in respect to one aquifer does not necessarily coincide with those of other aquifers.

GROUNDWATER DISCHARGE

The recharge of groundwater in an area equals the sum of discharged quanitities. The total discharge (Table 3) in the study area can be subdivided into evaporation and surface runoff. The annual volume of evaporation was found to be about 1550 MCM, which forms about 91% of the total annual rainfall received by the study area. The surface runoff discharge includes: spring and gauge station discharge (measured), and spring and seeps discharge (unmeasured). The total amount of annual runoff was calculated to be about 50 MCM, which forms only about 3% of the total annual rainfall. The evaporation and surface runoff together form about 94%.

GROUNDWATER RECHARGE

Groundwater recharge can be divided into infiltrated water and other resources. The infiltrated water is the residual part of the rainfall after subtracting the evaporation and runoff. This part penetrates the subsurface to recharge the groundwater aquifers. This part was calculated to be 110 MCM/Y, which forms about 6% of the total annual rainfall (Table 3). In addition to the infiltrated water that directly recharges the aquifer system, indirect recharge from surface runoff, flood spreading, irrigation losses into the aquifer, waste-water infiltration (return flow of the used water), and dam losses, also occured. Because of the small quantity of indirect recharge, it is usually negligible in arid zones like Jordan. Another source of recharge is the subsurface inflow between the aquifers.

HYDROGEOLOGY, HYDRODYNAMICS, AND HYDROCHEMISTRY OF THE AQUIFER SYSTEMS

Data on 375 wells, from files and documents of the Natural Resources Authority (NRA) and the Water Master Plan of Jordan (GTZ), were collected and tabulated. These data were stored in the Water Research and Study Centre at the University of Jordan/Amman. These records include coordinates and names of wells, surface elevation, names of aquifers penetrated by the wells, dates of drilling and production, depth to aquifers, total depths of wells, saturated thickness within the aquifers, depth to water (static water level in the wells), water level above sea level (potentiometric surfaces), tested yield, drawdown of water inside the wells, specific capacity of the wells, and electric conductivity of total dissolved solids. Most of the wells under study were drilled in consolidated and compacted sedimentary and basaltic aquifers. As will be seen later, a wide range in the calculated parameters (permeability, water flow velocity, transmissivity and, in turn, well yield) were predicted. This might be due to the strong tectonic activities affecting the area at various geological times.

Most of the groundwater samples taken from different wells in the study area (NRA files, and GTZ, 1977) were of calcium carbonate type. By increasing the salinity, the Na, Mg and Cl ions become dominant. The sulfate content is generally low. The water quality or salt content (Total Dissolved Solids, TDS) in the various aquifer systems (Table 5) varies widely depending on many factors, such as the recharge area, and surface flow recharging the aquifers, amount of evaporation, groundwater age, subsurface flow, circulation of groundwater, and others. Generally, the study area includes two main regions of low salinities, i.e the mountainous regions of Ajlun-Amman, and the area extending from Jebel Druze southwards to Wadi Dhuleil and Azraq. These areas are characterized by low salt content of between 250 and 550 ppm, which indicates that the groundwater in these areas is drinking water of very good quality. Isosalinity maps of the various aquifers are given in Salem (1984).

PETROPHYSICAL AND HYDROGEOLOGICAL PROPERTIES

The following section examines the hydrodynamics of the aquifer systems in terms of their hydrogeological and petrophysical parameters. These parameters are: discharge or tested yield (Q), hydraulic conductivity or permeability (K), drawdown (DD), specific capacity (SC), transmissivity (T), hydraulic gradient (I), groundwater flow (Qf), and filter and distance velocities (Vf) and (Vd), respectively. Information about these parameters provides a basis for determining the aquifer potential and its characteristic.

DISCHARGE OR TESTED YIELD (Q) AND PERMEABILITY (K)

The yield of any aquifer is highly dependent on its lithological composition and structural elements affecting the aquifer. According to Darcy's law (Todd, 1959), the yield (Q) can be calculated from the following equation:

$Q = K \times A \times (dh/dl)$, where,

Q = discharge or yield (in m3/sec)
A = cross sectional area (in m2)
K = hydraulic conductivity (in m/s)
dh/dI = hydraulic gradient (dimensionless).

Eq. (9) shows that increases in area and hydraulic conductivity lead to an increase in discharge. The hydraulic conductivity of a material is a measure of its ability to transmit fluid under a hydraulic gradient. Variation in (K) due to fracturing, heterogeneity of sediments, and three directional anisotropy causes an irregularity and variability in discharge within the same aquifer. For unconsolidated aquifers, (K in m/s) can be approximated by plotting (Q in m3/s) versus (DD in m) and by using the following formula:

$K = 2(Q2 - Q1)/ (H12 - H22)$, where

$Q1$ and $Q2$ = discharge at two steps (in m3/s)
$H1$ and $H2$ = drawdown magnitude (in m).

DRAWDOWN (DD) AND SPECIFIC CAPACITY (SC)

The drawdown (DD) of a well is used to calculate the specific capacity (SC). It is also essential in the calculations of transmissivity (T) and, as previously seen, the hydraulic conductivity (K). As will be seen later, the (DD) obviously varies well to well within the same aquifer and from one aquifer to another. Sometimes, it shows a magnitude between 0.1 and 100 m (1000-fold). The specific capacity (SC in m2/s) can be obtained by dividing the discharge (Q) of a well by its drawdown (DD). This parameter is a measure of the effectiveness of a well, and it is an indicator of the steady flow. It is also directly linked to the transmissivity of an aquifer as it determines the (DD) per unit thickness during pumping.

TRANSMISSIVITY (T)

Transmissivity (T) is a measure of the productivity of a unit thickness of an aquifer. It is defined (in m2/s) as the product of permeability (K) times thickness (B), namely:
T = K x B.

It can also be calculated using the following formula (Jacob, 1940):
T = (0.183 x Q)/S, where,
S = drawdown difference (in m) per log cycle of time, to the time intercept on the zero-drawdown axis.

In this study, (T) was calculate according to Eq. (12). The drawdown was plotted versus the logarithm of time (Salem, 1984). The National Water Master Plan of Jordan (GTZ, 1977) found an empirical formula relating the specific capacity (SC) to the transmissivity (T), namely:
T = SC x 34.

HYDRAULIC GRADIENT (I)

The hydraulic gradient (I), as a dimensionless parameter, is defined as the difference (dh) n the potentiometric surfaces (water head above sea level between two potential lines (in m), divided by the distance (dI in m) between them; i.e.:
I = dh/dI.
The values of (I) obtained for all the studied aquifers show very small variations.

GROUNDWATER FLOW (Qf) AND FLOW VELOCITIES (Vf AND Vd)

The amount of groundwater flow in a certain region or through a part of an aquifer can be calculated from the groundwater gradient and permeability by using the groundwater contour maps, and by applying the following formula given by Lohman (1971):
Qf = (T x h x Nf)/Nd, where,
Qf = groundwater flow (in m3/s)
T = transmissivity (in m2/s) = K x B, K and B as previously defined
h = total potential drop or head loss (in m)
Nf = number of flow lines
Nd = number of potential drops = head loss/contour interval.

The total flow of groundwater (Qt) for an aquifer system was estimated as follows:
Qt = ΣQ1 + Q2 + ... + QN, where,
N = number of sub-areas involved.

The flow velocities were studied in terms of filter velocity (Vf) and distance velocity (Vd). The filter velocity (Vf) was calculated by introducing the hydraulic gradient (I) and the hydraulic conductivity (K) in the following formula:
Vf = Q/A = K x I, where,

A = area (in m2).

The distance velocity (Vd) can be easily determined if the average porosity (Φ) is known. It was calculated as follows:
$Vd = Vf/\Phi$.

Because of the absence of laboratory-determined porosity (Φ), a value of 17% (Salameh and Udluft, 1984) was used for sandstone aquifer, and values of 5% and 8% (Todd, 1959) were used for limestone and basalt aquifers, respectively. For calculating the fluid velocity in the aquitards, a (Φ) value of 1% (Salameh and Udluft, 1984) was used.

The mean vertical permeability (Kv), as a parameter indicating the anisotropic behaviour of an aquifer and fluid flow in the vertical direction, was calculated according to the following formula (Bouwer, 1978):
$Kv = H/(\Sigma hi/Ki)$, where,
Kv = mean vertical permeability of the whole sequence (in m/s)
H = thickness of the whole sequence (in m)
hi = saturated thickness of unit i (in m)
Ki = permeability of unit i (in m/s).

AQUIFER SYSTEMS AND THEIR PROPERTIES

The aquifer systems were classified into five groups; Kurnub-Zerqa (K-Z), Nau'r (A1-A2), Hummar (A4), Amman-Wadi Sir-Basalt (A7-B2-BA), and Alluvial Deposits and Wadi-Fill (R). As previously seen, these formations were classified and discussed in terms of geology and hydrology. Below, the various aquifer system in the study area are examined in terms of their potential and hydraulic flow in relation to their hydrogeological and petrophysical parameters. Then, a summary of the hydrochemistry is presented. Isosalinity and potentiometric surface maps of the various aquifer systems are given in Salem (1984).

Table (5) shows the various hydrogeological parameters of the wells drilled in the study area, and the deduced physical properties of the different aquifer systems. Table (6) shows the aquifer systems and their sub-areas as shown in the potentionetric surface maps, Salem, 1984) with their hydrodynamic properties including hydraulic conductivity (K), hydraulic gradient (I), and filter (Vf) and distance (Vd) velocities of the groundwater flow (Qf). Table (7) shows porosity (Φ), in addition to the variables used in the construction of the groundwater contour maps (potentiometric surface maps) for all the aquifer systems under study.

SANDSTONE AQUIFER SYSTEM (K-Z)

The sandstone aquifer system is known as Kurnub-Zerqa group (K-Z) of Triassic-Jurassic-Lower Cretaceous age. It mainly consists of sandstone and shale. In Jeresh District, the lower part of this system has a great potential since it contains porous sandstone with very few argillaceous horizons. The upper part of this system has shown disappointing productivity due to its mixed sandy and shaly horizons characterized by low permeability. The wells drilled in the fine-grained sandstone aquifer have fairly good yields with an average of 40 m3/h. Direct recharge is limited due to its small outcropping area. This system is being mainly exploited in Baqa' region. The (K-Z) aquifer system is separated from Disi aquifer in southeastern Jordan by the Khreim Group, which consists if a complex of sediments made of sandstone, siltstone, and shale. On a large scale, the Disi-Khreim/Kurnub-Zerqa aquifer system are considered as one basal aquifer complex with a high potential.

Table 5. Data from Wells on Physical Properties of the Aquifer Systems in the Study Area.

Aquifer System	K-Z	A1-A2	A4	A7-B2-BA	R
Surface Elevation (m)	450-675	475-780	500-950	325-835	-115- -253
Depth to Aquifer (m)	50-250	50-170	65-240	60-400	60-230
Saturated Thickness (m)	20-155	30-130	20-50	<30->250	30-200
Static Water Level (m)	<50->100	<100-150	<50-295	50-305 (*4)	<35
Tested Yield (m^3/h)	8-100	25-130	4-150	10-120 215-400	60-160
Drawdown (m)(*8)	1.5-140	0.1-95	2-120	0.1-100 (*5)	12-83
Specific Capacity (m^2/h)	.01-20	.01-12	.01-73	.01-250 (*6)	0.7-7
Transmissivity (m^2/d)	8-88 (*1)	0.3-100	3-315 (*3)	$0.1\text{-}10^6$	25-350
Permeability (m/s)	$6.1x10^7\text{-}5.3x10^5$	$2.0x10^8\text{-}3.1x10^5$	$8.1x10^7\text{-}7.5x10^4$	$3.9x10^8\text{-}3.3x10^2$	$1.4x10^6\text{-}6.9x10^5$
Hydraulic Gradient	$2.12x10^3\text{-}3.73x10^3$	$3.1x10^3\text{-}5.1x10^3$	$1.28x10^3\text{-}6.5x10^5$	$2.33x10^4\text{-}4.21x10^3$	$1.75x10^3\text{-}1.65x10^2$
Salinity, TDS (ppm)	280-840 (*2)	333-650	350-565	220-800 (*7)	415-1344

NOTE: K-Z, A1-A2, A4, A7-B2-BA, and R denote, respectively, aquifer systems of Kurnub-Zerqa Sandstone, Nau'r Formation, Hummar Formation, Amman-Wadi Sir-Basalt, and Alluvial Deposits and Wadi-Fill. The marked-numbers indicate: (*1) = A few wells have values around 1500 m2/d. (*2) = Two wells have values of 1116 and 1985 ppm. (*3) = Some wells exhibit values around 3000 m2/d. (*4) = Some wells have static water even below 20 m. (*5) = Some wells penetrating basalt have drawdown less than 0.1 m. (*6) = Some wells exhibit values up to 6200 m2/h. (*7) = Very few wells have a range between 850 and 1120 ppm. (*8) = Some wells drilled in the (A4) Formation show a drawdown of up to 120 m with yield of less than 10 m3/h; other wells in the same formation show very low drawdown with yield up to 146 m3/h.

The groundwater contour map (potentiometric head or surface map) of the (K-Z) aquifer system (Salem, 1984) shows an average potentiometric head difference (PHD) of 95 m with an average hydraulic gradient (I) of 2.93x10-3, and average permeability (K) of 1.25x10-5 m/s. This map also shows a structural nose plunging southwards. Groundwater in this aquifer generally flows in two main directions. In the eastern part (R1 in Table 7) it flows to the southeast, while in the western part (R2 in Table 7) it flows to the southwest. The central part of the aquifer can be considered as a structural basin distributing water in the eastern and western directions. This basin could be related to an anticline extending for a long distance from northeast to southeast. This aquifer is recharged from the outcrops near Jeresh City, as well as from the rainfall through the Nodular and Echinoidal Units overlying the sandstone aquifer.

The average filter velocity (Vf) is about 8 m/y, and the distance velocity (Vd) is about 46 m/y. If average values of permeability and hydraulic gradient (Table 6) used, with an aquifer width of 120 km and a saturated thickness of 500 m (Salameh and Udluft, 1984), then according to Darcy's Law (Eq.9) the groundwater flow in the sandstone aquifer equals 13.1 m3/s. If the (K-Z) aquifer is recharged through an area extending 150 km N-S and 110 km E-W, and the Upper Cretaceous Units overlying and recharging the (K-Z) sandstone aquifer are 600 m thick, with a mean piezometric differance between the upper aquifers and the sandstone aquifer of 150 m (gradient = 150/600 = 0.25), then the mean vertical permeability (Kv) of the sequence is 3.18x10-9 m/s. By introducing this value in Eq. (19), in addition to the average permeabilities of the different lithological units (A1-A2, A4, A7-B2) and their saturated thicknesses of 75, 50 and 60 m, respectively, the average permeability (K4) of the aquitards beneath the Upper Cretaceous Units will be 2.27x10-9 m/s (these aquitards exhibit a total thickness of 435 m). This can be explained as follows: 3.18 x 10-9 = 610/[{75/7.73x10-6} + {50/1.21x10-4} + {60/5.30x10-5} + {435/K4}].

Table 6. Hydrogeological and Physical Properties of Aquifer SYstems and their Sub-areas.

Aquifer System	Sub-area	K (m/s)	I	Filter Velocity (V_f)		Φ (%)	Distance Velocity (V_d)	
				(m/s)	(m/y)		(m/s)	(m/y)
R	R1 R2	3.12×10^{5} 2.17×10^{5}	1.75×10^{3} 1.66×10^{2}	5.46×10^{8} 3.59×10^{7}	1.7 11.3			
Average		2.65×10^{5}	9.15×10^{3}	2.07×10^{7}	6.5	30	6.90×10^{7}	21.64
A7-B2	R1 R2 R3 R4 R5 R6 R7 R8	2.30×10^{5} 1.54×10^{4} 2.96×10^{4} 2.02×10^{5} 5.60×10^{3} 2.02×10^{2} 1.38×10^{4} 1.31×10^{4}	2.75×10^{3} 1.01×10^{3} 2.58×10^{3} 4.21×10^{3} 4.76×10^{4} 1.16×10^{3} 4.13×10^{4} 2.33×10^{4}	6.33×10^{8} 1.60×10^{9} 7.64×10^{9} 8.50×10^{8} 2.66×10^{6} 2.35×10^{5} 5.72×10^{8} 3.06×10^{7}	2.0 0.1 0.3 2.7 84.0 742.0 1.8 9.7			
Average		5.30×10^{5}	1.61×10^{6}	8.68×10^{8}	2.7	05	1.74×10^{6}	54.74
Basalt (BA)				6.02×10^{8}	1.9	10	6.02×10^{7}	19.00
A4	R1 R2 DA	4.56×10^{4} 2.46×10^{5} 3.17×10^{5}	6.50×10^{3} $4.73 \times 10_{3}$ 1.28×10^{3}	2.96×10^{6} 1.16×10^{7} 4.06×10^{8}	93.5 3.7 1.3			
Average		1.71×10^{4}	4.17×10^{3}	1.04×10^{6}	32.8	05	2.08×10^{5}	656.0
A1-A2	R1 R2	1.35×10^{6} 1.41×10^{5}	5.06×10^{6} 3.10×10^{3}	6.83×10^{8} 4.37×10^{8}	2.2 1.4			
Average		7.73×10^{6}	4.08×10^{3}	2.53×10^{8}	0.8	05	5.06×10^{7}	15.96
K-Z	R1 R2 DA	1.05×10^{5} 1.45×10^{5} 1.81×10^{4}	2.12×10^{3} 3.73×10^{3} 3.71×10^{3}	2.14×10^{8} 5.41×10^{8} 6.72×10^{7}	0.7 1.7 21.2			
Average		6.85×10^{5}	3.19×10^{3}	2.49×10^{7}	7.9	17	1.46×10^{6}	46.20

NOTE: (K) denotes permeability (in m/s); (I) denotes hydraulic gradient (dimensionless); filter velocity (Vf) and distance velocity (Vd) are given (in m/s and m/y); Φ is porosity (in %); (DA) denotes deep aquifer.

By considering the (K4) value obtained above, and a hydraulic gradient of 0.25 the filter velocity in the aquitards will be 5.66x10-10 m/s (1.79x10-2 m/y). A drop of water needs about 245 years to cross the Upper Cretaceous aquitards (Nodular and Echinoidal), considering a thickness of 225 and 210 m, respectively, and a distance velocity of 5.66x10-8 m/s. A drop of water needs about 1300 years to flow horizontally through the sandstone aquifer plus 245 years to cross vertically the Upper Cretaceous sediments, to give an averge time of about 1545 years. This figure indicates the average age of the water discharged from the sandstone aquifer.

Table 7. Variables Used in Calculating the Groundwater Flow (in m^3/s and MCM/y).

Aquifer System	Sub-area	K (m/s)	B (m)	h (m)	N_f	N_d	Groundwater Flow (Q_t)	
							m^3/s	MCM/y
R	R1 R2	$3.12x10^{-5}$ $21.7x10^{-5}$	}39	13	3	13	$3.1x10^{-2}$	0.98
Average		$2.65x10^{-5}$	TOTAL				$3.1x10^{-2}$	0.98
A7-B2	R1 R2 R3 R4 R5 R6 R7 R8	$2.30x10^{-5}$ $1.54x10^{-4}$ $2.96x10^{-6}$ $2.02x10^{-5}$ $5.60x10^{-5}$ $2.02x10^{-2}$ $1.38x10^{-4}$ $1.31x10^{-4}$	90 112 98 94 - - 44 63	20 10 40 60 - - 20 40	14 9 6 10 - - 12 10	2 1 4 6 - - 2 4	$2.9x10^{-1}$ $1.6x10^{-2}$ $1.7x10^{-2}$ $1.9x10^{-1}$ - - $7.3x10^{-1}$ $8.3x10^{-1}$	9.14 0.49 0.55 6.00 - - 23.10 26.10
Average		$5.30x10^{-5}$	TOTAL				2.07	65.33
A4	R1 R2 DA	$4.56x10^{-4}$ $2.46x10^{-5}$ $3.17x10^{-5}$	}43 10	280 70	17 10	28 7	$3.2x10^{-1}$ $3.2x10^{-2}$	9.97 1.00
Average		$1.71x10^{-4}$	TOTAL				$4.49x10^{-1}$	10.97
A1-A2	R1 R2	$1.35x10^{-6}$ $1.41x10^{-5}$	82 82	110 50	10 7	11 5	$3.1x10^{-5}$ $7.8x10^{-2}$	$9.62X10^{-2}$ 2.44
Average		$7.73x10^{-6}$	TOTAL				$8.05x10^{-2}$	2.73 2.83 15.10
K-Z	R1 R2 DA	$1.05x10^{-5}$ $1.45x10^{-5}$ $1.81x10^{-4}$	103 103 33	100 100 100	8 6 8	10 10 10	$8.7x10^{-2}$ $9.0x10^{-2}$ $4.8x10^{-1}$	20.66
Average		$6.85x10^{-5}$	TOTAL				$6.59x10^{-1}$	100.50
TOTAL OF TOTALS (Q_t)							3.29	

NOTE: (K) denotes permeability (in m/s); (B) denotes saturated thickness (in m); (h) dnotes total potential drop (in m); (Nf) denotes number of flow lines; (Nd) denotes number of potential lines; and (DA) denotes deep aquifer.

The sandstone aquifer system (K-Z) shows higher salinity (TDS) than the carbonate aquifer systems. It has a range of (TDS) between 300 and 1100 ppm. Its isosalinity map (Salem, 1984) shows three domains. The first is located in the southern part of the map with a range between 300 and 600 ppm. The second domain is located in the central part of the map with a range between 600 and 800 ppm, and the third domain is located in the northern part of the map with a range between 800 and more than 1100 ppm. The high values of (TDS) in this aquifer in comparison with the other aquifer systems are attributed to the long residual time of the groundwater. This can be enhanced by the fact that the wells penetrate more depths in the northern part of the aquifer exhibit values of (TDS) higher than those drilled in the other parts of the aquifer. The low values of (TDS) in the southern part probably indicate a continuous recharge from the other parts. In comparing the isosalinity map with the potentiometric map, it can be said that the salinity in this aquifer decreases in the directions of flow.

NAU'R AQUIFER SYSTEM (A1-A2)

Within this formation, the limestone portion forms a good aquifer. This aquifer is considered of low potential with yields of less than 10 and 30 m3/h. This low productivity is probably due to the shale horizons intercalated with the limestone layers. This system is overlain by aquitard of Fuheis Formation (A3).

The groundwater contour map (Salem, 1984) of this system shows a structural nose plunging to the west. The southwestern part of this map (R1 in Table 7) shows small spaces between the potentiometric head contours with high (PHD) between 110 and 200 m, while the northeastern part (R2 in Table 7) shows wider spaces than (R1), namely of 50 m. The nose-shaped area between (R1) and (R2) can be considered as a distributing zone for groundwater flow flow in the northwestern, south and southwestern directions. This system exhibits a hydraulic gradient (I) averaging 4.08x10-3, and an average permeability (K) of 7.73x10-6 m/s. The potentiometric map shows that the recharge of this aquifer takes place in the highlands of Ajlun and Jeresh.

Water in Nau'r aquifer system (A1-A2) is characterized by low salinity, ranging from 333 to 512 ppm. Only one well located in the study area shows a value of 608 ppm. The isosalinity map of this aquifer (Salem, 1984) shows that the salinity increases southwards. This indicates that the aquifer is recharged in the northern part of the map.

HUMMAR AQUIFER SYSTEM (A4)

This aquifer is composed of light to dark grey, occasionally pink, hard crystalline, coarse-grained and highly fractured dolomitic limestone. The aquifer crops out west of Amman. The wells drilled in this aquifer are located at high surface elevations between 512 and 955 m above see level. This aquifer is considered a good potential aquifer with a medium yield between 4 and 135 m3/h. It is directly recharged from precipitation as water enters the aquifer from the high rainfall zones.

The potentiometric map of the Hummar aquifer (A4) exhibits a (PHD) value of 280 m (Salem, 1984). The eastern part (R1 in Table 7) shows higher values of (I) and (K) than the western part (R2 in Table 7). The direct recharge to this aquifer takes place through fractures, joints and faults that affect the outcrops in the high rainfall areas. The map shows that groundwater generally flows from northwest to southeast.

The Hummar aquifer system (A4) shows salinities between 300 and 560 ppm. Isosalinity map of this aquifer (Salem, 1984) shows that salinity increases westwards against the flow directions. The lower values of (TDS) in the northern part of the map indicate that the aquifer is recharge from this direction.

AMMAN-WADI SIR-BASALT AQUIFER SYSTEM (A7-B2-BA)

The limestone of the Wadi Sir Formation (A7) and the chert-marl of the Amman

Formation (B2) hydraulically combine to form an aquifer of good yield. In some locations (between Irbid City and Yarmouk River) some springs issue from the (B2) Formation. This aquifer system is considered, throughout the country, the most important aquifer. Its wide extension and outcropping on the high rainfall areas supply it continuously with good annual recharge. Generally, this aquifer consists of limestone, sandy limestone and silicified limestone. These rocks are highly jointed and well fractured, and in some cases, solution channels exist in the carbonate rocks. This character enables the aquifer to be highly permeable. The fractures are irregularly distributed, and hence the aquifer can be described as a heterogeneous formation showing considerable variations in permeability in the horizontal and vertical directions. The piezometric head (potentiometric surface) of this aquifer differs from the deep sandstone aquifer (K-Z) by about 110 m. This means a strong hydraulic barrier of marl layers exists in the series between (A1) and (A6). This aquifer is overlain by a thick marly layer (B3), which forms a confining bed encouraging this aquifer to be artesian, as in the Azraq area. This aquifer receives water by direct recharge from rainfall areas, and by indirect recharge entering the aquifer from the adjacent groundwater fields. One of the major fields transferring water into this aquifer through subsurface flow is the Wadi Dhuleil area. Environmental isotope studies (UNDP, 1970) proved this to be indirect recharge.

Basalt rocks extend from Jebel Druze in Syria southwards to Azraq and Wadi Dhuleil regions in Jordan. They form an aquifer of high hydrogeological importance and good hydraulic characters. Water of very good quality is encountered in this aquifer. In some regions of extremely high permeability, it is possible to extract large quantities of water. Generally, the groundwater is not discharged directly from the basalt aquifer, but is transferred at a contact zone to adjacent aquifers (limestone and gravels) and discharged as springs and base flow from these aquifers. The basalt and other water-bearing formations of Tertiary and Quaternary age form an aquifer known as shallow aquifer hydraulic complex. In many areas the basalt (BA) and Amman-Wadi Sir (A7-B2) aquifers are connected and therefore they are considered as one hydraulic complex. In the study area, both aquifers (A7-B2) and (BA) have essentially the same characteristics of yield, permeability and groundwater flow. Therefore they were treated as one aquifer system.

The groundwater contour map (Salem, 1984) of this hydraulic complex was divided into eight sub-areas, from (R1 to R8, Table 7). Flat regions occur in the northeastern and southern parts of the map, where wide spaces exist between the potentiometric contours. These regions exhibit a range of hydraulic gradient between 2.33x10-4 and 4.21x10-3 with an average of 1.61x10-3, and a range of permeability between 1.54x10-6 and 2.02x10-2 m/s with an average of 5.30x10-5 m/s. The map indicates a northwest plunging nose in the Mafraq area. This feature suggests that a structural element distributing the groundwater to the northeast and southwest. Two other basins occur around Um El-Jimal and towards Sama Sdoud, where the groundwater flows towards the centres of these basins. Generally, the potentiometric contours of this aquifer complex are characterized by undulation, especially in the southern part and the adjacent areas of the Syrian borders, where the groundwater flows in northwest and southwest. The northern part of this aquifer is recharged from the Jebel Druze area, and partly recharged by subsurface groundwater circulation from other regions of the aquifer. Generally, the groundwater in this complex flows in northwest and northeast directions. The total (PHD) in the aquifer as a whole is 130 m (between contours 530 and 400 m).

Amman-Wadi Sir-Basalt aquifer system (A7-B2-B4) exhibits a range of (TDS) between 250 and 750 ppm. The isosalinity map of this system (Salem, 1984) shows that few wells exhibit values outside this range, either lower or higher. The isosalinity map shows no coincidence with potentiometric map, whereas the TDS level may show an increase as a decrease with the flow directions. Also, two domains of (TDS) were recognized from the map. The first one has a range between 250 and 550 ppm indicating that the aquifer in this area is directly affected by new recharge. The second domain has a range between 400 and 800 ppm, reflecting the fact that most of the wells located in this domain penetrate to deeper depths. It is obvious from the map that the aquifer system becomes more saline towards north, where the area is highly populated. The Dhuleil area (eastern part of the map, Salem, 1980) generally shows lower salinities than other areas. This reflects the nature of the aquifer, which is made of basalt with rapid recharge and discharge characteristics. The southern part of the aquifer system has higher flow velocities accompanied by less salinity relative to the northern part which is characterized by lower velocities and higher salinities.

ALLUVIAL DEPOSITS AND WADI-FILL AQUIFER SYSTEM (R)

This aquifer is restricted to the major wadies and plateau gravel deposits. It is mainly composed of gravel, sand and silt. In some locations it gives high yields due to its high porosity and permeability. It is mainly recharged from precipitation and runoff of the wadis, and by subsurface flow from the bordering groundwater fields. This aquifer shows an average hydraulic gradient and permeability of 9.15x10-3 and 2.65x10-5 m/s, respectively. From Tables (5) and (6) it can be seen that this aquifer system generally exhibits higher hydraulic gradients than other system.

It can be concluded, according to the results presented in Table (7), that the total groundwater flow (Qt) in the various aquifers [Kurnub-Zerqa Sandstone (K-Z), Nau'r Nodular Limestone (A1-A2), Hummar Echinoidal Limestone (A4), Wadi Sir Massive Limestone (A7) -Amman Phosphatic-Silicified Limestone (B2)- Basalt (BA), (A7-B2-BA), and Alluvial Wadi-Fill Deposits (R)] equals about 100 MCM/y, namely:

Qt = Q(K-Z) + Q(A1-A2) + Q(A4) + Q(A7-B2-BA) + Q(R) = 20.66 + 2.54 + 10.97 + 65.33 + 0.98 = 100.5 MCM/y.

Table 8. Transmissivity (T) Results of Different Aquifer SYstems in the Study Area including Sandstone, Carbonate and Basalt Aquifer Systems.

Number of Wells	Range of T (m^2/d)	Average of T (m^2/d)
07	1.0×10^{-1} -1.0	3.00×10^{-1}
45	1.0 -1.0×10^{2}	4.10×10^{1}
35	1.0×10^{2} -1.0×10^{3}	3.67×10^{2}
21	1.0×10^{3} -1.0×10^{4}	4.30×10^{3}
15	1.0×10^{4} -1.0×10^{5}	3.74×10^{4}

This numerical method of calculating groundwater flow is approximate, especially as it did not take into consideration the heterogeneity of sediments of the various aquifer systems that cause the wide range of variations in permeability, transmissivity and other quantities. Nevertheless, the figures for groundwater flow derived in this study reflect very satisfactory results, especially as we know from the previous infiltration analysis, that the annual volume of infiltration is about 110 MCM (Table 3).

The transmissivity (T), as a product of saturated thickness times permeability, was obtained for many wells under study penetrating all the aquifer systems. Table (8) summarizes these results.

CONCLUSIONS

* The study area is located in the northern part of Jordan, and extends between coordinates N 160-240, and E 200-399. It covers an area of 5890 km2, with a range of elevation between 300m (below sea level) and 1200m (above sea level).
* The study area is mainly covered by rocks and sediments of Cretaceous, Tertiary and Quaternary ages. In some locations Jurassic and Triassic rocks crop out. The rock subdivisions after Quennell (1951), Masri (1963), McDonald and Partners (1965), Wolfart (1968), Bender (1968) and Sandstone Project (UNDP, 1969, 1970) were used in this study. The main folds, faults and flexures in the study area correspond to the principal structures in Jordan. The most dominant structural elements in the area are a complex structure that runs along Zerqa River Valley, the Suweilih Flexure and the Ajlun Dome.
* The rainfall occurring in the wet season between October/November and April/May is affected by the general conditions of the Rift Valley, East Bank Hills and Eastern Plateau regions. The highest monthly rainfall (195 mm) was recorded at Ras Muneif Station in January, and the lowest value (1.8 mm) was recorded at Jeresh Station in October. Ajlun Sation recorded the highest average annual rainfall with a value of 636 mm, whereas the lowest value (139 mm) was recorded at Wadi Zerqa Station. The highest mean annual rainfall of 633 mm was calculated for Kufrinja Catchment (AJ), and the lowest value (347 mm) was calculated for the Zerqa River Catchment (AL). The western highlands are affected by the highest average rainfall of 600mm. This rate decreases toward the E,W,N and S. The various catchments (AB,AD,AE-AK,AL,and AM), with a total area of 5890 km2, recorded a total annual volume of rainfall of about 1707 MCM.
* The evaporation rates were calculated according to three methods, Wundt, Turk and Haude. The area shows annual evaporation of about 91% of the total annual precipitation. The highest value of annual evaporation (650 MCM) was calculated for the Zerqa River Valley Catchment (AL), and the lowest value (206 MCM) was calculated for the Jordan River Catchment (AB). The small part of Shueib Catchment included in the study area shows annual evaporation of 5.3 MCM.
* The mean annual volume of runoff was calculated to be about 50 MCM, which amounts to about 3% of the total annual rainfall. The specific runoff discharge in the Rift Catchments (AE-AK) ranges between 5.0x10-3 and 7.88x10-1 MCM/km2 corresponding, respectively to the alluvial deposits (R) and the chalky chert limestones (B3-B5). The mean specific discharge of AD, AE-AK, and AL, respectively, is 2.07x10-2, 1.12x10-2 , and 3.10x10-3 MCM/km2.
* The total annual volume of infiltration was calculated to be 110 MCM, which is about 6.3% of the total annual volume of the rainfall.
* The wells drilled in the study area range in surface elevation from -235 to 950 m. The depth of these wells ranges between 50 and 400m. The saturated thickness of the different aquifers is between 30 and 250m. The static water level lies in a range between 20 and

305m below surface. The tested yield of the various wells studied exhibits a range between 4 and 250 m3/h. A few wells drilled in the basalt produce some 400m3/h. The drawdown of the static water level in the different aquifer systems shows a range between 0.1 and 140m. The specific capacity of the various aquifer systems ranges between 1.0x10-2 and 250 m2/h. The same wells with high yield in the basalt aquifer also show high specific capacity values of up to 6200 m2/h.

* The potential of the various aquifer systems can be evaluated from knowledge of transmissivity and hydraulic conductivity. Transmissivity exhibits a general range aquifer systems under study, of between 0.1 and 104 m2/d. The different aquifer systems (K-Z, A1-A2, A4, A7-B2-BA, and R) show, respectively, average hydraulic conductivity of 6.85x10-5, 7.73x10-6, 1.17x10-4, 5.30x10-5, and 2.65x10-5 m/s. It can generally be concluded that the Hummar aquifer system (A4) shows high hydraulic potential in terms of its highest value of average hydraulic conductivity (permeability). The average hydraulic gradient for the same aquifer system lies in a range between 1.61x10-3, corresponding to the (A7-B2-BA) system, and 4.17x10-3, corresponding to the (A4) system. The average filter velocity exhibits a range between 2.53x10-8 m/s, corresponding to the (A1-A2) system, and 1.40x10-6 m/s corresponding to the (A4) system. The distance velocity exhibits a range between 5.10x10-7 for (A1-A2), and 2.10x10-5 for (A4). The basalt aquifer has an average value of 6.02 m/2 m/s. This high distance velocity can be attributed to the high porosity of basalt (30%). These averages of tramsmissivity, permeability, hydraulic gradient and flow velocity indicate that the Hummar aquifer system (A4) can be considered the highest potential aquifer in the area.

* Small and large difference in the deduced petrophysical and hydrogeological parameters were found for the various aquifer systems, and even within the same aquifer system. This might be due to the variations in lithology, macro- and micro-textural and structural elements, and due to the heterogeneity and anisotropy characterizing the various aquifer system.

* The thickness of the saturated Upper Cretaceous Units that recharge the sandstone aquifer is about 600 m, and the piezometric difference is 150 m, resulting in a vertical gradient of 0.25. By assuming an aquitard porosity of 1%, these parameters give a mean vertical permeability of the whole sequence of 3.18x10-9 m/s, a filter velocity of 5.66x10-10 m/s, and a distance velocity of 5.66x10-8 m/s. Accordingly, the average age of water discharged from the sandstone aquifer system was calculated to be about 1550 years.

* The (K-Z, A1-A2, A4, and A7-B2-BA) aquifer systems show, respectively, an approximate average potentiometric head difference of 95, 155, 250, and 100m. The groundwater flow in these aquifer exhibits, respectively, values of about 20.7, 2.5, 11.0 and 65.3 MCM/y. The total of these amounts is about 100 MCM/y, which approximately equals the calculated amount of the infiltrated water (110 MCM/y).

* The groundwater in the sandstone aquifer system (K-Z) flows n the SE, SW, and S directions. The central part of this aquifer is considered a structural basin that distributes water to the SW and SE. The central part of the Nau'r aquifer system (A1-A2) appears to be a groundwater divide distributing water in the NW and SW directions. In the Hummar aquifer system (A4), water flows from NW to SE and partly southwards. The flow in the Amman-Wadi Sir-Basalt (A7-B2-BA) aquifer system takes place in the NW, SW, and NE directions. The (K-Z) aquifer was found to be recharged from the overlying rocks and from its outcroppings in different locations (Jeresh, Ajlun and Baqa'). The (A1-A2 and A4)

aquifer systems are recharged from the outcrops in different areas, while the (A7-B2-BA) aquifer system is mainly recharged from Jebel Druze in Syria. All the aquifer systems are also recharged from the subsurface water flowing between them.

* It was shown that the quality of groundwater in the study area varies widely depending on the recharge-discharge and flow conditions, evaporation rates, and age of groundwater. Generally, the study area includes two main regions of low salinity, I.E. the mountainous region of Ajlun-Amman, and the area extending from Jebel Druze southwards to Wadi Dhuleil and Azraq. The sandstone aquifer system (K-Z) shows higher (TDS) than the carbonate and basalt aquifer systems. This is probably due to the age of water in the sandstone aquifer and to the wastes affecting the recharge near the outcrops.

* Finally, from this comprehensive study of hydrology and hydrogeology of the area north of Zerqa River, the following points are highly recommended as being urgently required:

1. A serious program management and planning of all water resources available in the area.
2. Protection of the aquifer systems from any contamination sources.
3. Careful planning of any new wells to be drilled in the future.
4. Continuous protection of the springs and the wells already drilled.
5. Continuous chemical analysis of water samples from the springs and wells.

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THE LEGAL-INSTITUTIONAL ISSUES INVOLVED IN THE SOLUTION OF WATER CONFLICTS IN THE MIDDLE EAST: THE JORDAN

by

Dante A. Caponera*

1. GEOPHYSICAL ASPECTS

The headwaters of the Jordan river are made by four main streams: the Nahr Leddan, the Nahr Banyas (Syria) with an annual flow of 157 million m3, the Nahr Braghith and the Nahr Hasbani (Lebanon) with an annual flow of 157 million m3, which unite below Banyas and flow into the former Huleh marshes. From there the river falls below sea level, rushing down 280 meters in 14 km to a delta opening into the Lake Tiberias. This lake occupies an area of about 100 km2 at 210 m below sea level; the annual evaporation from this lake amounts to about 300 million m3. From Lake Tiberias up to the Dead Sea the Jordan follows a valley usually not more than 6.4 km wide, with the exception of the two small plains of Beisan and Jericho. It runs for about 100 km before reaching the Dead Sea at an elevation of 392 m below sea level.

The Jordan river has two major tributaries, both of which are on the left bank: (a) the Yarmouk (or Hiejromax), the headwaters of which are located in Syria and which forms the boundary between Syria and Jordan up to its confluence with the Jordan river about 7 km south of the Sea of Galilee; this is one of the more important sources of the Jordan river, contributing 40 percent of the total with an annual flow of 475 million m3; (b) the Zerka (or Jajbok), wholly located in the territory of Jordan.

The minor tributaries on the right bank are the Jalud, coming from the plain of Ezdraelon to the surroundings of Beisan, and the Fara from Nablus. Various salt springs rise in the lower valley; the remaining tributaries are seasonal wadis.

In many areas of the Jordan, groundwater is considered as the major water resource and, in some parts, the only one. It includes both renewable and non-renewable resources.

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The co-riparians of the Jordan river basin are Lebanon, Israel, Jordan and Syria.

2. DEVELOPMENT PLANS

Various plans have been prepared for the development of the water resources of this river basin. Their acceptance, partial or total, and their actual development have depended upon political events. Much of the cause of today's water crisis concerning the Jordan can be traced to actions taken during the time of the British Mandate.

These plans are briefly described herebelow.[1]

The Balfour Declaration of 1917 is the first document whereby the British government pledged its support for the "establishment in Palestine of a national home for the Jewish people," with the explicit provision that "nothing shall be done which may prejudice the civil and religious rights of existing non-Jewish communities." The British White Books were the first plans to be prepared and included reports by the Anglo-American Committee (1926-28) and those of the British Committee.[2]

The British High Commissioner, in 1926, granted a 70 year concession to Pinhas Rutenberg of the Palestine Electricity Corporation to utilize the water of the Jordan and Yarmouk rivers, thus denying the right to the Arabs the use of these waters without permission of the corporation (never granted).[3]

In 1937 Great Britain requested Mr. M. Ionides, director of development for the East Jordan government, to prepare a study of the water resources and irrigation potential of the Jordan river basin.[4] This study was to serve later as a reference for the United Nations plan for the partition of Palestine. According to this plan, the Yarmouk flood waters were to have been stored in Lake Tiberias. A part of the Yarmouk river waters, together with

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[1] For a brief review of these plans, see also: Hosh, Leonardo and Jad Isaac, Roots of the Water conflict in the Middle East, paper submitted to the Middle East Water Crisis Conference, University of Waterloo, Canada, May 7-9, 1992.

[2] UN Doc. A/70, Mandate for Palestine of 24 July, 1922, approved by the League of Nations.

[3] L. Hosh and J. Isaac, op cit, p.3.

[4] M.C. Ionides, The Water Resources of Transjordan and their Development, p. 8, London, (1939).

those stored in Lake Tiberias, were to have been diverted through the East Ghor canal to irrigate 75 thousand acres of land. Finally, the irrigation water of the Jordan river system were to have been used primarily within the Jordan river basin. This plan did not succeed due to the opposition of the Zionists.

In 1943 Mr. Walter Clay Lowdermilk published a book called "Palestine, Land of Promise," in which he stated that the full utilization of the Jordan waters would be sufficient for the settlement of 4 million Jews in addition to the 1.8 million Arabs already in Palestine.[5] The main theme of this book was the diversion of the upper sources of the Jordan plus the Litani river waters in Lebanon to the Negev in south Palestine, and to maintain the water level in the Dead Sea with water from the Mediterranean, taking advantage of the difference in levels, at the same time generating electricity on its way. Control over this project was to be solely in the hands of the Jews, and it was enthusiastically endorsed by them.

The Jewish Agency then requested an American engineer, Mr. James B. Hays, to investigate the technical and economic aspects of the project. The Hays plan proposed to divert half of the Yarmouk waters into Lake Tiberias to replace the waters which were to be diverted from the Jordan river upstream, as proposed in the Lowdermilk plan.

To implement this plan, after the 1948 war the Israeli government formulated a Seven Year Plan, approved in 1953, to utilize the area's water resources, and the construction of the National Water Carrier began. This project included the diversion of the Jordan waters to the Negev and the establishment of a comprehensive network to provide water to all parts of Israel, in spite of the transfer of water from one basin or aquifer to another having been expressly prohibited by Jordanian water legislation in force before Israeli occupation.[6]

During the 1948 war, the Rutenberg electricity generating plant was destroyed by Israel to avoid exclusive control of the Jordan and Yarmouk waters by the Arabs.

In order to develop irrigation for the Palestinian refugees,

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[5] W.C. Lowdermilk, Palestine, Land of Promise, p. 169, Harper & Bros., New York (1944).

[6] Art. 60 of the Law of 1959, in Caponera, D.A., Water Policies, Legislation and Practices in Israeli Occupied Palestinian and other Arab Territories, report to the United Nations in pursuance of General Assembly Resolution 38/144 of 14 December, 1983; issued as GA ECOSOC A/38/282-E/1983/84, New York, 23 June, 1984.

in 1949 the Jordanian government, together with UNRWA (United Nations Relief and Works Agency) commissioned the firm of Sir Murdoch MacDonald to prepare a scheme as a complement to the Ionides Plan. Finalized in 1951, this plan proposed that the Jordan waters be utilized for irrigation along both banks, and that Lake Tiberias be utilized as a storage reservoir for the Yarmouk river waters. The Arabs were unhappy with the idea of utilizing Lake Tiberias for storage.

In 1952 Mr. M. Bunger, an American engineer working for the Point 4 program in Jordan, proposed another plan which was favored by the Arabs.[7] It included the construction of a dam to serve as a water storage reservoir along the Yarmouk at the junction of three valleys in the Maqarin area. Another dam at Addassiyah and a series of canals would irrigate the East Ghor area and would have included two hydro-electric plants at the sites of the two dams for the purpose of supplying electricity and water to both Jordan and Syria. The Israeli disapproved of the plan, claiming that the original Rutenberg Concession had exclusive rights to the Yarmouk waters. They convinced the US government and UNRWA to withdraw their support, and the plan was abandoned.

A special envoy of President Eisenhower, Mr. Erik Johnston, proposed still another plan in 1953, which was essentially a combination of the Lowdermilk-Hays and MacDonald-Bunger plans.[8] It was based on the philosophy of the TVA, i.e., taking water where it is available and bringing it to where it is needed, irrespective of political boundaries. This plan satisfied neither the Israeli nor the Arabs. It was rejected by the Arab states for a number of reasons, among which that it was formulated without any consideration of the political boundaries of the basin states, and that Lebanon would benefit little from the project, in spite of having land to develop in the basin. In addition, most of the Jordan water would be stored in the Tiberias lake inside Israel; it would give 33 percent of the total flow to Israel and 67 percent to the Arab states. The use of Lake Tiberias as a storage reservoir was not considered sound because of heavy evaporation. Finally, the acceptance of the project would have implied an indirect cooperation with Israel, not recognized by the Arabs. A modified form of the Johnston Plan was subsequently used by the United States as the basis for negotiation.

In response to the Johnston proposal, an Arab project for

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[7] MacDonald and Bunger Plans, in Encyclopedia of Palestine, Palestinian Encyclopedia Committee, Vol. 1, p. 153, Damascus, (1984).

[8] L. Hosh and J. Isaac, <u>op cit</u>, pp. 5-6.

the utilization of the Jordan waters was presented in March, 1954.[9] It was based on the principle that it is not possible to plan the utilization of the Jordan water without considering the political boundaries. On these grounds, it allocated 20 percent of the utilizable water to the occupied area and 80 percent to the Arab countries. The Yarmouk water would not be stored in Lake Tiberias, and the total area which would be developed would amount to about 880,000 dunums (1 acre = 4 dunums), of which 235,000 dunums or 26 percent would have been for the occupied area. The power produced under this scheme would be about 20 percent for the occupied area and 80 percent for the Arab countries.

The Israeli revived the National Water Carrier project under the Ten Year Plan in 1958, which included a proposal to divert the Jordan water north of Lake Tiberias to the Negev (outside the catchment area).[10] The total amount of water to be used was to have been 478 million m3. It involved the construction of an open canal up to Banhouf storage lake and from there to Tel Aviv for about 77 km, then south of Tel Aviv with a division of two lines with pumping stations and different structures. They would catch also the salty springs. Actions taken under the Ten Year Plan carefully complied to Israel's water allocation provided for in the Revised Johnston Plan.

As a reaction to Israel's National Water Carrier, at a summit conference of Arab states in 1964 steps were taken to build dams in order to utilize the Wazzani, Hasbani and Banyas waters for irrigation in Lebanon, Syria and Jordan to be conveyed to the Jordan valley through the East Ghor canal. Israel considered this action as a threat to its water resources and destroyed the work sites. The subsequent Israeli occupation of the Golan Heights in 1967 put an end to Arab utilization of the waters of the Jordan basin.[11] In 1969 the East Ghor canal in Jordan was destroyed, but after secret negotiations between Jordan and Israel, the structures were rebuilt.

No plan appears to have been developed concerning the use of groundwater resources, although it is said that some renewable groundwaters are being overexploited, even beyond safe yield.[12]

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[9] M. Brecker, Decisions in Israel's Foreign Ministry, p. 204, Yale University Press, New Haven, (1975).

[10] L. Hosh and J. Isaac, <u>op cit</u>, p. 7.

[11] Hosh, Leonardo and Jad Isaac, <u>op. cit</u>., 7.

[12] Bilbeisi, M., "Jordan's Water Resources and the Expected Domestic Demand by the Years 2000 and 2010, Detailed According to Area," in <u>Jordan's Water Resources and their Future Potential</u>,

In 1967 Israel occupied the West Bank, the Gaza Strip and the Golan Heights, thus expanding its control over the water sources including the underground aquifers. In 1982, with the occupation of south Lebanon, Israel's control was extended to include a part of the Litani river. It has been the consistent policy of Israel to derive maximum benefit from the available waters without increasing the portion of water allotted to the Arab population.[13]

3. EXISTING WORKS

Although in this brief survey it would be impossible to quote all of the works being carried out, mention of the major water use schemes which seem to have been developed are indicated herebelow.

In Israel the Lake Huleh Drainage and Irrigation Scheme has drained and reclaimed all the swampland north of the lake and in the area of the lake itself.

The Tiberias Beisan Scheme utilizes the water of Lake Tiberias for irrigating west Galilee, and the Jordan Negev Scheme transports the upper Jordan waters into the Negev region.

The Dead Sea catchment area plan provided for draining all the waters from the intermittent wadis around this sea and their utilization for irrigation purposes in the Negev. It was contemplated to substitute those waters with sea water brought in from the Mediterranean. In 1981 Israel planned a canal through the occupied Gaza Strip linking the Mediterranean and Dead Seas. This 100 km canal, to start at Qatif, would utilize the drop in level between the two seas to generate electric power. It was strongly opposed by the world community on environmental grounds.

Mention should be made of fishing on Lake Tiberias, which has been the cause of dispute with the Syrians. In addition, the extraction of chemicals which are present in the Dead Sea (potash and asphalt) is taking place, and the Dead Sea chemical industry requires that the water level of the lake be maintained more or less constant. Pollution caused by agricultural and industrial waste is present in the lower reaches of the Jordan.

In Jordan, the Jordan Valley Scheme utilizes the waters of the river, through the construction of the East Ghor canal, now named King Abdullah canal, for irrigation. This project diverts

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[13] Caponera, D.A., op.cit.

the normal flow of the Yarmouk river into a main canal 69 km long which, combined with the perennial flow of side wadis, feeds an irrigation and distribution system of about 120,000 dunums. Ultimately, it aims to irrigate over half a million dunums and generate electric power of approximately 50,000 kw.

In Lebanon the Johnston plan contemplated the construction of a dam on the Hasbani, a tributary of the Jordan, with a network of canals for irrigation and power production.

Syria utilizes the water of the Yarmouk river, its largest tributary, for irrigation in the Mezerib district before the same river becomes a boundary stream between Syria and Jordan.

Mention has to be made of the groundwater problem in the Jordan basin. Most of the groundwaters flow from the Occupied Territories to Israel; the Palestinians claim that these groundwaters, currently being overpumped by the Israeli, should be allocated for their own use.[14] In addition, this overpumping has reduced the water level and caused sea water intrusion.[15]

In general, according to a UN report,[16] Israel has effectively frozen Palestinian water utilization in the Occupied Territories and has allocated insufficient amounts of water to the Arabs. This situation must be taken into consideration in any future political and legal settlement.

To sum up, it would appear that in spite of the lack of formal agreements concerning the use of the Jordan waters and of the groundwaters located in the West Bank and flowing into Israel, most co-riparian states have been carrying out water utilization projects and schemes on the basis of a tacit agreement. It is worth noting, however, that the Jordan river and the underground waters are considered by the Arab League as "Arab waters" and as such they do not recognize the rights of Israel to them.

4. LEGAL ASPECTS

The legal situation of the Jordan river is one of the major problems still outstanding in the Middle East.

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[14] Global Viewpoints Forum, Water Resources: Israeli and Palestinian Concerns, Israeli-Palestine Center for Research and Information, Jerusalem, 1990 (unpublished).

[15] Global Viewpoints Forum, op. cit.

[16] Caponera, D.A., op. cit.

4.1. Conventional law

Conventional law, which is the first source of international water law according to Article 38 of the Statute of the International Court of Justice, is made up of the following agreements:

(1) Convention between France and the United Kingdom for the territories under their mandate, signed in Paris on 23 December, 1920.[17] This Convention, which is a general boundary convention, provides that experts nominated by the administrations of Syria and Palestine study the question of the use of the waters of the upper Jordan and Yarmouk and of their tributaries for irrigation and hydropower generation. In this connection, two principles were set up: the first establishes "the needs of the territories under the French Mandate" (in part upper riparian and in part contiguous) as receiving prior satisfaction. Secondly, the French Government is to give its representative "the most liberal instruction for the employment of the surplus of these waters for the benefit of Palestine," in part lower riparian and in part contiguous (Art. 8).

(2) Agreement of 3 February, 1922,[18] signed between the U.K. and France, defining the borders of Palestine, Lebanon, Syria and Transjordan along the Jordan river and the waters of the Lakes Tiberias and Huleh. According to this Agreement, the border runs 50 to 150 m outside the river and Lake Tiberias, thus including both the river and the lake inside Palestinian territory.

(3) Mandate for Palestine and Memorandum by the British Government relating to its application to Transjordan as approved by the Council of the League of Nations on 24 July, 1922.[19] It provides for freedom of transit under equitable conditions across the territories (Art. 18).

(4) Mandate for Syria and Lebanon, granted to France by the Council of the League of Nations, 24 July, 1922.[20] It also provides for freedom of transit (Art. 11).

(5) Exchange of Notes between France and the U.K. of 7 March, 1923,[21] grants the Government of Palestine or any person

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[17] 22 LNTS 355.

[18] 117 BFSP 293.

[19] U.N. Doc. A/70.

[20] U.N. Doc. A/70.

[21] 22 LNTS 364.

authorized by it "to build a dam to raise the level of the waters of Lakes Huleh and Tiberias above their normal level, on condition that they pay fair compensation to the owners and occupiers of the lands which will thus be flooded." It further provides for the settlement of disputes by a commission composed of representatives of the two mandatory powers, recognizes the existing rights of Syrian nationals to the use of the Jordan's waters, and accords equal fishing rights in the lakes, as well as in the river, to Syrian, Lebanese and Palestinian nationals, although reserving the policing of the lakes to the Palestinian Government only.

(6) Convention (multilateral) relating to the development of hydraulic power affecting more than one state, 9 December, 1923.[22] It would appear that, although signed by both France and the U.K. (on behalf of the territories under their mandate), this Convention was ratified only by the U.K. The Convention provides that a state wishing to undertake a project for the development of hydraulic power of interest to another state, or involving alterations on such territory, is to enter into negotiations with this state with a view to reaching an agreement (Art. 3). It is to be noted that according to the theory of state succession in international law, the provisions of this Convention are binding on the successor states. The Convention has been acceded to by Israel.

(7) Agreement of good neighborly relations, signed between France and the U.K. on behalf of Syria and Lebanon on the one side, and Palestine on the other, on 2 February, 1926.[23] This Agreement stipulates that "all the inhabitants, whether settled or semi-nomadic, of both territories who, at the date of the signature of this Agreement enjoy grazing, watering or cultivation rights, or own land on the one or the other side of the frontier shall continue to exercise their rights as in the past.... All rights derived from local laws or customs concerning the use of the waters, streams, canals and lakes for the purposes of irrigation or supply of water to the inhabitants shall remain as at present. The same rules shall apply to village rights over communal properties" (Art. 3).

(8) Protocol between France and the U.K., signed on 21 October, 1931, concerning the river and the wadis Zeyzum and Meiden; this Protocol reaffirms the principles contained in the Convention of 23 December, 1920.

(9) General Agreement on Tariffs and Trade (GATT) (multilateral),

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[22] 36 LNTS 75.

[23] 56 LNTS 79.

signed on 30 October, 1947.[24] It would appear that Lebanon and Syria have provisionally applied the GATT. The Agreement was signed by Israel.

(10) Armistice Agreement between Israel and Jordan, signed on 3 April, 1949.[25] While under the Mandate for Palestine the Dead Sea still formed part of Palestine proper, under the Plan of Partition of 1947 and this Agreement it is divided along a line which leaves only the western part of the southern half to Israel and all the rest to Jordan.

(11) General Armistice Agreement between Israel and Syria, signed on 20 July, 1949.[26]

(12) Agreement between Jordan and Syria concerning the utilization of the Yarmouk waters, signed on 4 June, 1953.[27] This Agreement deals with cooperation in the execution of the so-called "Yarmouk Scheme," i.e., the Maqarin dam and a series of installations, to provide electric power and irrigation water. Under Article 8, "a) Syria shall retain the right to the use of the waters of all springs welling up within its territory in the basin of the Yarmouk and its tributaries, with the exception of the waters welling up above the dam below the 250 metre level, and shall retain the right to use water from the river and its tributaries below the dam for the irrigation of Syrian land in the lower Yarmouk basin and eastward of Lake Tiberias or for other Syrian schemes. b) Jordan shall have the right to use the overflow from the reservoir and joint generating station at Maqarin... the irrigation of the Jordanian lands and other Jordanian schemes; it shall similarly have the right to use water superfluous to Syrian needs..." Other articles provide for the cost of studies, construction, operation and maintenance and, at Article 10, for a Joint Syro-Jordanian Commission for the supervision of the project. The Yarmouk project interfered directly with proposed Israeli plans to carry water from the Jordan to the Negev. Hence, Israel has opposed the project.

(13) Agreement of June, 1977, between Jordan and Syria, concerning the construction of the Maqarin dam.[28]

(14) Project Loan Agreement relating to the Maqarin dam and

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[24] 55 UNTS 187.

[25] 42 UNTS 303.

[26] 42 UNTS 329.

[27] ST/LEG/SER.B/12, 378.

[28] 21 M.E. Ec. Dig. 39.

Jordan Valley irrigation system design, signed by Jordan and the United States, 21 September, 1977.[29] On the grounds that the construction of the Unity Dam at Mukheiba and the other hydro-electric dams and diversion works planned by Syria and Jordan would reduce the quantity and quality of the Yarmouk waters utilized by Israel, the Israeli were originally contrary to the project. Nonetheless, the Jordanians, and, indirectly, the Syrians, have been secretly negotiating with Israel through the good offices of the United States concerning a share of the Yarmouk in return for withdrawing its opposition to the construction of the dam.[30] An informal agreement for a de facto division of the Jordan and Yarmouk rivers was reached between Jordan and Israel with financial aid from the United States, following the Johnston plan; however, Jordan claims that Israel and Syria are using more water than is allotted to them.[31]

No agreements seem to exist concerning the wadis surrounding the Dead Sea.

It may be said that the existing agreements relating to the Jordan basin are insufficient to regulate the utilization of its waters by all the riparian states. This, for a number of reasons.

First of all, the majority of the Arab countries do not recognize Israel as a state,[32] and therefore consider themselves as not bound by any previous agreements. Secondly, the Armistice Agreements quoted earlier cannot be considered as constituting a defined boundary settlement. In the absence of a clear demarcation of the boundaries between Israel, Jordan, Lebanon and Syria, a determination of the water rights of each country is not possible. Finally, existing treaty provisions relating to hydraulic works only take into consideration the position of the states directly concerned (Jordan and Syria in the case of the Yarmouk scheme) and not the possible claims of the other co-riparians (Lebanon and, later, Israel).

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[29] TIAS 9311.

[30] Shuval, Hillel, "Approaches to Solving Water Resources Conflicts in Arid Areas -Israel and her Neighbours as a Case Study," paper presented in Legal Issues in Water Resources Allocation, Wastewater Use and Water Supply Management, WHO, Geneva, 10-12 September, 1991, 41.

[31] Pearce, F., "Wells of Conflict on the West Bank," New Scientist, June, 1991; and Nordell, D., "The Wet War," Scopus-Jour of the Hebrew University of Jerusalem 41, 1991.

[32] See Rosenne, S., "Israel's Armistice Agreements with the Arab States," 1951, p. 47; texts in 42 UNTS 251-351.

4.2. International customary law and general principles

We have seen how of existing conventional law is inadequate for the settlement of the water rights of the Jordan basin's riparian states. We shall therefore refer to the second and third sources of international water law according to Article 38 of the Statute of the International Court of Justice. These are "international custom, as evidence of a practice generally accepted as law," and the "general principles of law recognized by civilized nations." The question is to see whether they have produced rules of international law which provide a solution to the conflicts present in the region. The main theories which have been asserted are:

(1) the doctrine of riparian rights. According to this doctrine, the owners of lands abutting on a river have an equal right to the use of the waters of this river, as long as they do not interfere with the rights of their co-riparians. Each riparian owner has a right to have the water flow pass his land undiminished in quantity and unimpaired in quality. This doctrine has never been accepted as a basis for the solution of international water law disputes. In fact, if applied, it would prevent states sharing an international river to use the river's waters beyond a quantity limited, for instance, to the satisfaction of domestic water needs. Therefore, it may not be considered as "evidence of a practice generally accepted as law."

(2) the prior appropriation doctrine. The prior appropriation doctrine asserts that water in its natural course is public property and is not susceptible to private ownership. The right to its use may be acquired by appropriation and application to beneficial use. The first appropriator establishes a prior right to the use of the water, always provided that this water is put to beneficial use. This theory has been applied only in the western states of the United States,[33] and thus has given origin neither to rules of international customary water law, nor to general principles of law recognized by civilized nations. If it were to be applied within an international context to the situation within the Jordan river basin, the prior appropriation doctrine would certainly not favour the position of Israel, which is a newly created state. On the contrary, it would benefit Jordan, Lebanon and Syria, which existed before, although under British or French mandate.

(3) the theory of absolute territorial sovereignty, or "Harmon Doctrine," according to which each state, because of the absolute sovereignty it exercises over its own territory, may use the

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[33] This theory has also been introduced into the domestic water legislation of the Philippines and Taiwan. However, it does not receive any practical application.

waters of an international river within such territory as it pleases, without regard to the damage which may be caused to the other riparian states. This theory, which was originally asserted by the United States Attorney General Harmon in a dispute over water rights between the United States (upstream state) and Mexico (downstream state), has had scarce application in international state practice. In fact, although it was also supported by India (another upstream state) for a limited time, it was then rejected both by the United States and by India, which have subsequently entered into agreements with their respective co-riparians.[34] Therefore, it has produced no rules of international customary water law.

(4) the theory of absolute territorial integrity, or natural flow theory. According to this theory, downstream states are entitled to the natural flow of an international river, unaltered in quantity and in quality by the upper riparians. An interruption of this flow would entail a violation of the territorial sovereignty of the lower riparian. Also in this case, which represents a downstream states' version of the theory of absolute territorial sovereignty, there is no evidence in state practice of the production of a rule of international customary law.[35]

(5) the theory of equitable apportionment, according to which each co-basin state is entitled to a fair share of the waters of an international river or basin, if this entitlement is justified. The determination of the fair share will depend on a number of factors in each case. The concept of "apportionment," which is favored by engineers, implies a quantification of the waters to be allocated to each state, which might be difficult to achieve due to the tendency to request more water than needed, to the benefit of future generations. In addition, it tends to crystallize a given situation, making changes difficult. As it has been observed, "Its meaning cannot be written into a code that can be applied to all situations and at all times."[36]

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[34] Treaty between Mexico and the United States relating to the utilization of the waters of the Colorado and Tijuana rivers, and of the Rio Grande, signed on 14 November, 1944 (ST/LEG/SER.B/12, 236); Indus Water Treaty, signed by India and Pakistan on 19 September, 1960 (ST/LEG/SER.B/12, 300).

[35] For a review of state practice as regards the theories on the sharing of international water resources, see Lipper, in Garretson, Hayton and Olmstead, The Law of International Drainage Basins, New York, 1967, 15 ff.

[36] Chauhan, B.R., Settlement of International and Inter-State Water Disputes in India, Indian Law Institute, Delhi, 1992, 34.

(6) the <u>theory of limited territorial sovereignty</u>. Under this theory, an international river constitutes a unitary whole, where the sovereignty of a riparian state is limited by that of another riparian state. It recognizes the existence of a community of interests among riparian states, which gives rise to a series of reciprocal rights and obligations, as was affirmed by the Permanent Court of International Justice in its judgement on the territorial competence of the River Oder Commission (1929).[37] This reciprocity of rights and obligations acquires the force of a generally applicable rule of conduct, the corollaries of which may be said to be the duty not to cause substantial injury, which includes the duty to prevent any injury, and the principle of equitable utilization, which is described herebelow.

(7) the <u>theory of equitable utilization</u>, developed by the International Law Association (ILA) in its Helsinki Rules of 1966, is a corollary of the theory of limited territorial sovereignty. According to it, "each state is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin."[38] This share is to be determined in the light of all the relevant factors in each particular case. Such factors, 11 in all, are enumerated in Article 5 of the Helsinki Rules. They include geography, hydrology, climate, existing uses, economic and social needs, population, alternative means, availability of other resources, practicability of compensation, the potential damage that a utilization in one state may cause to another state; the door is left open to the consideration of other factors. It is to be noted that each factor is not to be considered in isolation, but looked upon together with all the other factors, without any of them being given priority. This theory neither purports to identify fixed criteria in the sharing of international water resources, nor to protect existing water rights. Rather, it aims at establishing a mechanism for cooperation and negotiation (in good faith) with a view to reaching an agreement. The Helsinki Rules, which apply to both surface and underground waters, are the result of years of discussions among lawyers and engineers specialized in the field of international water resources. Most countries have accepted their philosophy. The International Law Commission (ILC) of the United Nations and other bodies have followed this approach.[39]

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[37] Permanent Court of International Justice, Series A, No. 23.

[38] Helsinki Rules, Article 4.

[39] International Law Commission, 43rd Session, 19 April - 19 July, 1991 (McCaffrey Report); Asian-African Legal Consultative Committee, "The Law of International Rivers," 1973.

5. CONCLUSIONS

It is obvious that the water resources of the area are insufficient to provide for the needs of the riparian countries and their increasing populations.

One solution to the problem would be to make water available from countries outside the basin: Turkey, Lebanon and Egypt. For this purpose a regional Water-for-Peace Plan is being envisaged which would provide for the following projects:
(1) a pipeline from the Nile through El Arish to the Gaza area and the Negev,[40] with proper compensation to be paid to Egypt. The question is to see if an agreement can be reached on this point, also in view of the fact that it involves an inter-basin water transfer to which other Nile basin states could object.
(2) a project to supply water from the Litani river in Lebanon to Israel, the West Bank, and Jordan on a commercial basis, with Lebanon receiving compensation.[41] In this case, also, an agreement would be necessary.
(3) a pipeline from Turkey through Syria, Jordan and the West Bank; this plan has been described as the Turkish Peace Pipeline.[42] As part of this project, the Sea of Galilee or the Unity Dam would be utilized as reservoirs to supply water to Jordan and the West Bank. To avoid crossing boundaries, an alternative would be to carry water to south Cyprus and from there to the coast of Israel. Turkey has substantial reserves of water resources for present and future needs, which are intended to be marketed. Here, also, the agreement of the states sharing these waters should be sought.

In any case, the partners to the dispute must be assured that each would have direct access from within their territories to an equitable and reasonable share of the water resources.

Later, sea water desalinization plants could provide water to fill the need. This option envisages the construction of multinational plants on the coastline between Israel and Gaza and on the border between Israel and Jordan at Aqaba and Elat and possibly at other sites. The Gaza plant could supply water to Israel, Gaza and the West Bank as an alternative solution if the

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[40] Kally, E. "A Middle East Water Plan Under Peace," the Armond Hammer Fund for Economic Cooperation in the Middle East, Tel Aviv University, 1986.

[41] Kally, E., ibidem.

[42] Kollars, J., "The Course of the Water in the Arab Middle East," American-Arab Affairs, No. 33, Summer, 1990. Also, in the report of the Turkish Ministry of Foreign Affairs, "The Peace Pipeline Project," Ankara, 1990.

above proposed projects should prove to be too complex.[43]

As regards the legal aspects proper, we have seen that the existing agreements concerning the use of the Jordan basin are inadequate for regulating the use of the waters by the co-riparians.[44] While their validity ought to be ascertained, their provisions do not reflect the existing situation. New rights on water have been established which cannot be denied. On the other hand, prior rights have to be respected. Any utilization or mismanagement, including pollution, of the Jordan river system waters in any part of the watershed by one country causes international problems. The underground aquifers of the West Bank are also a cause of concern. No legal settlement of the international water rights is possible until there is a clear demarcation of the boundaries between Israel, Lebanon, Syria and Jordan; the temporary armistice agreements do not constitute a defined boundary settlement.

Any agreement on water allocation and distribution in the area would presuppose joint control in the management of the waters. This joint control should take place at two levels: national, as regards the occupied territories, and international or regional.

At the national level, the commendable work of water management which has been carried out in Israel, based on the Water Act of 1959 which calls for full centralization of water resources management and water users' participation, should be completed, with the inclusion of either representatives of the Arab population, or, in the case of independence of the Occupied Territories, representatives of the Jewish settlers. This would ensure the participation of both the Israeli and the Arabs in the management of water resources.[45]

At the international level, any negotiation should give serious consideration to the principles embodied in the Helsinki Rules, which call for the equitable and reasonable share in the utilization of water resources. It is to be envisaged that there should possibly be arrangements, whether under a confederation or other form of institutional set-up, for joint management, monitoring, inspection and operation of water resources. This could include the management of import facilities, desalinization plants and the control of pollution.

The above could be achieved through the creation of a

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[43] Shuval, Hillel, op. cit.

[44] Hosh Leonardo and Jad Isaac, op. cit., 8.

[45] Caponera, D.A., op. cit.

regional water authority in which all the basin states would participate: Israel, Palestine, Jordan, Syria, Lebanon, and perhaps Turkey and Egypt. This authority could be governed by a council of ministers or a technical commission with a secretariat to carry out its decisions. The basic rights of the Palestinians, Jordanians and Israeli to an equitable and reasonable use of the water and cooperation in the management of the shared Jordan/Yarmouk system and groundwater aquifers would thus be facilitated.

A solution to the existing political situation in the area can certainly be found if a decision on the joint management for the allocation of the waters of this basin is reached among the co-riparians.

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SECTION III
Ground water – the mountain aquifer and Gaza

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An Israeli-Palestinian water-sharing regime[1]

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Abstract

This paper outlines one possible approach to the problem of allocating the waters of the three aquifers straddling the Green Line (the Yarqon-Tanninim, Northern, and Nablus-Jenin aquifers) between Israel and the West Bank. It begins with a discussion of the principles of a comprehensive Israeli-Palestinian water-sharing regime, drawn from the (evolving) international law of transboundary groundwaters. This is followed by a description of one set of procedures by which an equitable allocation of these shared groundwaters can be determined.

1. INTRODUCTION

At the heart of the Arab-Israeli conflict lies the Palestinian problem. With the election of a Labour government under Prime Minister Yitzhak Rabin, the prospects for significant movement toward limited Palestinian self-rule in the occupied territories are more promising now than at any time in the recent past. Assuming that an interim agreement on limited self-rule can be reached in 1993 as pledged by Prime Minister Rabin in his inaugural address to the Israeli Knesset, the next stage in the peace process will then be negotiation of the final status of the territories. An important, if not central, issue in these discussions will be the future management of, and access to, the transboundary aquifers which straddle the Green Line separating pre-1967 Israel from the West Bank. The waters of these aquifers -- Yarqon-Tanninim, Northern, and Nablus-Jenin -- are critical to the future socio-economic development of Israel and the territories, especially in light of the region's perennial water problems. Two issues are likely to dominate negotiations concerning these shared water resources: (1) the control and management of the aquifers; and, (2) the equitable division of these waters between Israel and Palestinians in the territories for domestic, industrial, and agricultural uses. This study focuses on the latter problem -- the development of procedures for equitably allocating transboundary groundwater resources between the two communities.

What follows is a description of a set of procedures which could assist negotiators as they attempt to determine an equitable allocation of waters under a comprehensive water-sharing regime. These procedures include two major steps:

(1) identify principles from international law for the equitable division of shared groundwater resources, and derive equity standards against which to measure alternative

allocation outcomes;
(2) evaluate alternative outcomes to determine which is "best" from an equity standpoint.

It should be emphasized that this approach is not held to be "the answer" to the problem of equitably allocating transboundary groundwaters; rather, it is only one of many possible approaches to this complex problem. The aim of this exercise is to introduce certain methodologies which may assist negotiators and their technical advisers in developing and evaluating alternative allocation outcomes. In sum, the approach presented here should be seen as a first step in grappling with the problem of transboundary groundwaters rather than as the final word.

Before proceeding, one fundamental assumption must be identified: for purposes of this analysis, it is assumed that negotiations on the final status of the territories lead to the creation of a Palestinian Sovereign Authority (PSA)[2] along side Israel.[3] Indeed, no water-sharing regime can be created in the absence of this condition; by definition, an "international regime" is a set of implicit or explicit principles, norms, rules, and decision-making procedures around which the expectations of *sovereign state actors* converge in a given area of international relations.[4] Thus, the perpetuation of the status quo -- that is, *de facto* Israeli sovereign control of the territories -- reduces the water management and allocation problem to one of domestic Israeli policy. It is only with the establishment of a juridically-equal state-actor in the West Bank and Gaza Strip, with equal claim before international law to a share of the common resource, that a water-sharing regime can be constructed.[5]

A detailed presentation of the approach follows. It begins with a discussion of the principles, drawn from international law, that should form the basis of an Israeli-Palestinian water-sharing regime, followed by a description of one set of procedures to determine the "best" division of waters between the two parties.

2. THE PRINCIPLES OF A WATER-SHARING REGIME

The principles of an Israeli-Palestinian water-sharing regime can be found in the (evolving) international law of transboundary groundwater.[6] Three principles, in particular, are fundamental to the regime:

- *Obligation not to cause appreciable harm.*
Under general international law, each State is obliged to ensure that actions taken within its territory do not cause appreciable harm to areas outside its national jurisdiction. In terms of transboundary groundwaters, a State must refrain from domestic water management practices that endanger the quantity or quality of water in the shared aquifer, or damage the aquifer's geological structure, e.g. extractions in excess of the natural recharge rate of the aquifer that deplete the operational stock and/or cause "cratering", the infiltration of contaminants that lower water quality, etc.

■ *Equitable and reasonable use.*
States drawing from a common groundwater source must ensure that use of these waters is "reasonable", i.e. withdrawals must be adjusted to the recharge regime, and priority needs must be satisfied first (e.g. domestic consumption should be prior to recreational needs). Reasonable use also implies "securing the maximum possible yield", otherwise known as "optimization."[7] Equitable apportionment, on the other hand, implies the distribution of benefits from the resource among the States according to need, taking due account of economic, social, cultural, and other factors.

■ *The obligation of prior notification and the duty to negotiate.*
A State is obliged under international law to notify others of its intended withdrawals from a common groundwater source, providing them, sufficiently in advance of the start of operations, with the information needed to make an assessment as to its probable effects, i.e. whether the planned withdrawals constitute unreasonable or inequitable use, or are likely to cause appreciable harm. These States, in turn, may communicate any objections, along with evidence supporting their misgivings, to the State concerned. Should the planned withdrawals remain in dispute after these exchanges, the States are duty-bound to engage, in good faith, in meaningful negotiations in order to resolve their differences. These negotiations may not lead to a resolution of the matter *per se*, but may set out the procedures for the settlement of the dispute, e.g. through mediation, arbitration, etc.

The definition of principles is only the first step in the process of regime creation. In some ways the more challenging task for negotiators is to translate these principles into operating rules and procedures to determine, for example, the equitable apportionment of waters from the shared aquifers. What follows is a description of one set of procedures by which such a determination can be made.

3. EQUITABLE ALLOCATION OF TRANSBOUNDARY WATERS UNDER INTERNATIONAL LAW

Those surface and groundwater resources wholly located within the boundaries of Israel and the West Bank/Gaza Strip are allocated for each state's exclusive use. However, the shared groundwaters straddling the Green Line must be equitably apportioned between the two states. What is a fair division of waters? We will examine this question in the context of a hypothetical division of waters between Israel and a PSA in the year 2000.

There are a host of possible allocation outcomes from which to choose. Assuming only integral values are used, the set of all possible allocation outcomes is defined as

$$R = \{R_1(0,100),\ R_2(1,99),\ R_3(2,98),\ldots R_{100}(99,1),\ R_{101}(100,0)\}$$

where the Israeli percentage share is listed first and the Palestinian percentage share second in parentheses, and the sum of the two shares equals 100 percent; these are depicted in Figure 1. All possible allocation outcomes in which the annual safe yield of the shared aquifers is apportioned between the two peoples are represented along the diagonal line in the Figure. For example, $R_{52}(51,49)$ denotes the outcome in which the Israeli and Palestinian shares are 51 and 49 percent, respectively, of the combined safe yield for the transboundary aquifers in the forecast year 2000.

However, which of these many combinations constitutes an *equitable* division of waters? First, the concept of *equity* must be defined. In international law, though appeal is often made to considerations of equity, the definition of the term remains elusive. As Akehurst maintains, the problem is that equity...

> ...can often be defined only by reference to a particular ethical system. Consequently, although references to equity are meaningful in a national society which can be presumed to hold common ethical values, the position is entirely different in the international arena, where the most mutually antagonistic philosophies meet in head-on conflict.[8]

In the realm of international water law, there is no universally-accepted definition of equity in the division of waters between users. For example, rather than attempt a definition, the International Law Commission (ILC) in its draft articles on the law of the non-navigational uses of international watercourses identified several factors thought to have a bearing upon equity and that, consequently, should be taken into account when determining a reasonable share of waters for each watercourse State. These factors include:

> (a) geographic, hydrographic, hydrological, climatic, ecological 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 the watercourse in one watercourse State on other watercourse States;
> (d) existing and potential uses of the watercourse;
> (e) conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;
> (f) the availability of alternatives, of corresponding value, to a particular planned or existing use.[9]

The difficulty lies in translating these legal provisions into practical allocation procedures; the process by which this can be done is described below.

First, the factors identified in the ILC approach must be operationalized. Alternative allocation outcomes, each based upon a specific operational definition of these factors taken *in isolation*, are then derived -- these represent the *equity standards* used in the subsequent analysis. Four alternative equity standards are presented in Table 1:

Table 1
Alternative equity standards (%)

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

The factors used in this analysis include: existing water utilization [corresponding to equity factor (d) listed above]; the extent of the recharge area [factor (a)]; the natural flow of the transboundary aquifers [factor (a)]; and, projected population for the year 2000 [factor (b)]. These particular factors and their derivative allocation standards are selected for illustrative purposes only and are not claimed to be exhaustive; as many or as few factors as are deemed relevant can be incorporated into this approach.

The four factors from which the equity standards are derived were operationalized as follows:

- *Existing Utilization (EU)*
The annual safe yield of the transboundary aquifers is allocated between Israel and the PSA according to current (circa 1991) utilization rates. The following (Israeli/Palestinian) utilization rates are assumed: Yarqon-Tanninim Aquifer (.94/.06); Northern Aquifer (.85/.15); Nablus-Jenin Aquifer (.21/.79).[10]

- *Recharge Area (RA)*
The annual safe yield of the aquifers is apportioned according to the extent of the recharge area lying within each state. Naff asserts that only 5 per cent of the combined recharge areas of the Yarqon-Tanninim, Northern, and Nablus-Jenin aquifers lies within the pre-1967 borders of Israel.[11]

- *Natural Flow (NF)*
According to Kolars, Israel maintains that "since there is a natural flow of aquifer water from the West Bank downslope into Israel, only about 20% of West Bank water is used by Israelis and that the remainder should not be counted as a depletion because any such water that is removed by pumping in Israeli territory legitimately belongs to that state."[12] In other words, 20% or 109 MCM/year of the 545 MCM/year combined annual safe yield of the three aquifers consumed by the Israelis is "West Bank water." The remaining 341 MCM/year consumed by Israel, representing 63% of the combined annual safe yield, legitimately belongs to the state of Israel.

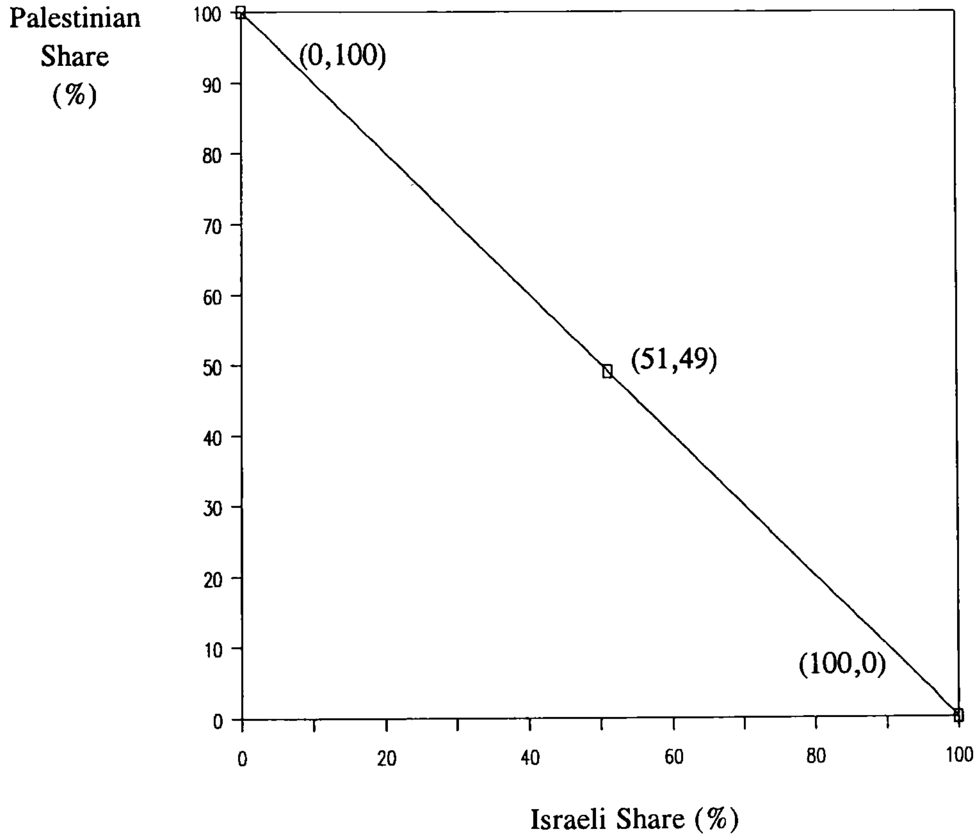


Figure 1. Allocation Outcomes

■ *Population (Pop)*
An Israeli population of 7,040,400 and a population of 2,861,400 for the West Bank and Gaza Strip are assumed[13], representing 71% and 29%, respectively, of the total population in Mandatory Palestine in the year 2000. As mentioned, the Palestinian population estimate includes the Gaza Strip. Currently, residents of this region do not use water from these shared aquifers. However, given projected population growth and existing overexploitation of the Gaza coastal aquifer, transfer of water from the West Bank region of a PSA to Gaza may have to be considered as an alternative to satisfy projected demand in that area. This could be done directly via connecting pipelines crossing Israeli territory from the West Bank to Gaza, or as part of an exchange with Israel (e.g. Israel supplies Gaza with water via the extension of the National Water Carrier to the Strip and withdraws an equivalent amount from the Palestinian share of the transboundary groundwaters).

Measured against *all four equity standards*[14], there is no manifestly "best" division of waters; the standards do not converge on one particular allocation outcome. The task, then, is to identify that outcome which does the "least violence" to the four equity factors taken together. In other words, is it possible to distinguish an optimal allocation outcome which, while not necessarily the best when measured against each equity factor in isolation, is the *least worst* of all outcomes when all factors are taken into account?

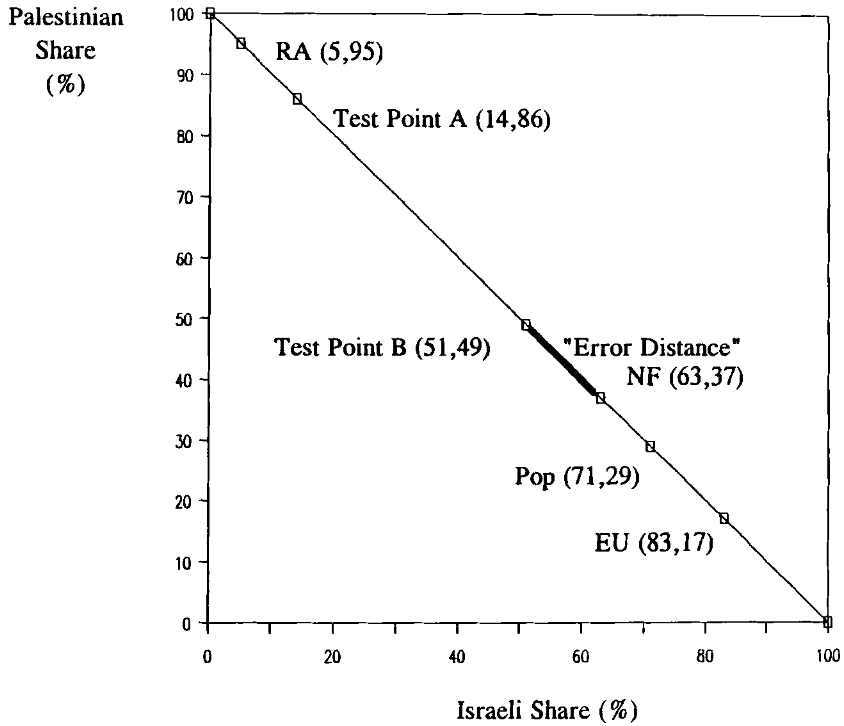
To explore this possibility further, assume two hypothetical allocation outcomes: *Test Point A* (14,86) and *Test Point B* (51,49) positioned relative to the four equity points in Figure 2. Upon reflection, it seems unlikely that an allocation outcome located at either extreme of the diagonal, such as *Test Point A,* would represent an optimal outcome. Though the shares of water allocated to each state in this outcome compare favourably with those of the equity point in its immediate vicinity -- *RA* (5,95) -- they fare poorly when compared with those of the other three points further down the line. Intuitively, then, the optimal outcome would seem to be one which "nestles" among the equity points, rather than flanking them on either extreme. This suggests a possible criterion for determining the optimal allocation outcome:

> ***The optimal allocation outcome is that which minimizes the summation of the "error distance" measured outward from itself to each equity point along the line.***

To illustrate, consider *Test Point B* (51,49). In the Figure, the "Error Distance" between *Test Point B* and the *Natural Flow* (63,37) equity point is highlighted. This distance is calculated as:

$$ErrDist=\sqrt{(51-63)^2+(49-37)^2}=16.97$$

In general, the formula for calculating the sum of the error distances from a given point on the line to each of the four equity points is:



Key.
RA - Recharge Area   Pop - Population   NF - Natural Flow   EU - Existing Utilization

Figure 2. Error Distance

$$TotalErrDist = \Sigma\sqrt{(x_t - x_i)^2 + (y_t - y_i)^2}$$

where,

x_t = Israeli share in the given allocation outcome;
y_t = Palestinian share in the given allocation outcome;
x_i = Israeli share in the *i*th equity standard, i = 1,...4; and
y_i = Palestinian share in the *i*th equity standard, i = 1,...4.

Using this formula, the total error distance for the two test points can be calculated (Table 2):

Table 2
Sum of error distances for Test Points A and B

Test Point A (14,86)		
Error Distance from RA (5,95) = $[(14 - 5)^2 + (86 - 95)^2]^{1/2}$ =		12.73
Error Distance from NF (63,37) = $[(14 - 63)^2 + (86 - 37)^2]^{1/2}$ =		69.30
Error Distance from Pop (71,29) = $[(14 - 71)^2 + (86 - 29)^2]^{1/2}$ =		80.61
Error Distance from EU (83,17) = $[(14 - 83)^2 + (86 - 17)^2]^{1/2}$ =		97.58
	Sum	260.22

Test Point B (51,49)		
Error Distance from RA (5,95) = $[(51 - 5)^2 + (49 - 95)^2]^{1/2}$ =		65.05
Error Distance from NF (63,37) = $[(51 - 63)^2 + (49 - 37)^2]^{1/2}$ =		16.97
Error Distance from Pop (71,29) = $[(51 - 71)^2 + (49 - 29)^2]^{1/2}$ =		28.28
Error Distance from EU (83,17) = $[(51 - 83)^2 + (49 - 17)^2]^{1/2}$ =		45.25
	Sum	155.55

As expected, *Test Point B* (51,49) emerges as the preferred allocation outcome - the sum of the error distances to each equity point is less for it than for *Test Point A*.

Returning to the general problem, a search program was written to determine which outcome from the set of possible allocation outcomes, ***R***, satisfied the stated criterion.[15] The search revealed that, rather than one optimal solution, there is, in fact, a range of equally good allocation outcomes extending from $R_{64}(63,37)$ to $R_{72}(71,29)$ in which the summation of the error distances to the four equity points is minimized; in Figure 2, this range is located along the line between the two equity points *NF*(63,37) and *Pop*(71,29). In other words, from an equity standpoint, the nine allocation outcomes within this range are equally preferred, given the optimality criterion as defined above. This represents the ***bargaining space*** within which a negotiated allocation outcome should be located (assuming the parameters of the problem as defined in this analysis).

4. CONCLUSION

It bears repeating that the preceding example is illustrative only. The procedures described above for determining an equitable division of waters between Israel and a Palestinian Sovereign Authority used only four operational definitions of the ILC equity factors; clearly, these definitions were not exhaustive. One of the first tasks for negotiators, therefore, is to define and operationalize such other factors as are deemed relevant to this particular water-sharing problem.

A word of caution on a question that often arises when considering these factors: that is, the question of factor weighting. An earlier attempt at defining the law of international watercourses - the *Helsinki Rules on the Uses of the Water of International Rivers*[16] - specified that weighted consideration must be given to all relevant equity factors:

> The weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be considered together and a conclusion reached on the basis of the whole.[17]

Although seemingly reasonable in principle, this provision can be troublesome in practice. Questions (and controversies) soon arise over the appropriate weight to assign to the various factors. For example, is *Recharge Area* more important than *Natural Flow*, and, if so, how much more important -- two times? three times? four times? The answers to these questions are, in most instances, based upon subjective judgements and, consequently, invite challenge. As the negotiations proceed, therefore, it may be less contentious to agree to weight each factor equally, and then focus efforts upon designating those factors which legitimately should be included, rather than accept a myriad of factors as relevant and then argue about the weights to be assigned.

Finally, the determination of an equitable allocation outcome must be seen as a dynamic process. Although the outcome was defined in this exercise in terms of one forecast year, it should not be assumed that, once defined, the share of water allotted to each state remains fixed. The regime must be dynamic in order to adapt to changing conditions. For example, actual extractions will fluctuate each year (or each season, month, or week) depending upon the level of the operational stock, precipitation levels, etc. In addition, the equity standards may themselves change over time. Continued extensive use of the shared aquifers may, for example, affect their natural flow rates or other hydrogeological characteristics. Alternatively, fluctuations in natural population growth or immigration could shift the relative balance of population dependent upon these shared resources. Thus, one of the critical tasks for whatever groundwater management structures are eventually put in place will be to adapt the allocation outcome to fluid hydrological, demographic and other conditions.

The development of a functional Israeli-Palestinian water-sharing regime -- both the definition of principles and the translation of these principles into operating rules and procedures -- is a complex undertaking. It will call upon the singular talents of demographers, economists, hydrologists, international lawyers, and others to ensure that a fair and reasonable regime is constructed.

5. ENDNOTES

1. This paper does not necessarily represent the views of the Canadian Department of National Defence.

2. This term is also used in A. M. Lesch (principal author), Transition to Palestinian Self-Government: Practical Steps Toward Israeli-Palestinian Peace, American Academy of Arts and Sciences, Cambridge, 1992.

3. The sequence to the creation of a PSA assumed in this exercise is as follows: Israel and the Palestinians conclude an interim agreement on Palestinian autonomy in the territories, with limited self-rule to begin as of end-1993; a five-year transition period ensues from end-1993 to end-1998; in the third year of the interim period, negotiations begin on a final settlement of the occupied territories' status; based upon agreements reached in these negotiations, a PSA assumes governing responsibilities in the West Bank and Gaza Strip as of start-1999.

4. S. D. Krasner, "Structural Causes and Regime Consequences: Regimes as Intervening Variables," in S. D. Krasner (ed.), International Regimes, Cornell University Press, Ithaca, 1983, p.2.

5. *Solely for purposes of regime creation*, the structure of the PSA -- whether a confederation with the Kingdom of Jordan or some form of Palestininan self-governing entity -- is unimportant. The requirement is simply for the existence of an autonomous governing entity which, like the state of Israel, possesses the authority to regulate activities within its jurisdiction as they relate to these three aquifers.

6. See, for example, R. D. Hayton, Nat. Res. J., 22 (1982) 71-93; A. E. Utton, Nat. Res. J., 22 (1982) 95-118; R. D. Hayton and A. E. Utton, Nat. Res. J., 29 (1989) 663-722; and, J. Barberis, Nat. Res. J., 31 (1991) 167-186.

7. J. Barberis, Nat. Res. J., 31 (1991) 176.

8. M. Akehurst, A Modern Introduction to International Law, 6th ed., HarperCollins Academic, London, 1991, 39.

9. United Nations, General Assembly, 46th Session, 10 September 1991, Report of the International Law Commission on the Work of Its Forty-Third Session, (A/46/10), 163.

10. Utilization rates for the Yarqon-Tanninim and Northern aquifers are taken from J. Schwartz, "Israel Water Sector Review: Past Achievements, Current Problems and Future Options," Tahal Consulting Engineers, Ltd., Tel Aviv, 1991, 3-5 (paper presented to *The World Bank International Workshop on Comprehensive Water Resources Management Policies*, Washington, D.C., 24-28 June 1991). Based on these utilization rates, Israel draws 320 MCM/year and 115 MCM/year from the Yarqon-Tanninim and Northern aquifers respectively, or 435 MCM/year of the combined annual safe yield of 475 MCM [J. Kolars, Can. J. of Dev. Stud., Special Issue (1992) 113]. Kolars maintains that Israel extracts 450 MCM/year in total from the three transboundary aquifers [ibid.]. This suggests, then, that 15 MCM/year comes from the Nablus-Jenin Aquifer, representing 21 per cent of its 70 MCM/year annual safe yield. Accordingly, the (Israeli/Palestinian) utilization rate for this aquifer is assumed to be (.21/.79).

11. T. Naff, "The Jordan Basin: Political, Economic, and Institutional Issues," 3 (paper presented to the *World Bank International Workshop on Comprehensive Water Resources Management Policies*, Washington, D.C. 24-28 June 1991).

12. J. Kolars, Can. J. of Dev. Stud., Special Issue (1992) 114.

13. A discussion of the assumptions and calculation of these population projections is found in J. W. Moore, "Water-Sharing Regimes in Israel and the Occupied Territories -- A Technical Analysis," ORAE Project Report No.609, Department of National Defence, Ottawa, 1992.

14. It is assumed that all four equity factors are given equal weight (see the **CONCLUSION** for a discussion of the rationale).

15. The computer search program is found in J. W. Moore, "Water-Sharing Regimes in Israel and the Occupied Territories -- A Technical Analysis," ORAE Project Report No.609, Department of National Defence, Ottawa, 1992, 40.

16. The *Helsinki Rules* were approved by the International Law Commission in full conference at Helsinki, Finland, in August 1966.

17. R. D. Hayton and A. E. Utton, Nat. Res. J., 29 (1989) 701.

Isaac/Shuval (Eds), Water and Peace in the Middle East

Eastward groundwater flow from the Mountain Aquifer

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Abstract

The anticlinal structure of the Mountain Aquifer sheds infiltrating rain water to the west and east The geological controls on the eastward groundwater flow are examined.Eastward surface drainage has cut deep wadis allowing the detailed lithology of the aquifer to be exposed. The significance of the Senonian chert bands, and argillaceous strata in the Cenomanian, and the uppermost parts of the Albian are considered as impermeable strata in controlling the variable water table levels. Seasonal variation, as well as an historical perspective, over the last half century in particular, raise questions about actual water availability, water management and future developments. Many of the important advances in geohydrology have been stimulated by studies designed to solve problems of economic and/or political importance. The West Bank is an area in a water crisis situation. Demands on the meagre and diminishing water resources increase the urgency to understand the nature of that precious resource and how it might be managed in the most efficient and appropriate way in the future.

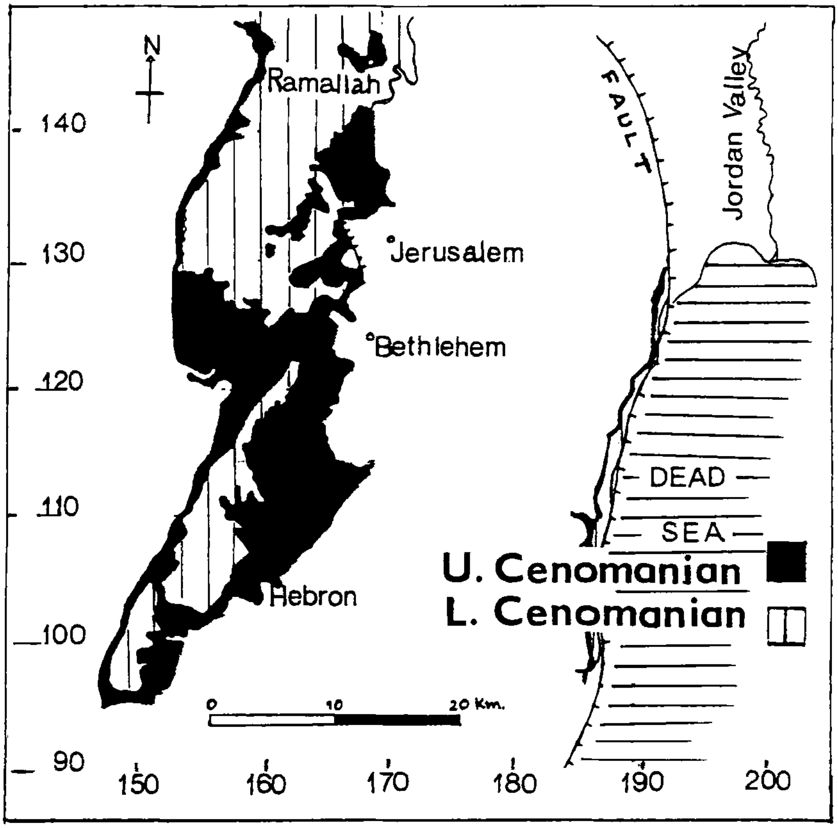
Introduction

Geohydrology is concerned with that part of the hydrologic cycle that takes place underground. Groundwater is the most important source of water in the West Bank and has, therefore, occupied the attention of hydrologists, particularly in these last seventy years. Blake and Goldschmidt (1947) summarised the geological and hydrological work completed during the time of the British Mandate of Palestine (1920-1948). Rofe and Rafferty (1963) provided the most comprehensive study during the subsequent Jordanian administration. Arad and Michaeli (1967) were followed by many other Israeli and Palestinian geologists and hydrologists in their concern to understand the nature of the groundwater flow of the Mountain Aquifer to the Jordan Valley and the Dead Sea. The "Hydrological Year Book of Israel" provides spring and well data that allow an appreciation of the annual fluctuations in the water table. The Palestinian Hydrology Group serves mainly municipal and farming interests in interpreting and applying data that is available.

The origin of the groundwater is almost entirely the rainwater which falls on the Jerusalem Hills. In this paper I will review the evidence provided by spring-water discharge, within the context of the lithological and geological structures of the Mountain Aquifer,in an attempt to appreciate, quantitively and qualitatively, the water resources available.

1.PRECIPITATION

Outcrops of mainly micritic limestones and dolomites of the Cenomanian Stage of the Upper Cretaceous Series, in the Jerusalem Hills and Hebron Mountains (Fig. 1) receive most of the rainfall that enters the groundwater system and emerges as springs near the Jordan Valley and Dead Sea. The interface between the Upper and Lower Cenomanian is taken as the mainly argillaceous Moza Formation and its equivalents (Table 1).The highest parts of this catchment area reach nearly 1,000 m above sea level and receive over 700 mm average annual rainfall. A rain-shadow desert is produced to the east as air descends to the warmer Dead Sea coast at nearly 400 m below sea level and receives less than 100 mm average annual rainfall.



Fig, 1 Cenomanian outcrops in the Jerusalem Hills, the Hebron Mountains and along the Dead Sea shore.

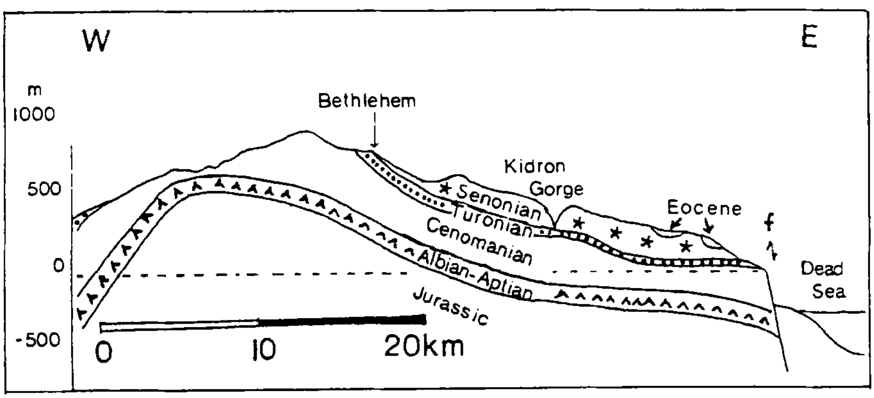


Fig. 2. Geological sketch section through Bethlehem in an east-west direction.

	Age	Lithology	Israeli Nomenclature: Jerusalem Hills	Israeli Nomenclature: Dead Sea	Palestinian Nomenclature
	QUATERNARY				
TERTIARY	NEOGENE				
	OLIGOCENE				
	EOCENE				
	PAL./MAAS				
UPPER CRETACEOUS	SENONIAN		MENUHA FORMATION		ABU DIS FM
	TURONIAN		BINA FORMATION	NEZER FM	JERUSALEM FM.
				SHIVTA FM.	
	CENOMANIAN		WERADIM FORMATION	HAZERA FM. – TAMAR MBR.	BETHLEHEM FM.
			KEFAR SHAUL FM.	AVNON MB	HEBRON FM.
			AMMINADAV FM.	ZAFFIT MB	
			MOZA FORMATION	EIN YORQEAM MB	YATTA FM.
			BET MEIR FM.		
LOWER CRETACEOUS	ALBIAN		KESALON FM.		
			SOREQ FM.	HEVYON MBR.	U. BEIT KAHIL FM.
			GIVAT YEARIM FM.	HATIRA FM.	L BEIT KAHIL FM.
			KEFIRA FM.		
			QATAN A FM.		
			EN QINYA FM.		KOBAR FM.
			KURNUB	KURNUB	KURNUB
JURASSIC					

Table 1 A generalised geological section showing nomenclature equivalents

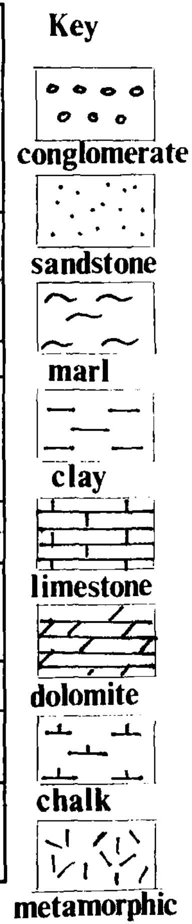


Fig.2. is a simplfied sketch section through Bethlehem, the monastery of St. Sabbas, above the Wadi Kidron, to the springs of Ein Fashkha near the Dead Sea shore. It can be seen from Fig.2 that headward erosion has shifted the surface watershed eastwards, while the groundwater divide remains a function of the anticlinal structure beneath.

The catchment area for the groundwater that flows eastwards to the Jordan Valley and the Dead Sea is 2,700 km^2. Arad & Michaeli (1967) calcuated that the average annual groundwater flow was 70 - 100 x 10^6 m^3. Even then, 25 years ago, exploitation exceeded natural replenishment and reserves were being tapped from the Lower Cretaceous Nubian Sandstone Aquifer. Most of the water in this aquifer may be regarded as "fossil water" and is not, therefore, renewed annually.

Fig. 3 shows annual rainfall totals at Bethlehem for this century. The considerable variab-

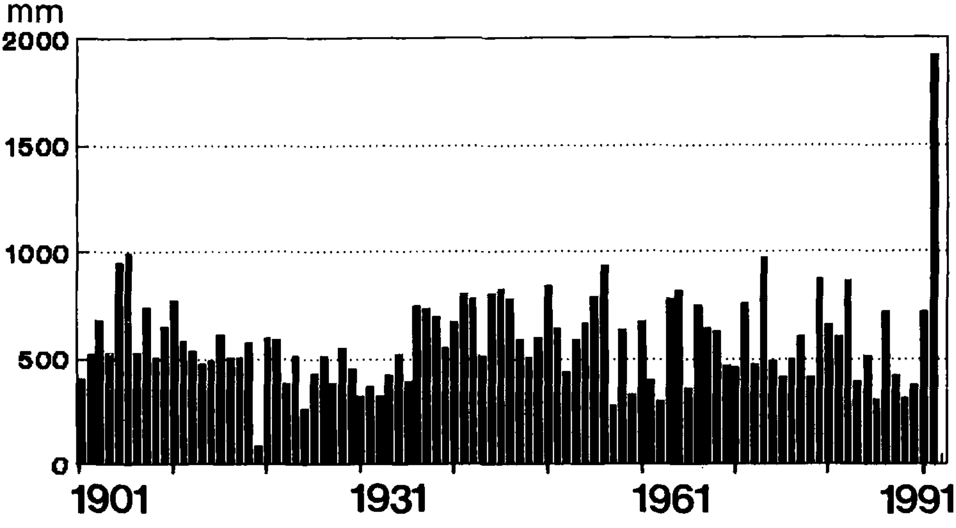


Fig. 3 Annual rainfall totals for Bethlehem (1901 - 1992).

ility of precipitation at Bethlehem, characteristic of the whole area, is clear. These data also *show an increasing aridity over the course of this century. These last two seasons in* Bethlehem (Fig. 4) illustrate well this variability. The mean annual rainfall (1961-1990) is

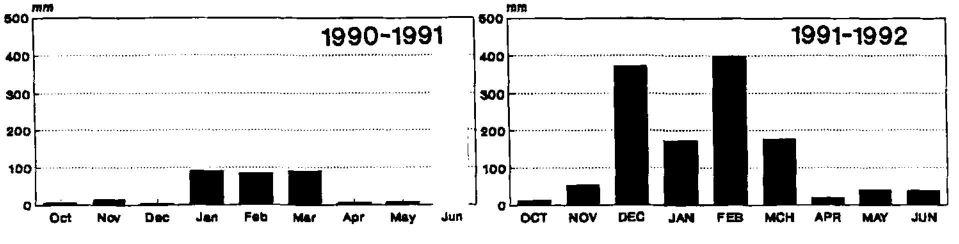


Fig.4 Bethlehem's monthly rainfall totals for the winter seasons, 1990-91 and 1991-92.

609 mm. During the 1990-1991 season, about half this amount fell, while for the 1991-1992 season, about twice the mean fell , Scarpa (1992). The rainy season usually begins about the middle of October and continues until the end of March. However, most of the seasonal rain usually falls in January and February. The dry season may have occasional, very heavy convectional rain, as in June of this year (1992) when 39 mm of torrential rain fell in two days of thunder storms. Sadly, the bare, hard ground and very high evaporation prevented most of this precious water from infiltrating to the aquifer.

2.LITHOLOGICAL CONTROLS

A generalised section (Table 1) reveals the main lithological controls. The differing nomenclature employed by Israeli and Palestinian geologists is indicated. A more detailed picture of the lithology and structure near to the watershed is seen in Fig. 5 which shows a map and sections for the Wadi Ahmed (Cremisan Valley) near Beit Jala. The effect of headward erosion in shifting the surface drainage watershed eastwards is clear in the section along the axis of the Wadi Ahmed. The major Jerusalem - Tel Aviv highway cuts through part of Qastel Hill, 9 km to the west of Jerusalem. The clays, marls and limestones of the Moza Formation are well exposed here. Fig. 6 is a graphic log for the Qastel Hill outcrop. Fig. 7 puts the outcrop into its structural context. One of the main wells that serves the west of Jerusalem is located about 2 km to the east of this outcrop

The infiltration of the rainwater through the mainly micritic carbonate rocks is by way of the joints and bedding planes, widened by solution weathering. This karstic infiltration is halted by impervious strata, as with the clays and marls of the Moza Formation. This formation divides the Cenomanian into an upper and lower part, Scarpa (1990). Similar argillaceous strata, just below the Kesalon cliff, at the interface of the Upper and Lower Bet Kahil formations, (top of the Soreq Formation) obstruct infiltrating ground water and cause the overlying strata to become saturated. The water table, that is, the highest level of saturation, is controlled by the surface geomorphology as well as the configuration of the impermeable base of the aquifer and any similar upper limiting factor which might confine the aquifer.

The water-bearing capacity of a formation is a function of its porosity. Limestone has a representative porosity of 0.1 to 10% void space. The hydraulic conductivity of a strata is the measure of that particular formation to transmit water. Limestone has a range in permeability of 10^{-10} to 10^{-5}m /sec. ,depending, to quite a large extent in our carbonate rocks that make up so much of the Mountain Aquifer, on the karstic solution weathering that has developed. The Moza Formation clays are highly porous (31% -21%void space) but the platy shape of the particles, together with their very small size (often only 4 µm in width) become virtually impervious, once saturated, due to the surface tension resulting from the adhesive and cohesive qualities of water, which thus seal the pore spaces.

3.STRUCTURAL CONTROLS

The 10° - 15° eastward dip of the major anticlinal structure allows most of the percolating water of the Mountain Aquifer to pass down dip towards the Jordan Valley and the Dead Sea by gravity. Fig. 8 shows the direction of flow from the main groundwater basin.

Spring discharge offers evidence of the groundwater flow. Where the water table coincides with the ground surface, the water will obviously be above ground; either flowing or static. Because of the seasonal rainfall regime and the variability of mean annual rainfall, flood-water flows become superimposed on perennial base flows, Farris (1992). Spring systems develop along the line of the fault scarp. As this is an active fault zone, the base level of the karstic drainage is lowered from time to time. We therefore have a series of false base levels as the solution weathering tries to work its way down to the new base level.

The catchment area for the groundwater that emerges as the springs of the Ein Gedi system is about 480 km^2. The average rainfall for this area is 300 mm per annum, which represents about 140 x 10^6 m^3 About 20% of this could be expected to enter the

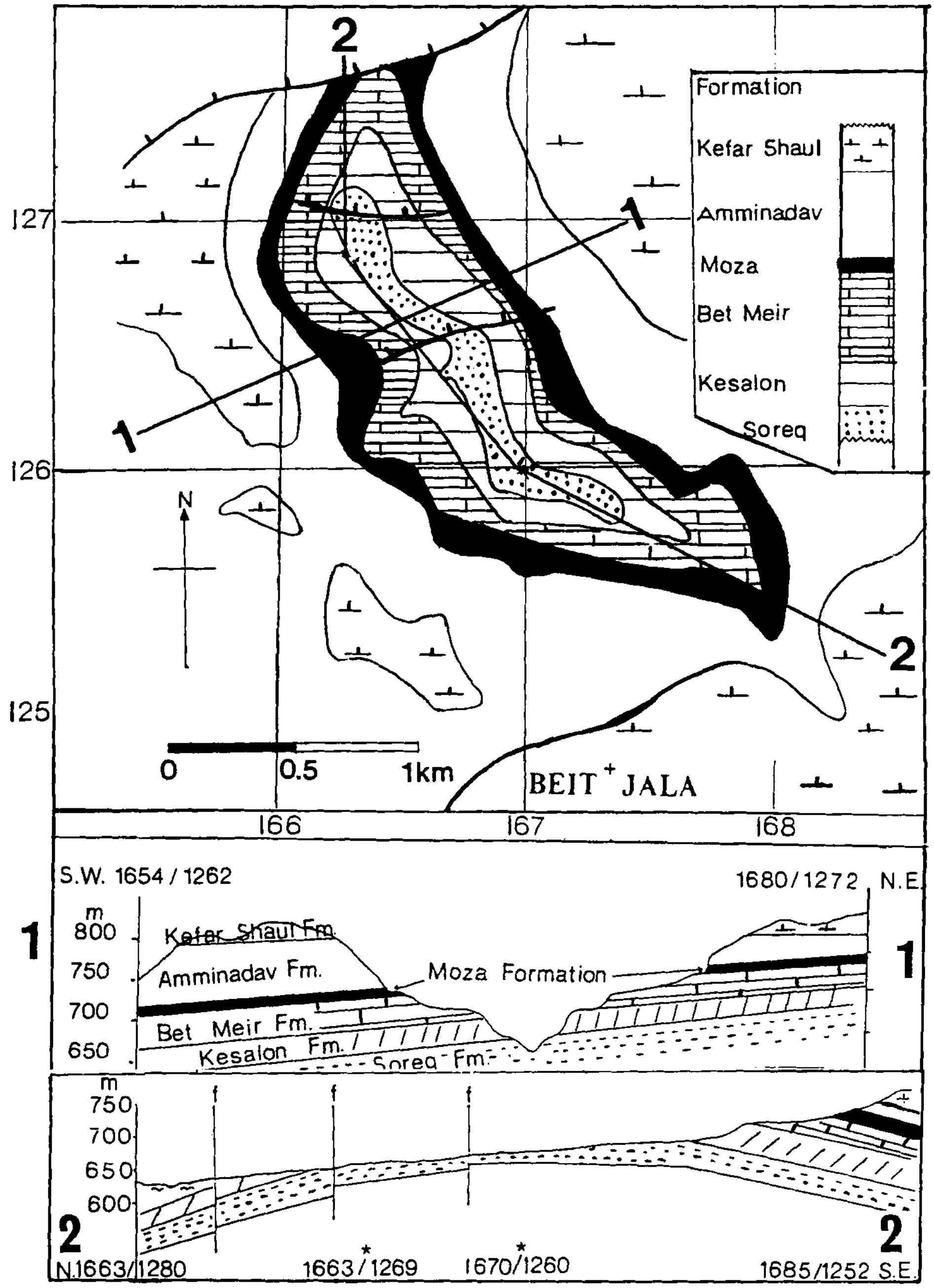
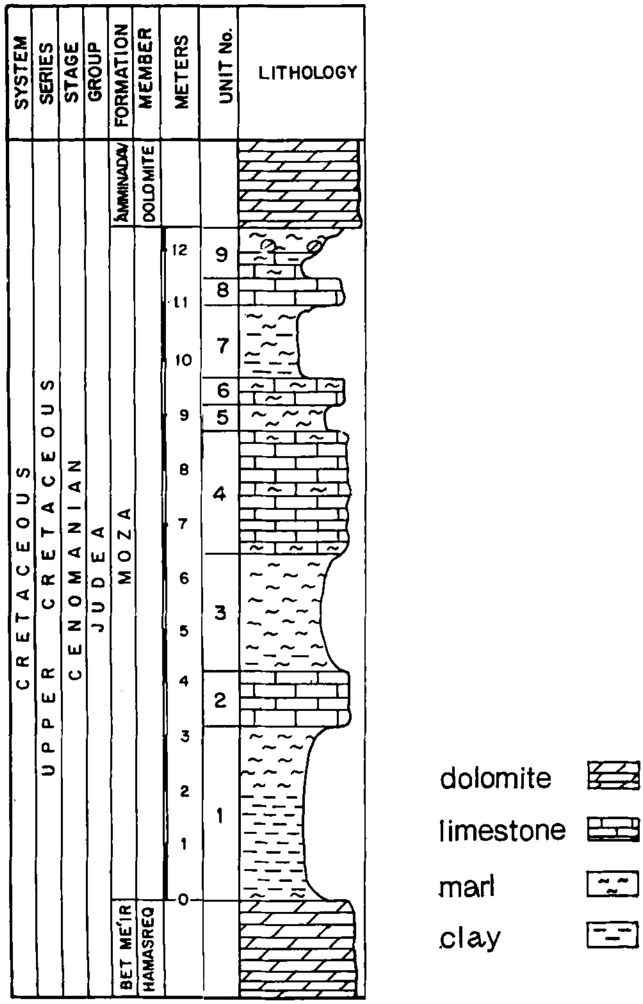


Fig. 5 The Wadi Ahmed (Cremisan Valley) geological map and sections (a) Geological section across Wadi Ahmed (1); (b) Geological section along axis of Wadi Ahmed (2).



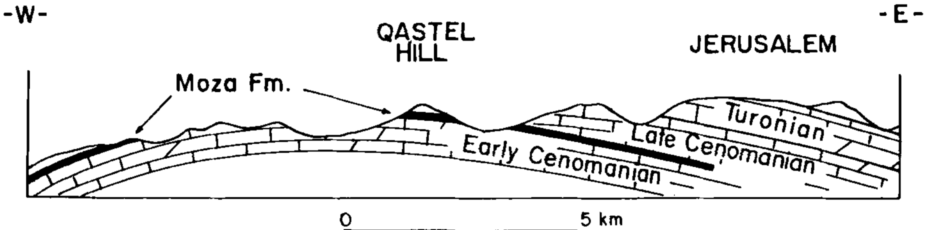


Fig. 6 (above) A graphic log of the Moza Formation at the Qastel Hill site, 163850/132950.
Fig. 7 (below) An east-west geological section through Qastel Hill. 1530 / 1335–1730 / 1335

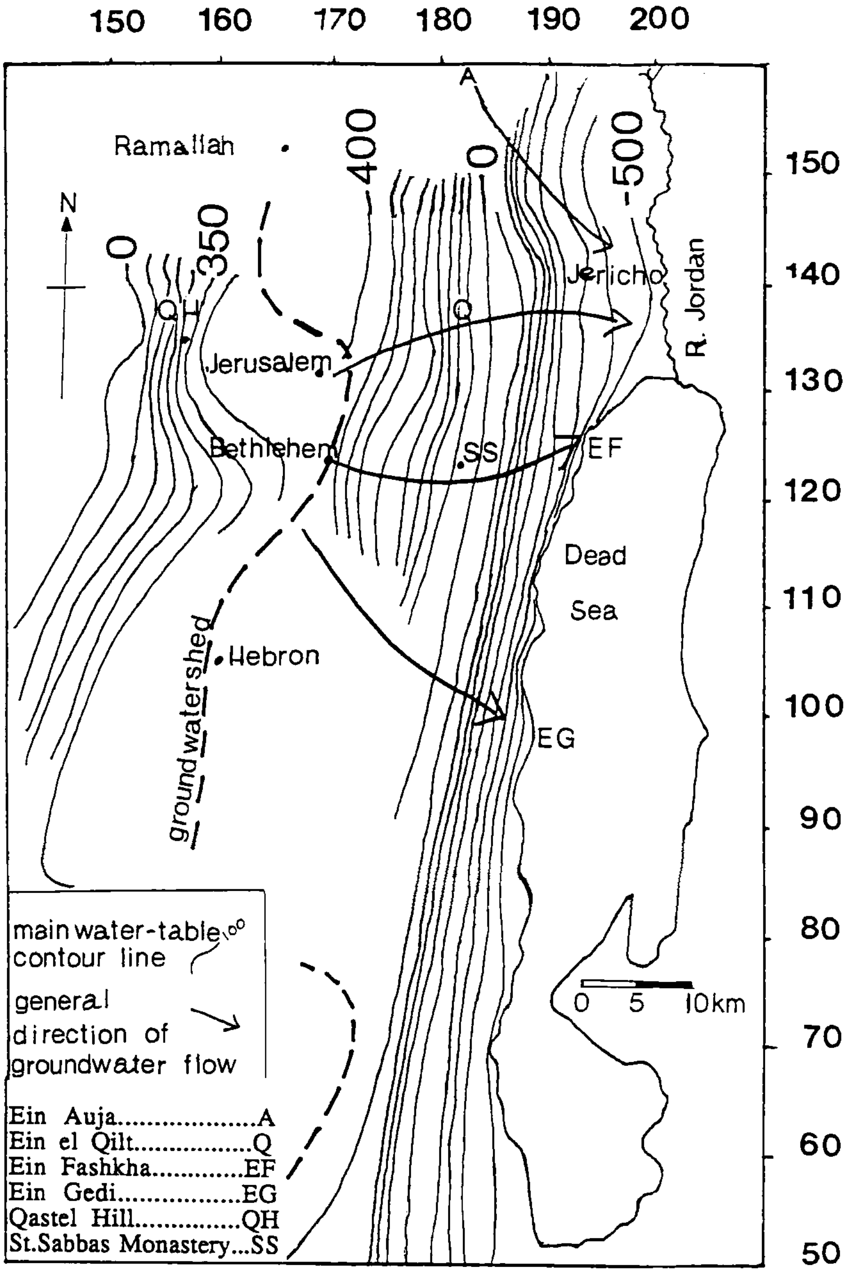


Fig. 8 Generalised flow directions of the main groundwater systems east of the Mountain Aquifer watershed.

groundwater system, that is, 30 x 10^6 m^3. Blake and Goldschmidt (1947) calculated that an annual average of 22 x 10 $^6m^3$ emerged from the system.

Further north along the Dead Sea shore and due east of Bethlehem is the Ein Fashkha system. Between Bethlehem and Ein Feshkha is the monastery of St. Sabbas, overlooking the Kidron Gorge, along which flows a perennial stream. A reversed fault is partly responsible for this gorge and, as with the other eastward flowing wadis, anticident drainage, related to the downfaulting of the major fault system, is the other factor. The structural control of the springs emerging around the northern part of the Dead Sea is the Jericho Syncline (Rofe and Rafferty ,1963). The eastern limb of this syncline is cut by the shear fault of the Rift Valley. The general direction of groundwater movement is, therefore, N.N.E. There are three parallel synclines at the edges of the eastern limb of the main anticlinal structure. Although these are quite shallow, they are the main groundwater channels. As these synclines get progressively lower eastwards, groundwater may break through from a higher to a lower synclinal channel. This is the case at St. Sabbas' Monastery. Here there is a groundwater gap caused by the downwarping at right angles to the other folds. Water therefore passes through the gap in an easterly direction, working down to the lowest level of the Jericho Syncline. Another structural control in this area is the system of cross faults which cause failure in the last retaining limb of the syncline, causing the groundwater to emerge as the springs of the Ein Fashkha system along the Dead Sea shore.

Three main springs feed the Wadi el Qilt; Ein Fara, ref.178850/ 137850, at an elevation of 325 m, Ein Fawwar, ref. 183100/138650, at an elevation of 80 m is 4 km downstream, and Ein el Qilt, ref. 186050/138015, at an elevation of 10 m, is a further 2.5 km downstream. These springs emerge through the floor of the wadi; Ein Fawwar, just below where the Wadi Suweinit joins the Qilt, is a seasonal spring, flowing vigorously during the rainy season only. Ein el Qilt emerges under pressure. In this latter spring, there is little variation in the rate of flow from wet winters to dry summers. A powerful, rushing torrent flowed down the Wadi el Qilt during the excessively wet 1991-92 season, washing away the foot bridge near the Qilt spring and flowing over the main road at Jericho. The smallest trickle during the dry season is the normal situation.

In the Jordan Valley itself, the Ein e' Sultan also probably receives its waters via the Turonian-Cenomanian aquifer, mainly from the Bethlehem (Weradim) Formation. Ein el Qilt has a catchment area of 115 km^2 with an average annual rainfall of 550 mm, giving a total volume of 63 x 10^6 m^3. About 20% of this water enters the groundwater system. Combined annual discharge from Ein el Qilt and Ein e' Sultan averages 9 x 10^6 m^3. Winter flows from Ein Fawwar vary between 80,000 m^3/day and 270,000 m^3/day. The average, though, ranges from 30,000 to 100,000 m^3/day. The siphonic effect of the spring is responsible for the extraordinary peaks which last only for a few minutes, Rofe & Raffety (1963). The highest of the three springs in the Wadi el Qilt is Ein Fara, which has an estimated annual yield of 1.4 x 10^6 m.^{3} Following heavy rainfall, muddy water emerges from this spring, proving that surface water, at least from flood runoff, enters directly into the aquifer. The steep limb of the Ein Fara - Khan Fasayil monocline lies immediately below the spring at Fara. The average gradient between the springs of this aquifer is 1:20 - 1:25 (Rofe & Raffety, 1963). Whilst the monocline probably has an influence on the flow from the springs at Fara and Fawwar, Ein Qilt appears as a normal fissure flow at about the Bethlehem - Jerusalem (Weradim - Bina) formation interface. The main recharge area is the Upper Bethlehem and Jerusalem formations which outcrop east of the Jerusalem to Ramallah Road. Here, the average annual rainfall is 550 mm over an area of 80 km^2. It is significant that about half of the Jerusalem Formation has been affected by "nari" calcification cover. The infiltration area, therefore, is only 42.5 km^2 . An additional 25 km^2 of the Bethlehem Formation in the area may be considered an aquiclude. Faults passing through the aquiclude allow leakage down to the Hebron (Amminadav) Aquifer. The waters of the Ein Fara, Ein Qilt and, emerging from the Quaternary alluvium in the Jordan Valley, Ein Elisha, are very fresh; approximately 400 ppm TDI, Kroitoru & Mazor (1985). Constant temperatures around 21°C. indicate a circulation depth of around 150 m. Ein Elisha maintains a remarkably consistent rate of discharge, indicating a large reservoir capacity when matched with the fluctuating annual recharge rates. An interesting conclusion from the isotopic experiments carried out by Kroitoru & Mazor (1985) was that the water is a mixture of "post bomb tritium water" and water that fell as rain at least 10,000 years ago.

North of Jericho, a series of fault escarpments, each with a shallow throw, trend NNW and are referred to as the Samia Fault Strip, Begin, (1975). South of the grid line, 158, these downfaulted blocks are to the east of the major shear-fault system. Between Jericho and Ein Samia the vertical displacement is about 250 m .

The Auja monocline is the result of stress, which forced the NW - SE trending escarpment to rise above the sea in Eocene times.Subsequent erosion removed the Senonian and the Tertiary sediments that had been laid down before uplift. By Neogene times, tensional forces had begun to create the Samia Fault System.

The passage of the groundwater flow above impermeable strata is interrupted, therefore, by fracturing and faulting as well as by lithological changes. The gentle dip of the eastern limb of the anticline is variable, and a series of minor synclines affect the groundwater flow.

The discharge at Ein Auja, ref. 185750/151400, forms a very large spring due to free discharge after heavy rain. In summer, the spring frequently runs dry. In the wet 1991-92 season, discharge averaged more than 70 m $^{3/}$ sec. but had been less than half this amount the previous very dry season, 1990-1991.

The variability of flow of the Auja System can cause problems, particularly for citrus groves and banana plantations. However one Palestinian farmer operates an ingenious scheme for recharging the Quaternary Aquifer, to his own and his neighbours' benefit. Overflow flood water and excess water from the Auja Spring System flow in concrete channels to two large ponds. A drip irrigation system uses this water for his extensive banana, citrus and market garden cultivation. Much of the water from the ponds, which is not needed during the winter, is pumped back down his well into the Quaternary Aquifer Assaf (1991). Ein Auja has a catchment area of 170 km^2 and receives an average annual rainfall of about 500 mm. This is a volume of 85 x 10^6 m^3, of which 17 x 10^6 m^3 is discharged by the spring system. The high salinity of these springs and the amount that is discharged suggest that underground flow is relatively slow and not sufficiently productive to prompt the sinking of many wells.

The Public Works Department of the Government of Palestine sank a well (ref.188400/ 1503000) in 1941,where, it was judged, the centre of the basin-like structure of the Auja Fauqa block was located. this well was sunk from a surface height of -100 m (below sea level) to the water table, reached at a depth of 169 m, i.e., 269 m below sea level, as shown in Fig.9. It would be most interesting to know now the depth of the water table in this well.

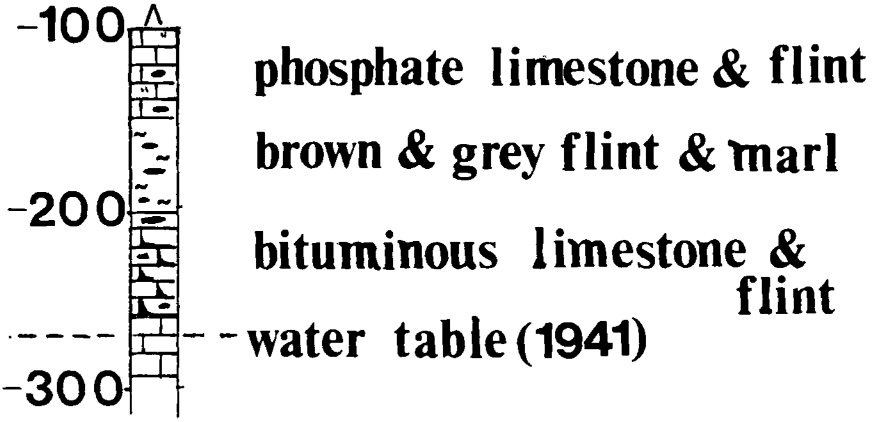


Fig. 9 Graphic well log through Auja Fauqa Block, after Blake & Goldschmidt (1947).

Mandel (1979) examined the anomalies of spring flow from the eastern edge of the Mountain Aquifer. He proposed that, prior to faulting, a karstic flow system developed in a south-west to north-east direction, with an outlet near the modern Ein Auja. Faulting lowered the base level, leaving the ancient karst system suspended and causing the groundwater to flow southwards towards Ein Tsukim. Rosenthal & Kronfeld (1982) differentiated the various water masses, based on the uranium isotopic signature and related the springs to the Upper Cenomanian - Turonian phraetic aquifer.

CONCLUSIONS

In order to make a valid assessment of the water that is available in the Mountain Aquifer, a much more accurate appreciation of this three dimensional system is required. We have karstic groundwater drainage, complicated by an active major shear-fault system. Our concern is to come to a greater understanding of the yield potential of the Mountain Aquifer.

In the karstic underground drainage systems we have in the Mountain Aquifer, the total void space is an unknown. The solution channels in the carbonate rocks have not been mapped. We do not know the extent of leakage downwards. We do have evidence of upward leakage, probably due to the release of confining pressure, but we do not know the extent of this leakage either. If we do not have detailed information of the reservoir potential of our karstic underground systems, efficient and economic recharging of the aquifer is not possible. The urgency for a comprehensive study of the Mountain Aquifer, in order to provide the negotiators at the current Peace Talks with an accurate assessment of groundwater availability is obvious.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Groundwater Allocation in Judea and Samaria

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Abstract

This paper analyzes the rights of Israel and of the Palestinians to the waters of the Mountain Aquifer, the major water resource shared by the two communities. As one of the possible peaceful solutions of the Israeli-Palestinian conflict is the establishment of a Palestinian entity, international law, as well as precedents from various international drainage basins, becomes relevant. They form the background for the application of hydrological and other natural aspects, in an effort to provide a framework for equitable and reasonable utilization and management of the aquifer. Based on analysis of international law (Benvenisti, 1993, these proceedings), this paper quantifies both parties' water rights in the Mountain Aquifer.

1. INTRODUCTION

An underground aquifer called the Mountain Aquifer supplies about a third of Israel's annual water consumption, as well as most of the consumption of the Palestinians residing in Judea and Samaria. The utilization and management of this important resource, is one of the major issues that must be addressed in any future peace talks between Israel and the Palestinians. In the semi-arid conditions of the Middle East, the access to shared water resources may be, as has been in the past, a source of friction and occasionally even armed conflict. Yet at the same time, this very interdependency may also prove a major incentive to peaceful cooperation.

If we examine the various suggestions that have been articulated by the parties during the recent rounds of talks, we will find that not all of them require an assessment of the water rights under the regular principles of international water resources law. The Israeli proposal, which consists of exclusive Israeli control over Judea and Samaria, with personal autonomy to the Palestinians residing there, is, like an Israeli annexation of Judea and Samaria, an example of an option which would leave Israel as the sole authority with respect to the management of the Mountain Aquifer. In this article I shall therefore examine the implications for the management of the aquifer of only those options which would establish a separate legal entity for the Palestinians of Judea and Samaria, be it a territorial autonomy, an independent state, or in confederation with Jordan.

Under International Law, the division of a shared water resource should follow the principle of "equitable apportionment". This principle essentially calls for the balancing of the needs of the communities sharing the resource. As Benvenisti (1993, these proceedings) shows, the principle has been recognized by the International Law Association in its 1966 Helsinki Rules, the International Law Commission in its 1991 draft water treaty, and the United Nations' Economic Commission for Europe in its 1989 Charter for Groundwater Management. These documents suggest factors to be considered in water apportionment. The factors that are of three kinds: natural characteristics of the resource, existing and potential uses of its water, and alternatives to the use of its water.

Which of these have priority ? The answer is not clear, but the documents do imply two general propositions as argued by Benvenisti (1993, these proceedings). The first is that the actual needs of the communities that depend on the basin take precedence over its natural characteristics. The second is that, from among the human needs, past and current uses take precedence over potential uses. In other words, what matters most is determining fair apportionment of a water resource is the current water use of the neighboring states. In fact, there is no evidence to support the alternative claim. No legal precedent suggests that waters should be divided based on the amount of water which lies within each state.

That being the case, why are the natural characteristics mentioned among the factors relevant to equitable apportionment ? Apparently, their use is in describing the factual background for the analysis, such as water availability, drought problems, groundwater contamination, and the like.

2. GROUNDWATER ALLOCATION BASED ON NATURAL FACTORS

2.1. Geography

Israel is longitudinally divided into three topographic units running from north to south: the Coastal Plain up to 200 m above sea level, the Mountain Ridge up to 1000 m elevation, and the Jordan Rift Valley down to 400 m below sea level (Figure 1). Judea and Samaria are located mainly along the central mountain ridge, called the Judea and Samaria Mountains, which stretch between the Izre'el Valley in the north and the Be'er Sheva Valley in the south. Judea and Samaria also includes a section of the Rift Valley, called the Jordan River Valley, between the Bet She'an Valley in the north and the Dead Sea in the south.

2.2. Climate

The western slopes of Judea and Samaria Mountains, between 200-700 m elevations, have an annual rainfall of about 500 mm. The high mountain peaks of 800-1000 m elevations, which include the major cities of Jerusalem, Hebron, Ramallah and Nablus, get about 700 mm annually. Along the eastern slopes of the mountains the average rainfall drops sharply from 600 to 150 mm. These slopes are located in "the shadow of the rain," and thus are sometimes called the Judea and Samaria Deserts. The Jordan River Valley which lies between 250 to 400 m below sea level, receives about 100 mm of annual precipitation. The climate is Mediterranean, with rains usually between November and March (Department of Surveys, 1985). In this region of semi-arid climate conditions, the

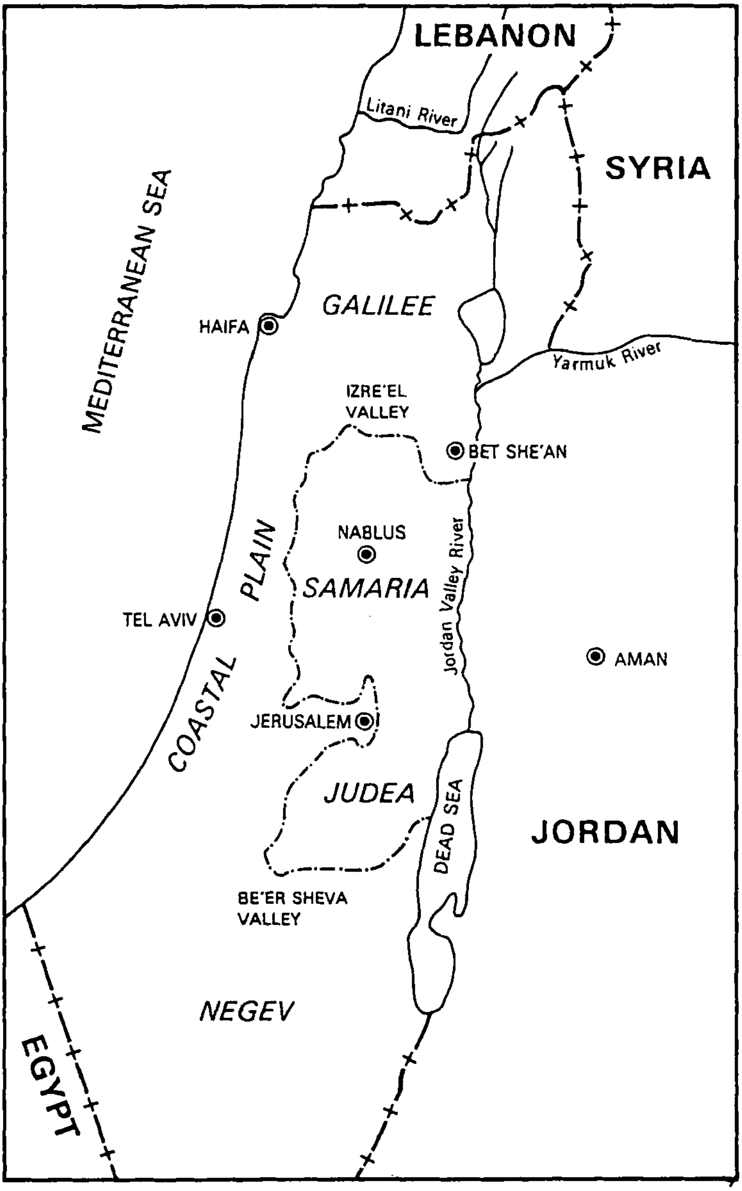

Figure 1. Geographic location map.

annual potential evaporation is 1900 to 2600 mm. Therefore, most waters evaporate back to the atmosphere. Only 25 to 30% of the rains enter groundwater systems, and about 5% run on the land surface as floods.

2.3. Hydrology

The rainwater that penetrates the surface moves downward through the soil and rocks and reaches a groundwater reservoir, called an aquifer (a water-bearing rock formation). The groundwater reservoir beneath the Judea and Samaria Mountains constitutes the largest water resource of the region, supplying 600 million cubic meters per year (MCMY).[1] This is the best quality water source in the region. A schematic cross-section across the mountain ridge (Figure 2) illustrates the water's flowpath. Rainwater that penetrates downward, reaches the water table and flows laterally, and enters the confined portion of the aquifer. Under natural undisturbed conditions, groundwater emerged through a small number of springs with a relatively high discharge rate. The largest springs were: Rosh Ha'ayin, Taninnim, and Bet-She'an. In the past centuries, these springs were sources of swamps. In the present century, the settlers in the Coastal Plain, Bet-She'an and Izre'el valleys began pumping from the aquifer and lowered the water table below the spring outlet levels. Today, the aquifer is utilized through hundreds of wells.

For the sake of simplification, let us consider as an example the western portion of the aquifer (left side in Figure 2) as a huge "box" of porous material (130 km length, 35 km wide, and 0.6 km thick) saturated with water. In reality, this "box" is composed of several sub-boxes of different rocks of complicated geological structure. Most of the water is included in a layer composed of limestone and dolomite rocks of the Cenomanian and Turonian age, called the "Judea Group" layer. Some interconnected smaller aquifers composed of other rocks exist in several sub-basins. We shall simply refer to all the various aquifer basins and layers beneath the Judea and Samaria Mountains as the "Mountain Aquifer".

We will define two terms: feeding area and storage area, parallel to two hydrogeological terms. The feeding area is known as the phreatic portion of the aquifer. This is the surface area composed of permeable rock outcrops through which rainwater is able to penetrate and enter the underground reservoir. This feeding area is also the area through which pollutants can infiltrate the aquifer and contaminate it. These outcrops, made of limestone and dolomite, spread along the entire length of the hilly backbone in the center of the country (Figure 3). The storage area is the confined portion of the aquifer. This is the area where the surface rocks are impermeable, and serve as a "roof" covering the groundwater reservoir. This storage area is located eastward and westward of the feeding area, beneath the margins of the Judea and Samaria Mountains and beneath the Coastal Plain. In this area the aquifer is bounded at top, bottom and on one side with impermeable layers (Figure 2). The vast majority of wells pumping water from the Mountain Aquifer are located at the storage area, where the pumping rate is stable and pumping is cheapest. The western boundary of the aquifer (Figure 3) is located along a line where the

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[1] Slightly different numbers are mentioned in different publications; yet they are all in the range of 580 to 600 MCMY. Among these publications are Israeli authors such as Schwarz (1982), and Palestinian authors such as Zarour and Issac (1991).

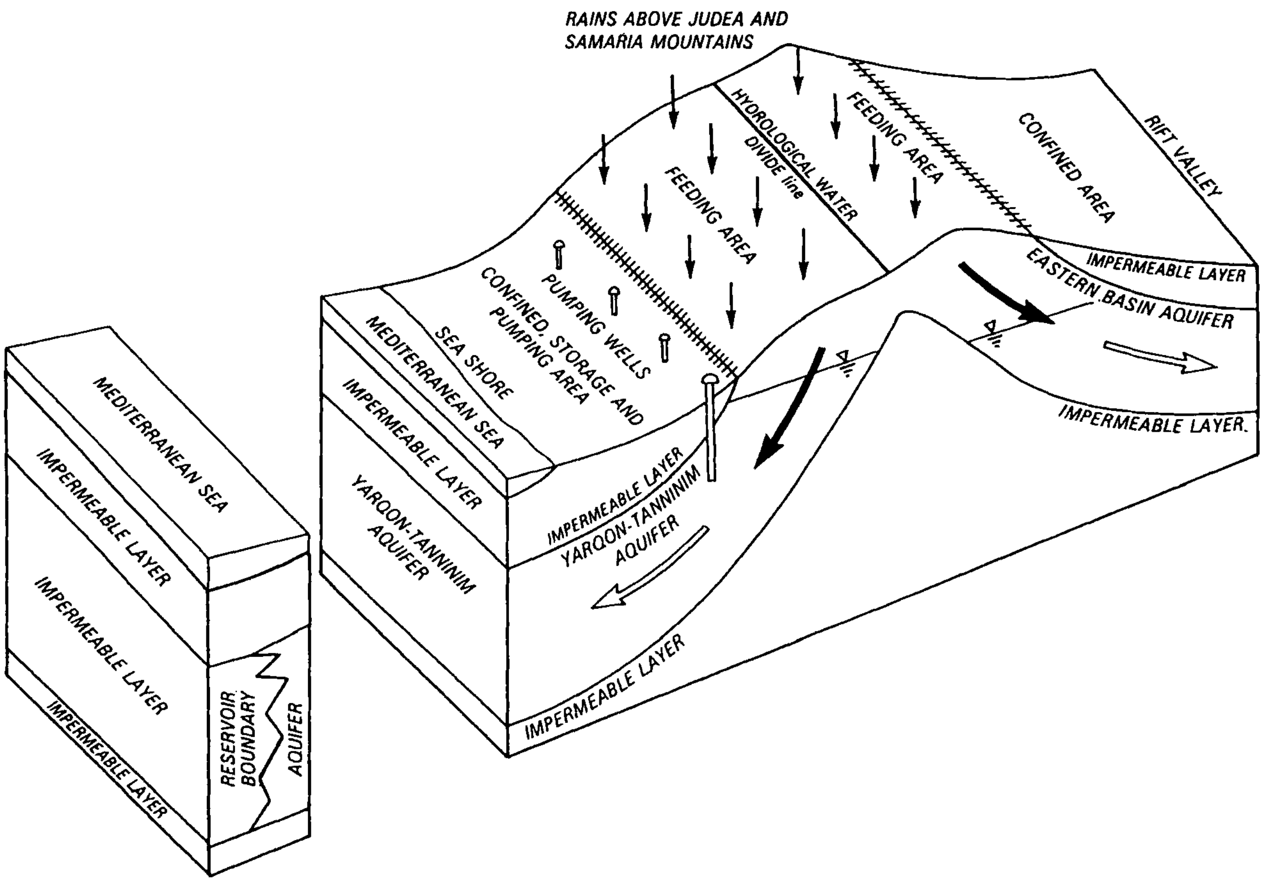

Figure 2. Block diagram of the Mountain Aquifer

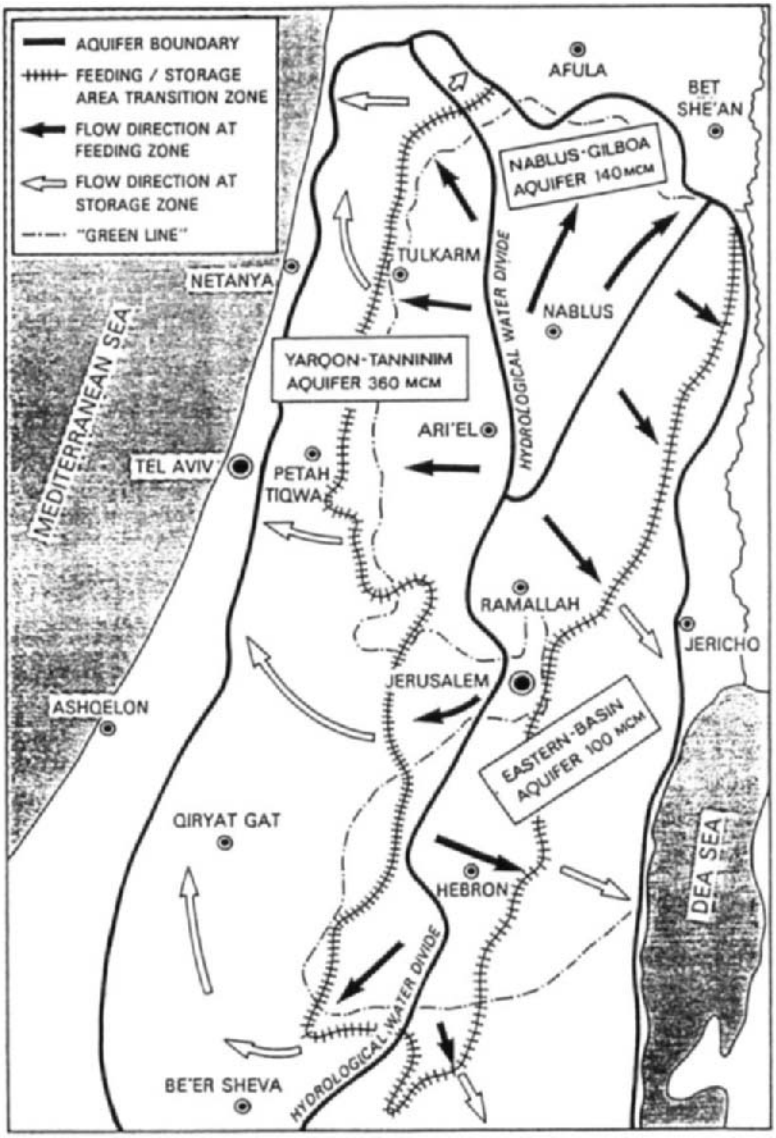

Figure 3. Hydrogeological map of the Mountain Aquifer

groundwater salinity exceeds 600 ppm chloride, which makes the water unsuitable for use. This western boundary is located beneath the Coastal Plain, at depths of 0.5 to 1.0 km. The eastern boundary of the aquifer is located along the structural faults of the Jordan River Valley (Figure 3).

2.4. Groundwater Basins

When water infiltrates the aquifer at the feeding area, it flows in all directions following the hydrological gradient. The axes of the main structural anticlines determine the main watersheds dividing the groundwater flow to the west, to the east and to the north. Accordingly, the aquifer systems related to Judea and Samaria Mountain can be divided into three major basins.

2.4.1. West: The "Yarqon-Taninnim" basin includes the whole west side of the central anticline, west of the main hydrological water divide line (Figure 3). The feeding area spreads over 1,800 square km, of which 1,400 square km lie to the east of the pre-1967 border (the so-called "green line," i.e. under previous Jordanian control) and 400 square km to the west of the border. The storage area of the aquifer spreads over 2,500 square km, almost all to the west of the "green line" (i.e., under pre- and post-1967 Israeli control). The two natural outlets (springs) of this basin, Rosh Ha'ayin and Taninnim, are located to the west of the "green line". This basin supplies 360 MCMY of water (Baida, 1986; Gutman, 1988).

2.4.2. North: The "Nablus-Gilboa" basin is located in the large syncline of the north-central part of the Samaria Mountains (Figure 3). Groundwater flows mainly northward. Both parts of the aquifer, the feeding area and the storage area, spread over 700 square km, of which 650 square km are located to the south of the "green line." Only 50 square km are located in the area north of the "green line" (i.e., under Israeli control before the 1967 war). However, most water emerging from springs or wells are located north of the "green line." This basin's total yield is 140 MCMY of water (Shaliv, 1980).

2.4.3. East: This basin is composed of several separated groundwater catchment basins. The total feeding area is spread over 2,200 square km and the storage area over about 2,000 square km, mostly to the east of the "green line." This basin yields about 100 MCMY of water (Schwartz, 1982; Zarrour and Issac, 1991). A small portion of the feeding area is located to the west of the "green line." This portion includes the city of Jerusalem and its surroundings. Although Jerusalem is located right on the ridge of the topographical watershed which divides the eastern basin from the western one, the hydrological watershed is located about ten km to the west of the "green line" (Figure 3). Thus, water that infiltrate the ground in the area near Jerusalem end up in the eastern aquifer. It is estimated that the contribution of the area of Jerusalem to the eastern aquifer, from both precipitation and leakages from the city's water network,[2] amounts to about 10 MCMY.

2.5. Quantifying Groundwater Rights

As has mentioned earlier, according to international law, the examination of an aquifer's natural conditions enables the identification of its international character and the countries that have rights to its waters. As the description above regarding the natural properties of the Mountain Aquifer shows, a territorial division according to the pre-1967 "green line," being one option for solving the conflict, would render the entire Mountain Aquifer, with its three basins, an international aquifer, to which the law of international water resources would apply.

An aquifer's natural conditions do not have much bearing on the question of the quantities of waters to be apportioned. Nevertheless, a contrary view has been presented by some Palestinian writers, namely that the apportionment of the waters of this aquifer should follow its natural attributes. According to this claim, each of the two parties would be entitled to the amount of rainwater that falls on the respective feeding areas in the territory of each party. Thus, the claim goes, Palestinians should receive all the rainwaters that fall on Palestinian soil. On the other extreme, Israel could argue that a groundwater resource is located where it naturally emerges, namely based on the spring locations. In other words, water allocation should be determined based on the location of the springs. Such an analysis would allocate the vast majority of the waters to Israel. Based on analysis of international law (Benvenisti, 1993, these proceedings), it is believed that both claims are wrong, but for the sake of the argument, two other allocations could be suggested based solely on natural properties. According to one, allocation could be calculated according to the ratio between the area of the aquifer (feeding area as well as storage area) which would be under Israeli control and that which would be put under Palestinian control. The second is that water allocation would be determined based on the volumes of groundwater under each territory. Both possibilities are quantified as follows.

The calculations assume that the "green line" would be the border between the two areas. In such a scenario, from the Yarqon-Taninnim basin Israel would control 400 square km of the feeding area and 2,500 square km of the storage area, while the Palestinians would control 1,400 square km of the feeding area (Figure 3). Thus, from this aquifer, Israel would control 68% of the aquifer territory, and the Palestinians 32%. The same calculation, applied to the Nablus-Gilboa aquifer, yields 7% controlled by Israel, and 93% by the Palestinians. In the Eastern Aquifer, the area of Jerusalem and its vicinity represents about 3% of the entire area of this aquifer. Alternatively, quantification of the water rights on the Mountain Aquifer of Israeli and Palestinian entities could be analyzed on the basis of the volumes of the water contained under each party's territory. Since water allocation is quantified by volumes, this method is preferred (Benvenisti, 1993, these proceedings, showed that this analysis has adopted by some writers). Therefore, due to the fact that the thickness of the water in the storage area is the full depth of the limestone

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[2] The city of Jerusalem consumes about 50 MCMY, of which 12% leaks from the 810 km-long pipelines, that is 6 MCMY, in addition to the rain that falls in Jerusalem and its vicinity; see Dinur (1991).

layer, while the water thickness in the feeding area becomes shallower as it approaches the hydrological watershed on the mountain ridge (Figure 2); and due to the fact that most of the storage area of the larger Yarqon-Taninnim basin is located under pre-1967 Israeli borders, according to this calculation Israel would be entitled to 310 MCMY (52%), while the Palestinians would be entitled to 290 MCMY (48%). In case that a future border would deviate from the "green line," the same methods of calculation would of course yield different results. However, as we stated above, we do not find arguments based on natural properties to be persuasive as a matter of policy, besides their being not in conformity with international law.

3. GROUNDWATER ALLOCATION BASED ON HISTORICAL USES

Before pumping started, almost all groundwater reached the natural outlets, namely the springs. The major springs are located at the foot of the hilly regions, along the Coastal Plain, the northern Gilboa slopes, and the Jordan Valley. Above the upper slopes of the mountains, some smaller springs with an unstable flow rate exist as well. Today the total groundwater potential is slightly greater than the total spring yield, since by pumping it is possible to retrieve water that used to flow to the sea and to be lost. The following analysis describes the past and existing uses of the three parts of the Mountain Aquifer.

3.1. Past and Existing Uses

The following analysis describes the uses of the three parts of the Mountain Aquifer in the order they were presented in the previous section.

3.1.1. West: The "Yarqon-Taninnim" aquifer was naturally drained through the Rosh-Ha'ayin springs (220 MCMY) and the Taninnim springs (100 MCMY). Both are located above the "storage area," in the Coastal Plain. Until the end of the last century, these springs were underutilized and thus created swamps. During the first decades of this century, the pioneering Zionist settlers succeeded in overcoming the undrained swamp problems and developed effective means to utilize these sources fully. When the natural spring flow was replaced by pumping, it became possible to achieve better regulation of water utilization between summer and winter seasons and from wet to dry years. Since the 1950s, the whole potential of this groundwater resource has been utilized (Mandel and Shiftan, 1981). In fact, during certain periods this resource was overutilized. In the early 1960s Israel utilized up to 30 MCMY more than the natural water potential; thus, water was mined and groundwater levels dropped. However, the introduction of the large-scale artificial recharge program, with water introduced through the National Water Carrier from the Sea of Galilee, enabled to replenish the aquifer (Schwartz, 1982). Before 1967, Israel used 340 of the 360 MCMY available in this basin. The other 20 MCMY were used by Palestinians in the towns of Qalqilya and Tulkarm, who diverted some springs and wells (Boneh and Baida, 1977). These figures have remained basically unchanged to this day.

The 340 MCMY pumped by Israel enter into the general Israeli "water bank," and it is therefore both impossible and meaningless to compute exactly how much of these waters go to irrigation, industrial uses, or domestic consumption. Suffice it to mention that a recent report of the Israeli State Comptroller found that due to the good quality of these waters, this aquifer, which is considered the principal long-term reservoir of the Israeli water system, provided the main source for drinking water for most of Israel's larger towns, including the Tel-Aviv area and its suburbs, Jerusalem, and Be`er Sheva (Israeli State Comptroller, 1990). This source provides also water for the Jewish settlements situated on the Judea and Samaria mountains, and also some of the domestic water needs of Arab towns and villages. The 20 MCMY that are drawn directly by the Palestinians in the Qalqilya and Tulkarm regions are utilized mainly for irrigation (Figure 4).

3.1.2. North: The Nablus-Gilboa aquifer was naturally drained through the Gilboa and Bet-She'an Valley springs (110 MCMY on the average), and the Wadi Farih springs (18 MCMY). Since the 1930s the Zionist settlers in the region have used the Gilboa and Bet-She'an springs mainly for irrigation. Later, the springs were replaced by pumping wells. Already before 1967 Israel utilized about 115 MCMY from this basin. In the same period, the Wadi Farih springs, the Bardela springs, and some other small springs, yielding all together 25 MCMY, were utilized by Palestinians mainly for irrigation (Schwartz, 1982; Boneh and Baida, 1977).

3.1.3. East: The Eastern aquifer is composed, as mentioned, of several sub-aquifers. They were naturally drained through the Auja springs (10 MCMY), Samiya spring (5 MCMY), Feshkha springs (40 MCMY), Wadi Qilt springs (5 MCMY), Jericho springs (13 MCMY) and Ein Gedi springs (3 MCMY) and many other smaller springs (Schwartz, 1982). Many additional springs contain high salt concentrations which render them useless. Before 1967, the fresh water springs, estimated to be about 58 MCMY, were diverted by Palestinian farmers mainly for irrigation. After 1967, the Israeli authorities developed a new well system on the upper slopes of the mountains in order to catch the groundwater before it reaches the natural outlets where it becomes saline. Using the new pumping system, it became possible to utilize larger amounts of the groundwaters of this basin. Today, this basin yields about 100 MCMY. Of the additional amount that is thereby utilized, 35 MCMY is allocated for irrigation by Jewish settlements of about 7,200 hectares (Figure 4), and the rest is used for domestic consumption in both settlements and Arab towns and villages in the region (Central Bureau of Statistics 1991) .

To sum up the survey of existing uses: of the entire potential of the Mountain Aquifer, Israel (including Jewish settlements in Judea and Samaria) uses 495 MCMY, while the Palestinians use 105 MCMY. For Israel, this aquifer is the source of a substantial part of its total annual consumption (which is about 1,400 MCMY of fresh water).[3] For the Palestinians in Judea and Samaria, the aquifer provides about 80% of their annual consumption, and the rest, about 15 MCMY, comes from other resources.[4] Of this amount, 95 MCMY go for irrigation of about 9,500 hectares, and about 25 MCMY is used for domestic consumption (Boneh and Baida, 1977).

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[3] Israel's other resources are mainly the Sea of Galilee and the Coastal Aquifer.

[4] These resources are the Jordan river, the Israeli National Water Carrier, local cisterns, and other surface waters.

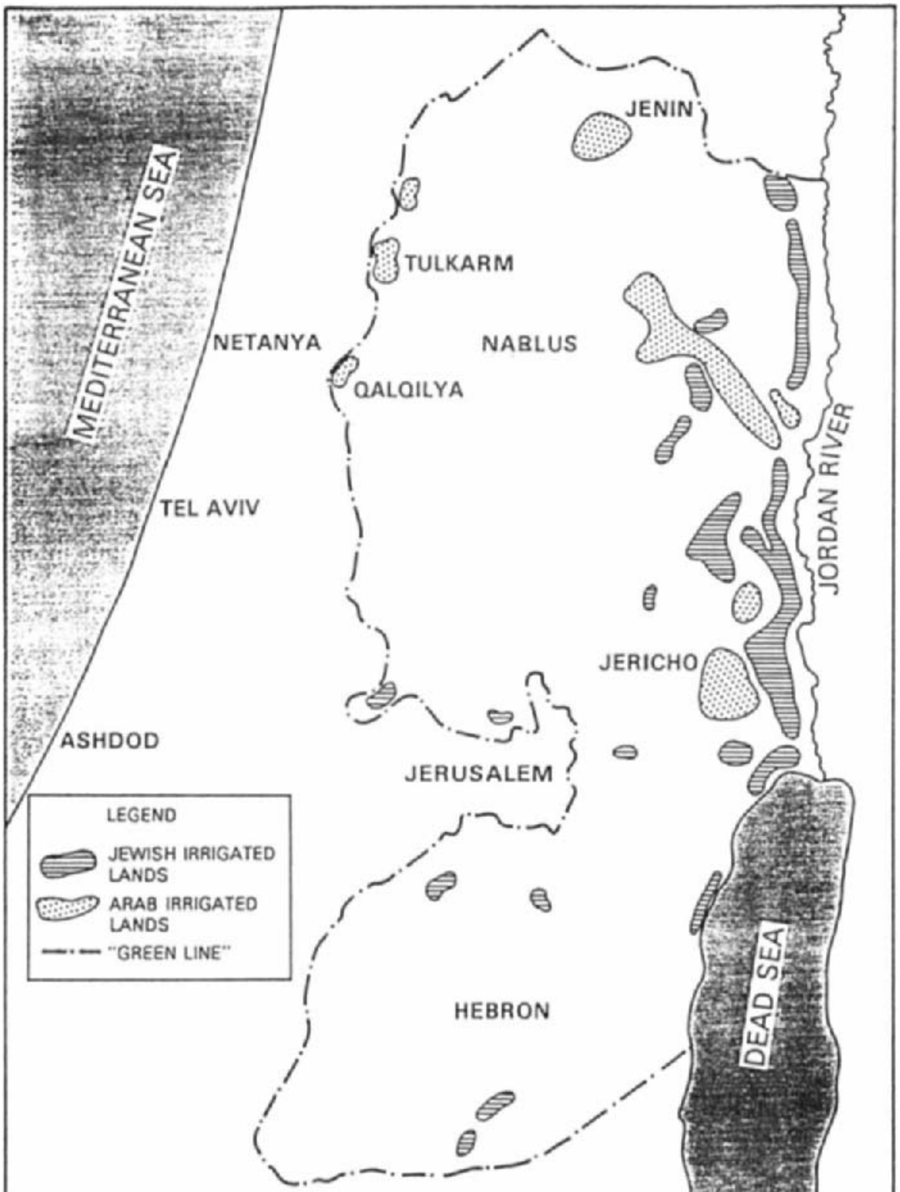

Figure 4. Irrigated lands in the Area.

3.2. Quantification of Groundwater Rights

As was mentioned earlier, water allocations are usually made on the basis of existing uses. Therefore, Israel is entitled to 83% of the water of the Mountain Aquifer. Yet changed circumstances and new demands may require adjustments of existing allocations. Ultimately, these new demands may conflict with prior usages, and thus the states sharing the basin must negotiate an agreement to accommodate their conflicting interests. The same is true in the case of the Mountain Aquifer: the analysis of the various factors may lead to allocations which differ from the existing one.

The peculiar historical circumstances, i.e., the Jordanian administration from 1948 to 1967, and since then the Israeli administration, complicate the "regular" balancing principle between existing and potential uses. The Palestinians would claim that the existing uses are the result of their being prevented by external forces from asserting their true needs for water during these years of occupations, before Israeli uses were crystallized, and therefore existing uses merit less deference than otherwise. To this Israel would probably respond by noting that the allocations have not changed significantly since the 1950s (aside from the additional amounts used by the Jewish settlements in Judea and Samaria).

When discussing potential uses, we should distinguish between domestic uses on the one hand, and agricultural and industrial uses on the other. Domestic needs are of course the primary concern in water allocation. Regarding domestic use, the basic distributive principle must be equal allocation of waters to all users according to their needs. This principle would lead in the future to additional quantities allocated to the Palestinians for domestic purposes, since the current Palestinian average per-capita consumption is about a third of average per-capita consumption in Israel. Second to domestic uses are the agricultural and industrial needs. This is in any case a more speculative area, since it is very hard to assess the competing potential agricultural needs. There are many factors, aside from the availability of waters and lands, that determine the economic viability of agriculture, and hence its potential demands. Among these factors are the population growth in the region, agrotechnical techniques (automation, fertilizers, pesticides, and greenhouses), more efficient methods of irrigation, available manpower, and potential markets.[5] For example, by using drip irrigation rather than flooding, it would be possible to almost double the irrigated fields.[6]

4. SUMMARY

The scarcity of water in the region makes water allocation one of the central issues to be resolved in the Arab-Israeli conflict in general, and the Israeli-Palestinian conflict in

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[5] Kahan (1987) lists a number of factors, besides the lack of water, that inhibited the growth of Palestinian irrigated agriculture during the occupation period.

[6] The efficiency of drip irrigation technique is usualy 90%, whereas by flooding, a method widely used by Palestinians in the Area, about 50% of the water is wasted by leaks or evaporation (personal communication, Prof. Eli Ravitz, Soil and Water Deptartment, the Hebrew University, Faculty of Agriculture).

particular. Among the suggested peaceful solutions that have been made, this article examined the ramifications of those options which call for the application of the international law, namely, the establishment of a separate legal entity for the Palestinians residing in Judea and Samaria, be it a territorial autonomy, an independent state, or in confederation with Jordan. Based on analysis of the concept of the "equitable apportionment" of the shared water resources under international law (Benvenisti, 1993, these proceedings) , it is concluded that the actual needs of the communities that depend on the waters take precedence over the natural properties that exist in the basin; and that among these needs, priority is usually given to past and existing uses, at the expense of potential uses. In applying these principles to the Mountain Aquifer, the past and existing uses of the aquifer were analyzed, and it appears that Israel is entitled for 83% of the groundwaters. However, by indicating the relevant factors that may shape the potential uses of these waters, this water allocation may slightly be modified in order to increase the Palestinian domestic consumption to be equal to the consumption level usually find in Israel.

Nevertheless, issues of control over water resources and their apportionment may fashion the parties' attitudes towards settlement. In fact, important circles in Israeli politics have already begun advocating against any territorial concessions, lest a Palestinian state would control the flow and quality of water upon which Israel so heavily depends. Therefore, maps of "vital regions" must be drawn in order to define the regions that will never be included in a Palestinian entity if and when it would be established. These regions should be defined according to the potential danger they may pose on water pumping in Israel in a case that the peaceful agreement will not be kept.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

The Development of the Water Resources of the Occupied Palestinian Territories: some key issues

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Abstract

The paper discusses key issues in the development of the water resources of the West Bank and Gaza Strip. First, there is the uniqueness of a situation where the major proportion of the transboundary flows between the OPT and Israel is groundwater, which infiltrates in the West Bank and flows to Israel. There are few decisions of international courts on the allocation of transboundary groundwaters. Second, perspectives and timeframes for problem resolution are an issue in the OPT, due in part to the uncertainties inherent in the peace process. The water resources crisis in Gaza, where the debate often focuses on large-scale solutions while appearing to ignore the need for a range of short, medium and long-term perspectives, is described and possible phased solutions are discussed. Third, there is a general lack of information and statistics and much of the limited information available is conflicting. Increasing the level of water resources information and skills at the disposal of the Palestinian community to that of their counterparts in the Region would raise the integrity and acceptability of any overall plan for water resources allocation and management, benefitting all the concerned countries in the Region.

1. INTRODUCTION

The paper draws on a recent United Nations Development Programme review mission (October 1992). The mission's task was to recommend strategies for the future work of UNDP's Programme of Assistance to the Palestinian People. The paper presents personal observations on water resources issues in the West Bank and the Gaza Strip; these observations do not necessarily reflect the views of the mission or of UNDP.

The problems of water resources allocation and augmentation in the Middle East are among the most challenging problems faced by the international community of water professionals today. Nowhere are the problems more challenging than in the Occupied Palestinian Territories (the OPT). Access to water underlies the viability of human settlement and the agroeconomy of the OPT. Water resources are scarce and are at risk from overabstraction. In addition, indiscriminate disposal of liquid and solid wastes, and reported overapplication of chemical fertilisers and pesticides are creating serious pollution risk. Efforts to address these problems are constrained by the occupation itself. Nevertheless, much can be done to improve the current situation, within the present constraints. Furthermore, efforts now to address these issues will provide strong foundations for the future.

Much has been written on the subject of water resources in the OPT and there is a convergence of views among the many writers. This paper discusses aspects of the present water resources situation in the Occupied Palestinian Territories (OPT), highlighting some key issues that have received less attention than they deserve: the precedents to be set in international water law and the complexities inherent in their implementation; the need for pragmatic solutions and not only grand designs; and the need to address the serious lack of water resources information and skills within the Palestinian community.

2. ALLOCATING TRANSBOUNDARY GROUNDWATERS: a key question for the West Bank

Fresh water is the Region's most precious resource. As such, the allocation of water has been the subject of lengthy international negotiations and agreements for decades. Jordan, Israel and the OPT are all characterised by water scarcity. With rapidly increasing populations, all three peoples together face serious water shortfalls unless regional solutions to enhancing water resources are implemented. Jordan and Israel have long accepted the principle of shared allocation of the surface waters of the Jordan River. In the current peace talks, the water rights of the Palestinian people have become a central issue. These would include rights to a riparian share of the surface waters of the Jordan Basin.

Less well known and probably more complex, is the equitable allocation of the groundwaters of the Region and in particular those of the *mountain aquifers*. The uplands of the West Bank form the recharge area for these aquifers, with groundwaters flowing west and north into Israel and east into the Jordan valley. These aquifers comprise the major source of water for the West Bank, although the Palestinians only abstract a very small proportion of the total groundwater resources and further abstraction has been severely restricted since 1967. They are also very important sources of water for Israel and are exploited both within and outside the "green line", providing a significant proportion of Israel's total water resources. The literature contains many references to estimates of total quantities and figures exploited by Israel and the Palestinians, however, there has been no (published) water resources assessment since 1965 (Rofe and Rafferty, 1965) and the availability of hydrological data is restricted. As a consequence, there is room for much speculation in data presentation and interpretation.

The groundwaters of the mountain aquifers are transboundary water resources of great importance. Israel has argued historic rights to these groundwaters, which have flowed into their present territory and been exploited since the beginning of this century. In direct counterpoint, the Palestinians have argued sovereignty over the water resources that originate in their territory. These opposite arguments have been made over surface water allocations in many parts of the world. However, the case is more complex with groundwaters.

First, alternative allocations can rarely be engineered, unlike surface water which generally allows strategically located dams and large scale interbasin transfers of water (as for example in the Indus Basin). With groundwaters, major changes in recharge and flow regimes are difficult to achieve over the short term, although minor changes, through altered landuse, artificial recharge and scavenger pumping can be significant. Thus, rain falling on the recharge areas of the West Bank will infiltrate through the unsaturated zone into the saturated zone and then move laterally as groundwater to discharge areas that may be beyond the borders of the territory; little can be done to change this regime.

Secondly, the groundwater regime of the mountain aquifers is itself very complex, due to the great depths to water across large parts of the West Bank, the highly variable rainfall and corresponding infiltration, the very long time scales between recharge and discharge, and the karstic nature of the aquifers. These *dual porosity* aquifers (with flow through both fissures and through the rock matrix) are not easy to model, with storage values and flow characteristics difficult to determine. Thus quantifying the resource accurately and estimating "natural" flows, a pre-requisite for rational allocation, are particularly difficult. Spring flows will often show two components; a fast, fissure flow component and a much slower matrix component, where movement may only occur in the order of 1 metre per year. Thus groundwaters emerging from springs or being pumped from beyond the "green line" may be many thousands of years old and recharged under very different conditions to today.

Thirdly, the state of international water law is much less developed for groundwaters than for surface waters. There are few if any precedents in international courts where the allocation of transboundary groundwaters has received substantive attention. In recent years, the principles of international water law have been considered to extend to groundwater, insofar as groundwater is a component of an international watercourse system. The 1966 Helsinki Rules (International Law Association, 1967) seek to overcome the apparent impasse indicated by the Israeli and Palestinian stands by advocating negotiated allocations, where "each State is entitled, within its territories, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin". Further, the Helsinki Rule provides for alternatives, such as water transfers or economic compensation, and for joint inspection commissions.

The 1988 Bellagio Draft Treaty (Hayton and Utton, 1989) is a model international groundwater treaty (based particularly on experience from the US - Mexico border region) which details the possible responsibilities of a joint commission, including the management of a database and the identification of conservation areas. Such a commission is envisaged as having oversight responsibility, with limited substantive discretion, leaving enforcement to the internal organisations of the respective countries. Alternative approaches to the allocation of water resources between the riparian states of the Region have been described in the literature (e.g. Shuval, 1992). However, the application of the principles of the Helsinki Rules and the adaptation of the Bellagio Draft Treaty to the groundwaters of the Region on the scale needed introduces major complexities of resource assessment and control.

3. SEEKING PRAGMATIC SOLUTIONS: the case of the Gaza Strip

The water resources debate often focuses on large-scale solutions, while appearing to ignore the need for a range of short, medium and long-term perspectives. The water resources crisis in Gaza illustrates this issue well. While equitable allocation between Israel and the Palestinians of the water resources originating in the West Bank will result in the need for careful water demand and asset management, viable coping strategies can be found. The situation in the Gaza Strip is very different.

The Gaza Strip has a very high population density, with 800,000 people living in 360 sq. km, and a high growth rate, estimated at 4%. Gaza has an economy under occupation that is severely distorted, with high unemployment and low agricultural and industrial productivity. Largely as a consequence of these factors, the Gaza environment has been under great strain for some time, and is now in crisis. This crisis is one from which its people suffer today and its landscape may never fully recover.

For thousands of years, the well-watered city of Gaza has been the gateway to the fertile lands of Canaan, bordering the Sinai Desert. The Strip is located in an area of delicate balance, between the low rainfall (<200 mm/yr) desert to the south, and the better watered (>400 mm/yr) Israeli coastline, stretching northward to Tel Aviv and Haifa. Part of this rainfall evaporates and is transpired by vegetation, part runs off overland to the sea, and part infiltrates into the soil. For over one hundred and fifty kilometres, the Israeli and Gaza Strip coastline is underlain by a narrow strip of Quaternary sands, the Coastal Aquifer; this relatively thin (0-180 m) sandy deposit overlies impermeable Tertiary marine clays.

The Coastal Aquifer (CA) in Israel is an extremely important resource, providing almost one fifth of the nation's annual renewable freshwater reserves. In addition, the CA has enormous reservoir storage capacity, giving it strategic and central importance in managing the National Water System. As a consequence, the aquifer has been extensively studied and developed and is carefully monitored. Large scale artificial recharge has been widely practised, to store water surpluses, to restore water levels and to control saline intrusion. State-of-the-art hydrological monitoring and numerical modelling has resulted in aquifer management strategies for which Israel is internationally renowned. Despite this effort, the aquifer is under stress, due to continued overdraft and consequent falling water levels and inland movement of the saline interface (Schwarz 1990).

The CA beneath Gaza (which extends a further 10 km or so eastward into Israel) is an even more sensitive resource than that of Israel, because of reduced infiltration due to the decreasing rainfall southward, and because it is the only source of water for the Gaza Strip. Yet the Gaza CA has *not* been the subject of serious study, at least not with results in the public domain. There are few verifiable data available, even though these are essential to define the problem accurately and to identify rational solutions. The hydrological monitoring work of the Water Department of the Civil Administration is not disclosed. Many papers have been prepared by Palestinians and by various aid agencies in recent years that estimate groundwater recharge and abstraction, and draw conclusions on overdraft (eg Bruins et al., 1991). The value of information cannot be overstated; data on water resources in Gaza have no strategic importance to any other territory (West Bank data probably do), and are of great importance to the preservation of Gaza's environment and natural resources.

3.1 The Problem

Stated simply, the problem is one of massive overdraft, where groundwater resources pumped from the CA far exceed its replenishment, and extensive contamination, by saline water intrusion caused by falling water levels, by untreated wastewater, by diffuse pollution from agricultural fertilisers and pesticides, and by point source pollution from domestic and industrial solid wastes. Wells are going out of operation and water is becoming unpalatable and even locally unusable for irrigation. This is a problem of crisis dimension and rapidly becoming irreversible. The problem can be characterised as follows.

- Water replenishment. The literature contains estimates of natural recharge to the CA in Gaza, ranging from 25 to 80 Mm^3/yr. This enormous range may in part reflect whether or not recharge into the CA to the east of the Strip (i.e. within Israel) is included. The impact of seasonal flows from Israel to Gaza within the three main wadis, and in particular in Wadi Gaza, is not known. Most estimates of natural aquifer replenishment are in the range 50-65 Mm^3/yr. The fact that this figure of recharge to a relatively small and accessible aquifer is not known with any accuracy is symptomatic of the problem.

- Water consumption. There are over two thousand wells pumping groundwater within the 360 km^2 of the Gaza Strip. Total abstraction is variously cited in the literature, with estimates ranging from 80 to 130 Mm^3/yr. Whatever the true figures, there are three consistent messages that can be derived: abstraction significantly exceeds replenishment; domestic and industrial consumption is increasing; and agricultural consumption for irrigation is reducing. The reasons for the latter are, first, the decline in the area of citrus under irrigation due in large part to increasing water salinity and second the progressive reduction in irrigation pumping quotas set by the Civil Administration. Nevertheless, irrigation still accounts for the majority of water pumped and the efficiency is low.

- Water quality and contamination. The water quality picture is complex and, apparently, little understood. The shallow, unconfined nature of the aquifer renders it particularly vulnerable to contamination, as does its proximity to the sea. Groundwater salinity (characterised by chloride) levels have been increasing, due to overabstraction of groundwater causing saline intrusion from the coast, the movement of connate saline waters from the east and from depth, and the progressive salination of soils due to over-irrigation. Poor sanitation practices are a further culprit. It is estimated that about 20% of the population in the refugee camps and about 40% of those outside the camps are served by sewered sanitation. The remainder of the population use latrines draining to cess pits, many of which overflow into surface drains, resulting in the ponding of raw sewage in depressions. Even where sewers are in place, the institutional arrangements are poor and often disputed; as a consequence maintenance is inadequate, sewers are blocked and treatment plants do not function. Sewage is thus a feature of the Gaza urban environment. Expected health consequences are apparent, such as the very high prevalence of intestinal parasites. The impacts on water resources are indicated by extremely high nitrate levels (reported at levels exceeding 10 times the WHO limits) near some population centres. High background levels of nitrate across the Strip are evidence of diffuse pollution from excess application of nitrogenous fertilisers; there are related but unproven concerns regarding high pesticide levels in groundwater; many of these compounds are toxic at very low concentrations and are thought to be mobile and persistent in aquifers. Solid waste is another feature of the urban environment, with indiscriminate dumping everywhere. Even when collection is undertaken, disposal sites are uncontrolled. The risks of contamination of a shallow unconfined aquifer by leachates are high, although there is little information on the scale of such contamination.

- Water resources management and development. Given the scarcity and vulnerability of water in the CA of the Gaza Strip, effective management of water resources appears very limited, particularly in contrast to the careful management of the water resources of Israel's Coastal Aquifer. The Civil Administration maintains a hydrometric network and a groundwater level and quality monitoring network, but data from these networks are not generally available. The Administration is apparently developing a digital model of the Gaza CA. Limited demand management is being promoted, through gradually reducing licence quotas for irrigation pumping, and through subsidising drip irrigation equipment. Under prevailing Egyptian law, water on the land belongs to the landowner, so no charges are levied (although quotas have been introduced), meaning that the potentially powerful economic instrument of pricing is not employed. On the supply side, 5 Mm^3/yr is apparently being imported from the National Water Carrier of Israel to the central area of the Gaza Strip, where groundwater is no longer potable. The Civil Administration is also developing a pilot reverse osmosis plant. While providing some relief in the present crisis, the desalination of brackish groundwater alone is not a long-term solution to the problem of over abstraction and contamination, as it will result in continued falling groundwater levels and saline water intrusion. There is now much debate regarding the development of a major seawater desalination plant for Gaza, a technology that could be expected to provide water at US$ 1-2 per m^3 (Keenan, 1991).

3.2 Problem resolution

Solutions to the problems described will not be effective until a sound water resources management strategy is in place. The precedent is set in the CA in Israel in terms of careful assessment, monitoring and development; the CA in Gaza needs the same - if not more - attention. Effective water resources management, particularly under conditions of scarcity, requires strong institutions, appropriate regulatory and economic instruments and popular awareness and participation. The occupation and Intifada pose serious constraints on achieving these conditions: however, without their achievement, there is only limited scope for significant improvement.

Even if they were well managed, the naturally replenished water resources of the Gaza Strip, loosely estimated to be about 80 m^3 per person per year, are far below the requirements for economic development in a modern state. Even with fully exploited potential for conservation, including rainwater harvesting, waste water reuse and artificial recharge, freshwater imports are likely to be needed in Gaza in the longer term. However, a coping strategy currently being promoted appears to require very large investments - for example in seawater desalinisation - without a full investigation of the nature of the problem and a phased approach to problem resolution. Desalination, while a solution to be considered carefully, is a solution of last resort wherever financial resources are scarce (as they are in Gaza), due to its high capital and operating costs, complexity and long-term energy requirements.

A strategy for resolving the problem will need to consider, first, an *enabling environment* and, second, a range of short, medium and long-term perspectives:

- The enabling environment. This includes the institutions, rules, policies, data, plans and prices needed for effective water resources management. It would be unrealistic to expect great progress on this front until autonomous and legitimate institutions can be established in the wake of a political settlement. The water resources of Gaza are mismanaged because there are few incentives for the responsible authority (the Civil Administration) to manage them effectively, and there are disincentives for any other institution or individual to try. In the interim, a coping strategy could be for a Palestinian task force, under the auspices of an international body, to commence coordinated data collection, planning and priority project identification. It will be important to consider Gaza within an overall framework for the OPT, not least because the resources of one may well be part of the solution to the scarcity in the other.

- The short-term. There are several possible components of a short-term strategy that could alleviate water scarcity problems and mitigate the worst consequences of inaction. A coping strategy must be developed which will allow the matching of abstraction and replenishment, as well as minimising further contamination. However, this course of action can only be a short-term solution (a few years?), As over the longer term it may stifle economic growth. The political, institutional and financial implications of these actions are varied: some would be more achievable than others under the present constraints. The actions could include:

  - Detailed *water resource assessment*, to include installation of a comprehensive hydrometric network, the establishment of a monitoring programme, and the development of digital models of surface and groundwater quality and flow. This will seek to quantify resources, and provide predictive models for water resources planning and management. Clearly, access to data and models held by the Civil Administration and its advisers would be invaluable. Information would also be needed on groundwater in the up-gradient extension of the Coastal Aquifer eastward into Israel.

  - *Public education* on environmental issues broadly, and on water resources scarcity in particular, to promote community awareness and participation, as a key element of the strategy for water resources conservation and protection.

  - *Agricultural substitution* to less water-consuming and more salt-tolerant crops, and even to dry land farming, coupled with improved farm water management. This substitution is already taking place and will continue, but by too little, too late. This could be accelerated by agricultural extension and by grants and loans for land clearing, planting and greenhouse construction. This would need to be accompanied by the revoking of abstraction quotas. The economic pricing of irrigation water would be the ultimate instrument for ensuring the right signals are sent to farmers. This must be considered, although traditional rights and practices will be difficult to alter and market pricing will probably kill irrigated agriculture altogether in the Gaza Strip. There are, however, examples of Gazan farmers who have made the transition to dry land farming (e.g. figs and grapes) very profitably.

  - Effective *demand and asset management* in municipal supplies. This will require the reduction of unaccounted-for water and the conservation of water by domestic and industrial consumers. Sound tariff structures are key instruments for achieving the latter. In addition, the promotion and even the subsidized supply of water conserving devices (such as low volume flush toilets) can significantly reduce consumption. However, weak water supply institutions will not carry out these actions effectively.

  - *Waste water reuse* for irrigation, replacing fresh groundwater quotas. The Gaza North area alone produces over 10 Mm^3/yr of wastewater that could substitute for groundwater abstraction of approximately the same quantity currently used for irrigation in Beit Hanoun and Beit Lahia. However, there are major cultural and educational barriers to be overcome, as well as concerns regarding loss of long established water rights, before wastewater reuse will be widely accepted. The economics of wastewater reuse by farmers would appear to be very sound.

- *Artificial recharge* of surplus waters, including seasonal wadi flows (particularly in Wadi Gaza, where perhaps 10 Mm^3/yr could be captured), treated wastewaters, and rainwater catchment and other runoff. A major ANERA project in Gaza City provides stormwater drainage to a large spreading basin, at the same time recharging the aquifer. Although a sound principle, care needs to be taken in the siting of recharge basins, to minimize the risks of contamination, for example from fuel spills.

- *Desalination* of brackish groundwater at strategically located wells, to meet local drinking water needs and to minimise the impact of local overabstraction. Groundwater modelling would aid the selection of suitable sites.

- Small-scale *purchase of water* from the Israeli National Water Carrier, as apparently already initiated by the Civil Administration. Market pricing should make this a profitable option for Mekorot and still a competitively-priced option for Gaza.

- The medium term. Over the next five to ten years, a more sustainable solution is required than the coping strategy implied in the short term solutions discussed above (although most of these solutions would remain elements of any effective water resources management strategy). For a political settlement to be implemented effectively, rational allocation of the waters of the mountain aquifers of the West Bank and of the Jordan Basin is a likely pre-requisite. This could provide a possible opportunity for a medium-term solution to Gaza's water resources problems. A settlement in the spirit of the Helsinki Rules, with "reasonable and equitable share in the beneficial uses of the waters of an international drainage basin" could allow barter, where a reduced allocation to the West Bank would be traded for onward transmission of water within the Israeli National Water Carrier to Gaza. The infrastructure costs of such an option would be small. There would, however, be no net gain of water to the countries of the Region.

- The long term. Ultimately, the solution to the environmental crisis in the Gaza Strip is inextricably linked to an overall solution to the Region's water scarcity. This is a subject that is extensively discussed in the literature, in which a range of mass transfer options is explored. Over the longer term the Region, in particular Israel, Jordan and the OPT, is likely to need more water, even with the most stringent demand management in place. The proposal for sea water desalination in Gaza needs to be put into this perspective, so that costs may be compared. Considered separately, there is a risk that Gaza may end up with the most expensive water, and yet its people are among the poorest in the Region.

4. ACQUIRING INFORMATION AND SKILLS

The description of the water resources crisis in the Gaza Strip illustrates the constrained access to hydrological data and information. As a consequence, there are unsubstantiated figures for total water resource inputs and outputs, together with various figures for transboundary flows of groundwater, for impounded wadi flows on the Israeli side of the border, for Israeli settlement abstraction, and for transfers from the National Water Carrier. There is therefore little clarity in a vision for the way forward. The confused situation in the West Bank is similar, with claims and counter claims regarding groundwater flows in the mountain aquifer systems.

The identification of sustainable solutions to the water resource problems of the Region requires careful assessment of resources and analysis of options. With limited skills and experience, no accessible hydrometric network gathering water resources information, and the most recent water resources assessment dating back to 1964, the Palestinian community are severely disadvantaged, both at the negotiating table and in their efforts to prepare sound economic development plans. There is a need to raise the standards of skills and information at the disposal of the Palestinians to that of their regional counterparts, to "level the playing field" in the allocation, monitoring and management of water, thus increasing the integrity and acceptability of an overall plan, benefitting all the parties concerned, including Israel. Without skills and data, the Palestinian community will be unlikely to have confidence in any proposed water resource allocation arrangements, and subsequently will not have the capacity to manage and control those resources effectively. There are three obvious areas of need:

- Access to, or, if necessary, establishment of a rational hydrometric network in the OPT, providing data on weather (including rainfall), surface water flows (including flows of all major springs), and groundwater levels and water quality.

- The comprehensive assessment of the water resources of the West Bank and Gaza (updating earlier studies, such as the 1965 study of the West Bank by Rofe and Rafferty, op. cit.). This would involve literature review, access to Israeli-held data, field work to gather fresh data, and detailed analysis. Objectives would include the determination of total storage and recharge volumes, overall flow characteristics, and water quality.

- Extensive training of Palestinian water professionals, and more limited training of others (including planners and policy makers) in the technical, economic and policy aspects of water resources management. This could be well served by the establishment of a Palestinian Centre for Water Resources Management, attached to one of the universities. In addition, the establishment of the hydrometric network and the water resources assessment described above should both have as specific objectives the building of professional and technical skills.

5. CONCLUSIONS

Allocating the waters of the mountain aquifers will be a difficult task and one requiring a collaborative effort of the different parties, first to establish workable principles, second to quantify the resources, third to propose rational allocations, and fourth to establish a commission to manage and monitor the allocations. It is important that a start be made in bringing together Israeli and Palestinian specialists, possibly under the auspices of one or more international professional associations, to lay the foundations on which a future commission could be built. A valuable foundation would be the development together of resource models of the mountain aquifer systems, using mutually agreed data. Although there are international river basin organisations in many parts of the world, there is very limited experience in the allocation of the resources of a major and complex aquifer between riparian states. In the Region this task is complicated by the political situation. The challenge is considerable and there are few precedents to follow; there are, instead, precedents to set.

Resolving the water crisis in the Gaza Strip is a different but equally challenging task. At the core of any solution is the need for an expert group of Palestinians to be assembled and permitted to develop and implement a coping strategy to limit further deterioration of Gaza's fresh groundwater resources. While there is work for the same or a similar expert group in the West Bank, the problems of Gaza cannot wait and must be treated with urgency. Longer term solutions can be explored within the broader scope of the peace process and subsequent economic development planning.

Support will be needed in the execution of these tasks. The UN system is well placed to provide objective support to the resolution of the questions of water allocation in the Region, as well as direct support to the Palestinian community. This assistance deserves high priority.

6. ACKNOWLEDGEMENTS

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Isaac/Shuval (Eds), Water and Peace in the Middle East

INTERNATIONAL LAW AND THE MOUNTAIN AQUIFER

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Abstract

International law strives to delineate riparian states' rights to international water resources, whether lakes, rivers or underground aquifers. This paper analyzes the principles of international law, and applies them to the specific case of the Mountain Aquifer which is shared by Israel and the Palestinians, assuming the restoration the "Green Line" as a political border.

1. INTRODUCTION

An underground aquifer called the Mountain Aquifer supplies about a third of Israel's annual water consumption, as well as most of the consumption of the Palestinians residing in the West Bank.[1] Israel and the Palestinians have also major stakes in the waters of the Jordan river system.

International law strives to delineate riparian states' rights to international water resources, whether lakes, rivers or underground aquifers. Initially, attention was given mainly to the allocation and conservation of surface waters. But as the importance of groundwater became more apparent, efforts were made to elaborate on the law relevant to international groundwater. In addition to the general clarification of international prescriptions, some neighboring states reached regional arrangements for the joint utilization and protection of international aquifers, as, for example, in the Rhine region and in Lake Geneva in Europe, or in North America (between the U.S. and Mexico, and between the U.S. and Canada).[2] Both the international prescriptions and the

1. The West Bank region had been under Jordanian administration between 1948 to 1967, and since then under Israeli control. For the description of the natural characteristics of the Mountain Aquifer *see* H. Gvirzman, these Proceedings.

2. In other cases, agreement still eludes the parties, as in the case of the huge North-Eastern African aquifer that lies below Libya, Egypt, Chad, and Sudan. For a general overview of international groundwater law see Caponera & Alheritiere, *Principles for International Groundwater Law*, 18 Natural Resources Journal 589 (1978); Barberis, *The Development of International Law of Transboundary Groundwater*, 31 Natural Resources

experience of regional regimes offer the basis for discussing the principles of a future arrangement with respect to the waters in the Middle East.

Together with my colleague Dr. Haim Gvirzman of the Hebrew University, we endeavored to draw upon this experience, and apply the generally accepted principles of international law to the specific case of the Mountain Aquifer. Our aim is to outline the legal aspects of a possible peaceful arrangement regarding the management of this crucial resource.[3] We examine the implications for the management of the aquifer under the assumption of the re-establishment of the pre-1967 "green line" as a political border between Israel and a Palestinian entity.

The question of joint management of the waters of the Mountain Aquifer never arose beforehand. From 1948, when the West Bank became occupied by Jordan, until 1967, no challenges have been made to the Israeli utilization of the aquifer. During that period, the Jordanian government was content with little investment in the West Bank, and Palestinian demand for water from this aquifer remained relatively low through 1967. The Israeli authorities who administered this area since 1967 prevented similar challenges by consolidating their control over all of the local water systems, and by severely limiting Palestinian access to additional water resources. These circumstances suppressed a fierce struggle over this aquifer from taking place.

2. OUTLINE OF APPLICABLE INTERNATIONAL NORMS

Increasing demand for water has brought states that share water resources to conclude treaties regarding their joint utilization and management. Concurrently, the growing awareness of the necessity of community-wide principles on this issue, prompted two parallel international efforts to explore and enhance the international legal guidelines.[4] In 1966 the International Law Association (ILA) adopted the Helsinki Rules, which were supplemented in 1986 by the Seoul Rules concerning international groundwater resources.[5] The International Law Commission (ILC) started in 1971 to work on the drafting of rules concerning the non-navigational uses of international watercourses. On July 19, 1991 the ILC adopted a text consisting of 32

Journal 167 (1991), who also gives an account of the existing regional arrangements (at 184-85).

3. For Dr. Gvirzman's article *see* these proceedings. We do not discuss the utilization of these waters under the current Israeli administration. On this issue see E. Benvenisti, *The International Law of Occupation* (Princeton University Press, 1992).

4. The Institute of International Law preceded both efforts in its Resolution on the Utilization of Non-Maritime International Waters (Except for Navigation), adopted at its session at Salzburg (3-12 September 1961), 49 (2) *Annuaire de l'Institut de Droit International*, 370 (1961); trans.: 56 American Journal of International Law 737 (1962).

5. The Helsinki Rules appear in the ILA's Report of the Fifty-Second Conference, at 484 *et seq.* (1967); The Seoul Rules appear in the *Report on the Sixty-Second Conference*, at 251 *et seq.* (1987).

articles which it sent to governments of member states for comments.[6] In addition, regional efforts to clarify rules on this subject have taken place. Most noticeable is the activity of the United Nation's Economic Commission for Europe (ECE), which on April 21, 1989 adopted a Charter on Groundwater Management.[7]

With respect to the allocation of the waters of an international water resource (surface as well as underground) by riparian states, the underlying principle that emerges from the developing norms of international law, and which is recognized as such by the ILA, the ILC, and the ECE, is the principle of equitable allocation.[8] Basically, this principle calls for the balancing of the needs of the communities that share the common resource. In doing so, a proper balance between the protection of existing uses and the initiation of new uses must be found. The Helsinki Rules, the ILC draft rules, and the ECE Charter accept this principle. Trying to define this general principle more minutely, both the Helsinki rules and the ILC draft rules provide a partial list of factors that should be taken into consideration in determining the proper allocation of waters in a specific basin. The following analysis of the rights to the Mountain Aquifer will be based on this general principle of equitable allocation, and will follow the list of factors indicated by the two documents.

Despite the wide acceptance of the principle of equitable allocation, some have recently suggested that it is or should be replaced by the notion of "no appreciable harm", originally a principle employed in the context of the duty of one state to prevent environmental damage ("appreciable harm") to a neighboring state. It appears that the drafters of the ILC rules chose not to subject the rule of "no appreciable harm" to the rule of equitable allocation, and thus opened the door to a new thesis, namely that the *quantities* of waters should be allocated under the no appreciable harm principle. Thus a host of questions are raised: what are the rights that may not be appreciably harmed? does the rule refer to *legal* rights or to actual uses (thus strengthening historic usages beyond what is necessary)? which harm is "appreciable" and which is not, and who determines it? These are but a few questions that this new thesis raise, questions which have the effect of blurring the "older" picture. In any case, since the ILC draft rules are yet to be accepted as law, this - to my mind unwarranted - deviation from the equitable allocation analysis do not merit attention at this time.

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6. For the text of the articles see 30 I.L.M. 1575 (1991); 21 Environmental Policy and Law 191, 247-49.

7. ECE Annual Report (1989-90), ECOSOCOR 1989, Supp. No. 15.
In addition, attention must be given to a private multi-disciplinary initiative of scientists and legal scholars to provide a blueprint for regional treaties for the regulation of shared aquifers: see Hayton & Utton, *Transboundary Groundwater: The Bellagio Draft Treaty*, 29 Nat. Res. J. 663 (1989).

8. For an impressive number of regional treaties that adopted the same principle either expressly or impliedly see Barberis, *Bilan de recherches de la section de la langue francaise du Centre d'Etude et de Recherche de l'Academie*, in Hague Academy of International Law, *Rights and Duties of Riparian States of International Rivers*, 38-47 (1990). The same principle was applied in 1906 to the apportionment of the waters of the Rio Grande river between Mexico and the U.S.: Armstrong, *Anticipatory Transboundary Water Needs and Issues in the Mexico-U.S. Border Region in the Rio Grande Basin*, 22 Nat. Res. J. 877, 904 (1982).

3. THE PRINCIPLE OF EQUITABLE ALLOCATION

The various factors suggested by the ILA and the ILC may be divided into three sets: the natural characters of the drainage basin, the existing and potential uses of its waters, and finally, the alternatives to the waters of the basin or to their existing uses. Since there are three distinct sets of factors, it is pertinent, before applying these factors to the Mountain Aquifer, to discuss the relative weight of each of the sets. In particular, it is necessary to explore the relative weight of the natural factors *vis-a-vis* the man-made conditions.

Although both the Helsinki Rules and the ILC draft articles do not give a clear priority to one set of factors over the others, two basic propositions may be culled from the abundant material that exists on this subject. The first proposition is that human conditions, i.e., the actual needs of the communities that depend on the waters, take precedence over the natural properties that exist in the basin. The second proposition is that among the human conditions, priority is given to past and existing uses, at the expense of potential uses.

Stephen C. McCaffrey, the third Special Rapporteur to the ILC, concluded after reviewing all the available evidence on the general practice of states accepted as law, that "no State whose territory is bordered or transversed by an international watercourse has an inherently superior claim to the use of the waters of that watercourse."[9] Therefore, in applying the principle of equitable allocation, what counts are the needs of the neighboring communities: "In the most basic terms, the task of arriving at an equitable allocation involves striking a balance between the needs of the States concerned in such a way as to maximize the benefit, and minimize the detriment, to each."[10] This conclusion is based on ample evidence of state practice, judicial decisions and legal authorities,[11] and is also in line with the law of federal states.[12] And in fact, there exists no evidence to support the contrary proposition,

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9. Second Report on the Law of the Non-Navigational Uses of International Watercourses, Doc. A/CN.4/399, *ILC Yearbook 1986*, Vol. II (Part1), 87, at 131.

10. Id., at 132.

11. This conclusion has never been contested. See J. Lipper, "Equitable Utilization" in A. Garretson, R. Hayton and C. Olmstead eds., *The Law of International Drainage Basins*, 41, 45 (1967); Griffin, *The Use of Waters of International Drainage Basins under Customary International Law*, 53 American Journal of International Law 50, 78-9 (1959); Bourne, *The Right to Utilize the Waters of International Rivers*, 3 Canadian Yearbook of Int'l. Law 187, 199 (1965); Buirette, *Genese d'un droit fluvial international general*, 95 Recueil general de droit international public 5, 38 (1991); Barberis, *supra* note 8, at 40.

12. See McCaffrey, Second Report, *supra* note 9, at 129-130; Bourne, *supra* note 11, at 245-253. In the case of *Arizona v. California*, 373 U.S. 546 (1963), Justice Douglas mentioned, in his dissent, the size of the basin within each of the two states as a relevant factor under the principle of equitable apportionment (at 627). The Court has not adopted this

namely that waters should be allocated for example according to the contribution of each state to the basin's waters, or the length of the river in each's territory. It is interesting to note that the priority for human needs over natural parameters was recognized by Israel and its Arab neighbors already in the 1950s, in the negotiations with respect to the allocation of the waters of the River Jordan. The negotiating partners, Jordan, Israel, Lebanon and Syria, viewed the agricultural needs of these states as the primary consideration for allocation, rather than each state's natural contribution.[13]

Evidence for the general acceptance of the second proposition is equally abundant. As Article 8(1) of the Helsinki Rules states, "[a]n existing reasonable use may continue in operation unless the factors justifying its continuance are outweighed by other factors leading to the conclusion that it be modified or terminated so as to accommodate a competing incompatible use."[14] This principle is accepted also in the jurisprudence of federal courts. The last ruling of the U.S. Supreme Court on the subject, in the case of *Colorado v. New Mexico*,[15] emphasized the predominance of existing uses, and placed a heavy burden on the state challenging this usage to prove the desirability of the proposed change.[16] Two considerations support this proposition. The first takes note of prior uses of the waters. The allocation of waters is always historically contextualized. Communities that came to utilize these waters relied on their availability, and their reliance merits respect. But this proposition is justified also from a prospective point of view. As the commentary to the Helsinki Rules explains, "failure to give any weight to existing uses can only serve to inhibit river development. A State is unlikely to invest large sums of money in the construction of a dam if it has no assurances of being afforded some legal protection

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factor. On this point *see* Sherk, *Equitable Apportionment After Vermejo: The Demise of a Doctrine*, 29 Nat. Res. J. 565, 577 n.65 (1989).

13. The main factor used to calculate the allotments to the two principle users, Israel and Jordan, was their potential irrigable lands: Doherty, Jordan Waters Conflict, in *International Conciliation*, No. 553, at 25-28 (1965).

14. In the same vein see the Resolution of the Institute of International Law, *supra* note 4, Articles 3 and 4.

15. 459 U.S. 176, 103 S.Ct. 539, 74 L.Ed.2d. 348 (1982).

16. Id., at 187 (U.S.): "We recognize that the equities supporting the protection of existing economies will usually be compelling." To justify the detriment to existing uses, a State would have to "demonstrate[] by clear and convincing evidence that the benefits of the [change] substantially outweigh the harm that might result." *See also* Simms, *Equitable Apportionment - Priorities and New Uses*, 29 Nat. Res. J. 549 (1989); Tarlock, *The Law of Equitable Apportionment Revisited, Updated, and Restated*, 56 U. Colo. L. Rev. 381 (1985).

for the use over an extended period of time."[17] While this proposition is well grounded in customary international law, it seems to be challenged by the ILC draft that does not accord special weight to any of the factors, including that of prior utilization.[18] Such a challenge appears to be motivated by the ideology of the new international economic order, and is yet to be reflected in state practice.

Based on this analysis, one may ask what the relevance of the international basin's natural properties is for the purpose of allocating its waters among the users. Why does the ILA mention these factors among those relevant to the determination of equitable allocation? The answer seems to be that the main thrust of the natural factors is in setting the background for the legal analysis, by describing the factual conditions of the shared drainage basin, such as the availability of waters, as well as special problems such as drought conditions, potential development of dams and other constructions, as well as the drawing of the boundaries of the basin (to determine the states which are parties to the basin).[19]

The peculiar historical circumstances, i.e., the Jordanian administration from 1948 to 1967, and since then the Israeli administration, complicate the "regular" balancing principle between existing and potential uses. The Palestinians would claim that the existing uses are the result of their being prevented by external forces from asserting their true needs for water during these years of occupations, before Israeli uses were crystallized, and therefore existing uses merit less deference than otherwise. To this Israel would probably respond by noting that the allocations have not changed significantly since the 1950s (aside from the additional amounts used by the Jewish settlements in the Area).

When discussing potential uses, we should distinguish between domestic uses on the one hand, and agricultural and industrial uses on the other. Domestic needs are of course the primary concern in water allocation.[20] Regarding domestic use, the basic distributive principle must be equal allocation of waters to all users according to their current or future needs. This principle would lead in the future to additional quantities allocated to the Palestinians for domestic purposes, since the current Palestinian average per-capita consumption is about a third of average per-capita consumption in Israel. Second to domestic uses are the agricultural and industrial

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17. See the commentary to the Helsinki Rules, *supra* note 5, at 493.

18. See the commentary to the ILC draft Article 7, *ILC Yearbook - 1987*, Vol. II, Part 2, at 36 (1989).

19. See B. Godana, *Africa's Shared Water Resources*, 58 (1985): "Factors (a) to (c) mentioned in Article V of the Helsinki Rules merely re-emphasise the need for an accurate assessment of the nature and extent of the interdependence between utilisation in the different basin states."

20. See, *e.g.*, the Commentary to the Helsinki Rules, *supra* note 5, at 491-92: "[I]f a domestic use is indispensable - since it is, in fact, the basis of life - it would not have any difficulty in prevailing on the merits against any other uses in the evaluation of the drainage basin."

needs. This is in any case a more speculative area, since it is very hard to assess the competing potential agricultural needs. There are many factors, aside from the availability of waters and lands, that determine the economic viability of agriculture, and hence its potential demands. Among these factors are the population growth in the region, agrotechnical techniques (automation, fertilizers, pesticides, and greenhouses), more efficient methods of irrigation, available manpower, and potential markets.[21]

The principle of equitable allocation calls also for the assessment of the availability of other water resources in the region.[22] The other major water resource in the region, to which both Israel and the Palestinians are riparians, is the Jordan river. It is significant that among the riparians to the Jordan river, the two countries in the north, i.e. Lebanon and Syria, enjoy a solid supply of waters for all current and near-future uses.[23] For these two countries, the waters of the Jordan river are not as crucial as they are to Israel, Jordan, and the Palestinians.[24] It is therefore suggested, under the Helsinki and ILC rules which call for the assessment of other available resources to riparian states, that the downstream partners would have a claim to the waters of the Hasbani and Banias rivers. This additional amount could then be allocated among the lower riparians according to their potential needs. The Johnston Plan, negotiated between the riparians of the Jordan river in the 1950's, would have allocated waters to both Lebanon (35 MCMY) and Syria (132 MCMY).[25] The negotiation history of the Johnston Plan seems to indicate that the allocation of waters to both Lebanon and Syria was not the outcome of an analysis of potential uses in both countries, but rather the result of a condition that was submitted to Mr. Johnston by the so-called Arab Plan.[26]

The Johnston Plan was never formally accepted nor followed by Syria and Lebanon; it was overshadowed by military conflict and animosity; and finally, it was aimed at supplying agricultural needs of the 1950's. It is therefore suggested that the allocation of the Jordan river's waters must be reexamined during negotiations for a peaceful settlement of the Arab-Israeli conflict, in view of contemporary needs and legal guidelines. While it is not the purpose of this article to discuss the currently equitable allocation of the Jordan river's waters, it is important to emphasize that under

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21. For the analysis of these factors *see* Dr. Haim Gvirzman, these Proceedings.

22. Helsinki Rule 5(h); ILC draft rules, Article 6(f).

23. Lebanon has other resources such as the Awali and the Litani rivers. Syria's major sources of water are the Euphrates and the Orontes rivers. These two rivers originate in Turkey, and thus Syria's supply depends on Turkey's respect for its rights. On these countries' water economies see Naff & Matson, *Water in the Middle East: Conflict or Cooperation?* (1984); Shuval, *Approaches to Resolving the Water Conflicts between Israel and Her Arab Neighbors - A Regional Water-For-Peace Plan* Water International, 1992.

24. See Naff & Matson, *supra* note 23, at 43-44: the sole motive for the pre-1967 joint Syrian-Lebanese attempts to divert the water of the Hasbani and Banias were to deny the water to Israel.

25. See Doherty, *supra* note 13, at 27.

26. Id., at 27.

the established international rules, Lebanon and Syria would seem to have to yield to the water needs of their drier neighbors downstream. Compared with their potential water reserves, the relinquishing of the rights to the Jordan river waters would hardly be significant to both countries.[27]

4. THE DYNAMIC CHARACTER OF THE ALLOCATION PROCEDURE

I argued that existing uses are the starting point for any discussion of the re-allocation of waters. Yet I also maintained that the existing allocation may change due to conflicting potential uses on the one hand, and alternative resources or new ways to use water more efficiently on the other. Thus, for example, if increased demand for water in one state may be satisfied by using other resources or more efficient irrigation techniques, the existing allocation would possibly remain unchanged. My final argument with respect to this allocation relates to its procedural aspects. The apportionment of an international water resource is an ongoing process. The relative demands of the riparian states may change over a period of time. The quantity of available water may also change, depending on the actual precipitation in any given year. Drought, not an uncommon feature in this region, or massive pollution, could require the reapportionment of the available waters on a ad hoc basis. The principle of equitable allocation therefore calls for constant exchange of relevant information and continuing negotiations over the exact allocation in any given year. Thus, in the attempt to settle this issue the parties should not include exact amounts of water to be apportioned. Rather, they should aim to establish a set of guidelines for apportionment, with a complementing mechanism for the reevaluation of future supplies and demands. The institution of mechanisms for the joint management of aquifers seems to provide an appropriate answer to such a challenge. As I explain in the next part, the joint management of an aquifer is crucial for other reasons as well.

5. THE JOINT MANAGEMENT OF THE MOUNTAIN AQUIFER

The appropriation of the waters of a given aquifer is not the only issue to be addressed. Among the other issues that must be jointly regulated are the location of wells, the monitoring of amounts actually pumped and of water quality, the artificial recharging of the aquifer, its conservation, and the prevention of pollution. All these concerns must be subjected to an ongoing process of effective communal decision-making. The establishment of institutions for the joint management of joint water resources is therefore essential.

Such joint management is especially important with respect to underground waters. This is so because of the natural properties of underground reservoirs. In underground systems, water flows at a relatively slow rate, as the permeability of porous rocks is much slower than those of surface systems. Thus, withdrawal effects may take many years to be transmitted from place to place, and therefore without monitoring it is impossible to verify the amounts of waters pumped by the parties. Underground reservoirs are sensitive to overpumping and to contamination, which may cause irreversible damage. Sometimes it is difficult to judge whether an aquifer has

27. See supra notes 23, 24.

been polluted, or to identify the sources of the pollution.[28] In the case of the Mountain Aquifer, the special rock types should be considered as well. The karstic properties (caves and underground canals) of the limestone rocks that spread over the Judea and Samaria mountains,[29] can create shortcuts for pollutants reaching the aquifer, without any natural impediments for their penetration like sorption or filtration. These concerns call for close cooperation between the riparians. The optimal way to achieve such cooperation is through the joint management of aquifers.

Currently there are some precedents of joint management of international aquifers through interstate commissions. Since 1973 the U.S.-Mexican International Boundary and Water Commission (IBWC) has been dealing with issues concerning certain aquifers underlying the common border between the two states.[30] Similarly, since 1977 the U.S.-Canada International Joint Commission (IJC) has begun to look into issues relating to the groundwater.[31] The management of the Lake Geneva aquifer, which is shared by France and Switzerland, is since 1978 entrusted to a joint commission.[32] The importance of regional institutions to the optimal utilization of international aquifers has been recently recognized in international documents. The ILA's 1986 Seoul Rules on international groundwater provide that "[b]asin States should consider the integrated management, including conjunctive use with surface waters, of their international groundwater at the request of any one of them."[33] Although there is yet no evidence on the crystallization of a customary norm to that effect, the ILA commentary foresees that more states will understand the importance of regional regimes and will therefore enter into joint management agreements.[34] The Charter on Groundwater Management adopted in 1989 by the ECE calls upon member states to establish joint commissions to cooperate in the management of joint groundwater resources.[35] A similar emphasis on the necessity to establish joint

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28. Many states have realized the danger of polluting aquifers and have promulgated laws to minimize the risk: see the Economic Commission for Europe, *Ground-Water Legislation in the ECE Region*, ECE/Water/44 (1986).

29. *See* Gvirzman, these Proceedings.

30. Minute No. 242 of August 30, 1973, reprinted in 68 A.J.I.L. 376 (1974). On the powers of this commission concerning the aquifers see Utton, "International Groundwater Management: The Case of the U.S.-Mexican Frontier", in L. Teclaff & A. Utton eds., *The Law of International Groundwater* 157, 159-60 (1981).

31. Caponera & Alheritiere, *supra* note 2, at 613.

32. The unpublished text of the French-Swiss agreement of June 9, 1978 appears in L. Teclaff & A. Utton, *supra* note 29, at 464-77.

33. Seoul Rules, *supra* note 5, Article 4.

34. Id., at 272.

35. Article 25(1): "International cooperation: Concerted endeavours to strengthen international co-operation for harmonious development, equitable use and joint conservation of ground-water resources, located beneath national boundaries, should be intensified. To

commissions is found in the Bellagio Draft Treaty.[36] This draft treaty also indicates the typical assignments that such institutions may be called upon to perform, and suggests modalities for decision-making and a third-party dispute resolution mechanism.

Based on the above analysis I conclude that any political arrangement creating a separate Palestinian entity would have to include a procedure for the joint management of the Mountain Aquifer. In designing the suitable institutions, it would be advisable to study the experience of similar arrangements in other international groundwater basins.

6. SUMMARY

1. Under the scenario of a return to pre-June 67 borders, all three aquifers are international. Under international law, the waters of these aquifers are subject to the principle of equitable allocation.

2. Two basic propositions may be culled from the international law of water resources on the issue of equitable allocation. The first proposition is that human conditions, i.e., the actual needs of the communities that depend on the waters, take precedence over the natural properties that exist in the basin. The second proposition is that among the human conditions, priority is given to past and existing uses, at the expense of potential uses.

3. When discussing potential uses, we should distinguish between domestic uses on the one hand, and agricultural and industrial uses on the other. Domestic needs are of course the primary concern in water allocation. Regarding domestic use, the basic distributive principle must be equal allocation of waters to all users according to their needs. Second to domestic uses are the agricultural and industrial needs.

4. The principle of equitable allocation is an on-going process, taking into account new demands and changing amounts and quality of waters. It therefore calls for exchange of relevant information and continuing negotiations over the exact allocation in any given year.

5. It is essential to establish institutions for the joint management of shared water resources, especially in the case of shared groundwater.

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this end, existing or new bilateral or multilateral agreements or other legally binding arrangements should be supplemented, if necessary, or concluded in order to place on a firmer basis co-operative efforts among countries for the protection of those ground-water resources which can be affected by neighbouring countries through exploitation or pollution. In order to implement such co-operation, joint commissions or other intergovernmental bodies should be established. The work of other international organizations, particularly on data harmonization, should be taken into account." *See supra* note 7.

36. Article 3, *supra* note 7, at 684.

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Approaches to the Legal Aspects of the Conflict on Water Rights in Palestine/Israel

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Abstract
Law can play a positive role in the resolution of water disputes between the Israelis and Palestinians. While international Law relating to water resources is not fully developed, it does indicate a proper procedure for resolving these issues and it does have a number of specific provisions which relate to the water situation which ought to be respected as a first step towards the complex process of resolution contemplated in the developing law on the subject.

1. INTRODUCTION

The conflict between Palestinians and Israelis, and to a lesser degree the conflict between Israel and the Arab Countries, has centered around the issue of land and water. As the parties move towards substantive discussions of a possible resolution of the conflict, it is important to understand the specific details of the problem involved and to obtain a proper handle on methods of its resolution. The academic and scientific community has a primary obligation in this regard since the alternative leaves the situation in the hands of others who are guided either by the logic of power or the passions of political partisanship.

For the purpose of legal analysis, three major clusters of issues regarding water resources in the Occupied Palestinian Territories can be delineated:

1. The first relates to water resources that originate and are discharged completely in the Palestinian Occupied Territories. The most obvious example of this sort is the Eastern aquifer resulting from rains falling East of the hydrological line that crosses the West Bank towards the Ghor Valley.
2. The second relates to the riparian waters which feed into the Jordan river. These resources are shared by the Occupied Territories as a unit together with Jordan, the State of Israel and Syria. Despite the absence of clear precision, there are sufficient guidelines in international law as it pertains to surface riparian rights that can and should fully govern the allocation and distribution of the waters of the Jordan river among Israel, the Palestinians and other parties as will be shown below.

3. The third problem pertains to water resources resulting from rainfall in other areas which falls West and North West of the hydrological line and which feed two main aquifers that are shared with the State of Israel. The vast majority (about 80%) of the waters in these aquifers originate in the West Bank catchment area (1), and the aquifer itself flows and actually straddles the border between the two areas with the majority of it found in the West Bank and Occupied Territories.

The International Law pertaining to underground aquifers is less clear and specific as to the required allocation of water resources between two areas which share the same underground aquifer, and the simple analogy from surface waters of rivers flowing into a lake is scientifically unsound since ground waters are far more complex.

Another problem under this classification relates to the harmful effect of Israeli drilling just off the borders of the Gaza Strip in raising the water table to harmful levels.

A further complication to a strictly legal analysis arises from the existence of exclusive Jewish settlements in the Occupied Territories. These are individuals and communities that have been illegally implanted into the Occupied Territories contrary to the provisions of international law. While relatively small in numbers, these exclusive enclaves in fact utilize the water resources of the Occupied Territories massively for their own use. Judging by Israeli figures alone, the settlers in the Occupied West Bank and Gaza use approximately 90 million cubic meters per year out of exclusively Palestinian water resources as compared to about 200 million cubic meters allocated for the indigenous Palestinian population (2). While maintaining the necessary scientific skepticism about these figures, it must be acknowledged that the settlers thus constitute a major and not insignificant consumer of water in the Occupied Palestinian Territory which must be reckoned with.

A further complication arises from the absence of a clear legal entity entitled to represent the Palestinian people in International Law. The Palestinian Occupied Territories are not yet a state, and Palestinian water rights at present are dealt with more under the principles relating to belligerent occupation than the principles governing the allocation of water resources among contiguous riparian states. This distinction, while most relevant for the present and past practices, is only a formal problem for any forward - looking analysis that wishes to consider future utilization and water allocations between Israelis and Palestinians.

2. The Question of Data

The first task of neutral and objective academicians in this sphere is to delineate the parameters of the problem as objectively as possible and to obtain the factual data on the water situation in all its aspects. This does not only mean outlining the climatic and topographic nature of the area but also the water resources available, their location, movement, quality and origin. Detailed facts must be obtained as to the location of the aquifers, the geological nature of the ground in which they are located, the direction of their movement, the degree of salinity and the purity of the water. There also must be data which permit a reasonable assessment of the actual consumption, as well as potential requirements, needs and priorities of the different peoples in the area. One of the first requirements of the Helsinki Rules, described below, is the free sharing of such information (3).

In the case of the conflict at hand, there is a major problem that has not been dealt with sufficiently. Detailed information does exist both in Israel and the Palestinian Occupied Territory because the Israeli authorities have investigated the problem thoroughly, have undertaken exhaustive and continuous research and have accomplished centralized control over all the water resources which are heavily regulated. They occasionally dig exploration wells at great costs to determine the quality and quantity of subterranean water resources at different locations and have a myriad of legal and administrative units monitoring and regulating water use. This thorough regime of regulation and control was also implemented in the Palestinian Occupied Territory where the Israelis have placed meters on existing wells to determine and control with great precision and specificity the exact amount of use (4). This regime resulted in a very high level of centralization and control as well as sufficient data to permit short and long term planning on a grand scale.

Yet this regulation has also been combined with an obsessive level of secrecy. Information pertaining to water is considered in Israel as sensitive as the movement of troops and as such must pass the rigorous censorship before figures are released (5). Even the relatively robust Hebrew press has strict standing orders to submit any water - related articles to the censor before publication. Israeli academics acknowledge that certain information is not available to them either (6). In point of fact, throughout my research in this area. Almost no data is available pertaining to Israel and the West Bank that was not specifically released by Israeli official sources. A close analysis of the figures reflects some glaring inconsistencies, and the figures only represent summary conclusions and do not provide a verifiable break down. There is no access allowed to primary data and all academicians must rely on the official highly censored version of the facts (7). No international or even independent academic Israeli verification exists. Yet despite this, the scientific community has shown a pointed absence of scientific curiosity and skepticism and has tended to accept the official Israeli figures at face value. In this , I believe the academic community is remiss. This is all the more disturbing, since tools exist, such as satellite surveillance to obtain more reliable data, or at least broad verification of facts. In the absence of sharing full information, the entire discussion becomes either meaningless, or directed by partisan Israeli interests and perspectives. Having outlined the types of problems that may arise in the three major areas of water use and conflict between Palestinians and Israelis, it would be helpful to discuss the different approaches to dealing with these problems from a strictly legal point of view.

3. First approach; Pure power and lawlessness

This approach is facilitated by the ongoing hostilities and the absence of peaceful negotiations and agreements. It is also further enhanced by the absence of international mechanisms for the enforcement of international law and its obligations and a proper forum in which such issues can be litigated. To a lesser degree, this approach is also aided by the lack of precision and clarity as to some of the provisions of international law as they pertain to shared water resources and allocation, particularly of subterranean waters. Even where there is a clear principle relating to riparian rights, few scholars and even fewer precedents exist to accept such a principle as binding where subterranean waters are concerned. Even where there is a clear principle relating to surface water rights, few scholars, and fewer precedents exist to accept the application of such a principle where subterranean waters are concerned.

Under this approach, each party or country grabs whatever water resources are within its military reach and exercises its military and political leverage to impose its interests and to deny others, particularly its enemies, of what would be their rightful share of the water resources. This approach includes not only utilizing exclusively available water resources without care for the consequence to other individuals or groups or the quality or quantity of water that is left to them after exhausting one's own needs; but it also includes forcibly capturing, diverting and controlling water resources that falls within the territory of others. It also includes the use of military power to destroy wells and water works prepared by others and using force or threat of force to prevent others from digging wells or utilizing their own resources, or imposing their own restriction on their use of water.

While many nations and peoples can be accused of acting according to this approach, Israel as the dominant military power in the area has been the most flagrant practitioner of this approach and has used it with respect to the Palestinian and other Arab territory and population under its control as well as with Jordan, Syria and Lebanon. In the 60's, Israeli Prime Minister Levi Eshkol publicly announced that any attempt by the Syrians to utilize their water resources in a way that would reduce the flow into Israel, would constitute a causus belle. On other occasions, Israel used its military power to physically destroy Jordanian and Lebanese waterworks in the Yarmouk and Jordan rivers. Even before 1967, Israeli soldiers conducting cross-border raids into then Jordanian-held territory in the West Bank always took care to destroy water wells, hereby insuring continued flow of water Westward towards their own territory. The claim that this, or even that 1948 border gives Israelis, through prior use, a valid claim over Palestinian rights in the water of the aquifer that were utilized before 1967 begs the question. Palestinians have always asserted their historical rights to all of Palestine and their rejection of the Zionist Conquest of their homeland. Acceptance of Resolutions 242 and 338 dose not include a renunciation of their legitimate rights in Palestine water resources in what is now Israel. Such rights, together with other thorny issues need to be negotiated and settled within the framework of political agreements - not by sheer force and imposition de facto of one side's will upon the other.

In a primitive and small attempt of the same kind, the Palestinian Resistance Movement (Fateh) initiated its own military operations against Israel by attacking and attempting to blow up one of the Israeli water works on January 1, 1965. Perhaps this was symbolic of the use of the first approach to the water question as merely any object for the exercise of power and influence unrelated to international law and principles.

Unfortunately, this approach has never lacked for professional academicians who provide some scholarly justifications to what is otherwise a lawless approach of selfish interests. Some of the advocates of the "Prior use" theory often turn out to be mere post facto apologists for the users of the brute power approach by attempting to give legitimacy and justification to clearly illegal practices as if such a theory could grant retroactive legitimacy to what is otherwise clearly illegitimate acquisition of water use through force.

4. Second approach; Strict compliance with international law

While international law has its lacunae, particularly where it pertains to shared subterranean aquifers, there are none the less sufficient explicit provisions of international law that impact the current situation and which are worthy of support for their implementation. While academicians usually are powerless to impose or enforce provisions of international law, they have the obligation to place their moral weight and authority in favor of accepting and implementing already existing provisions in relevant international law, as well as developing it in helpful directions.

Those who insist on developing and extrapolating a new principle of law will do well to first insist on strict compliance with already existing accepted principles of law.

As it pertains to the water disputes between Israelis and Palestinians, there are several broad concepts of international law that are applicable both to the existing situation and past practices of the parties; and as guidelines for future allocations of water resources. The first and most obvious principles are the provisions of international law pertaining to Israel's conduct in the Occupied Territories. These include

Articles 52, 53 and 55 of the Hague Regulations of 1907; the Fourth Geneva Convention of 1949, and particularly Article 54 of Protocol 1 of that Convention, and numerous resolutions of the General Assembly and the Security Council of the United Nations which specifically address Israel's conduct in the Occupied Territories.

It is the universal opinion of the international community, which is also supported by the highest Israeli legal body, the Supreme Court, that the status of Israel in the Occupied Territories is that of a "belligerent occupier" (8). The Laws of belligerent occupation are found in their most comprehensive form both in the Hague conventions and more specifically in the Geneva conventions and their protocols. The State of Israel accepts the application of the Hague convention as part of customary international law but has employed a variety of legal arguments to avoid the application of the more detailed Geneva conventions which Israel has signed.

No international legal authority outside Israel accepts any of the Israeli attempts to avoid the applications of the Geneva conventions and Israel itself claims that it is in fact applying <u>de facto</u> these conventions. It avoids the de jure application through the following devices:

a. The Israeli high court has claimed that these conventions are not customary, but treaty law which have not been specifically incorporated into the Israeli legal system by Knesset ratification. Therefore as a domestic court, it is not empowered to enforce them even though Israel may have been signatory and therefore obligated under international law to obey them.

b. The argument is made that the Geneva conventions are only pplicable to territories that have been captured from another recognized sovereign. Here Israelis argue that only two countries, England and Pakistan have ever recognized Jordanian sovereignty over the West Bank, and therefore, given the doubt over Jordanian sovereignty in the West Bank and Gaza, Israel is not obliged to respect the applicability of the Geneva conventions.

No international authority accepts this argument because even assuming that there is any question about Jordanian sovereignty in the West Bank, the issue is irrelevant since the protection of the Geneva Conventions is extended to every population that falls under the control of a government other than their own during time of belligerency (Article 3) and it is irrelevant who the previous sovereign or controller was. The argument is also disingenuous since Israel never bothered to respect the Geneva Convention in the Golan Heights, whose previous Syrian sovereignty was never disputed.

c. Some Israeli politicians have argued that land captured in a defensive war is exempted from the application of the Geneva Conventions, which only apply to territory captured by offensive operations. Apart from the absence of universal agreement as to whether the '67 war was defensive or offensive, the issue is again totally irrelevant since the Geneva Conventions make no such distinction but only apply the regime of belligerent occupancy to a situation that follows on the heels of hostilities.

At any rate, as it pertains to water resources the conceptual and philosophical basis of belligerent occupation, whether under the Hague or the Geneva conventions is the same: The occupying power acts as a usufruct or trustee over the occupied territories until such a time a peace treaty resolves the issues in dispute and the territory is returned to its proper sovereign. Both the Hague and Geneva conventions attempt a delicate balance between the military needs of the occupying army and the rights of the occupied civilian population, prohibiting the alteration of the status quo except within limited boundaries.

The occupying forces are restricted in their exercise of authority to issues required by their security and the maintenance of public order. They are prevented from altering the existing legal and administrative structure in the occupied territories and their use of the resources is equally restricted.

One element that determines the degree of restriction on the use of resources is largely governed by whether these resources are movable and immovable resources. Movable resources, particularly those with military application such as means of transportation can be confiscated and used by the occupying powers under certain conditions, provided the use is for the military forces themselves, and that proper compensation is paid. Use of immovable resources is even further restricted. The issue of whether subterranean water sources are movable or unmovable property therefore becomes significant.

The precedents and international opinion has held on more than one occasion that subterranean oil resources are to be included as immovable resources and not movable ones. Several international cases related to oil resources in the Philippines and more recently in the Sinai Peninsula pointed in this direction and held that it is not permitted for an belligerent occupation to utilize previously untapped subterranean oil fields, and that to the extent that it is necessary to utilize one of these resources for the military use of the occupation forces, it needs to be compensated, and it cannot depleted (9).

The principle of usufruct is well known principle by which the occupation trustees can utilize the replenishable fruits of existing resources (trees, timber, etc.) without exhausting the principal source or depleting it to the point where it will become unusable upon the return of the territory to its former or proper status.

Israeli water policy in the Palestinian Occupied Territory has been clearly violative of these principles. Israel altered the existing water laws by passing military orders 89 and 157 giving it complete and full control over these resources including the metering of existing wells and the prevention of granting necessary permits for Arab water works including the improvement of existing wells or the digging of new ones (11). More dangerously, Israel used this regulatory power to confiscate, divert and utilize the existing water resources not of the benefit of the existing population, or for its military use, but to pump the water to Israel itself and to provide for its civilian settlers. No compensation was paid or offered for the acquisition of these water rights.

A second major violation was the introduction into the Occupied Territories of Israel's own population in the form of exclusive Jewish settlements. Here international public legal opinion is unanimous. With no exception, not even the United States, the world community has condemned the building of civilian Jewish settlements as illegal and contrary to international law. The Geneva conventions clearly prohibit such activities as well as resolutions of the United Nations Security Council and General Assembly. Therefore, the use of any of the water resources of the Occupied Territories by the Israeli settlers is patently illegal and void and it is very clear that such illegal use cannot give rights to future water rights under any conceivable settlement.

A third violation is the expropriation of a portion of the water rights attributable to Palestinian "absentees" and the transference of those water rights and allocations to Jewish settlers or to Israel itself.

In all the above cases, Israel has been acting in its own interests as a full though undeclared sovereign in the Occupied Territories, rather than as a trustee and usufruct acting for the public order or the interest of the local population, or for the needs of its military forces.

Looking forward to the future and away from these previous and existing violations, one can look to international law for some guidance for the proper allocation of shared water rights between a new Palestinian entity and the State of Israel. Here the controversial legal issue only relates to the shared water resources on the western part of the West Bank. Under existing international principles, the water which falls on the West Bank and is discharged there is fully the sovereign property and entitlement of that territory. International law is not sufficiently clear, however, on the allocations of water resources which fall or begin in one territory but eventually make their way through subterranean channels into a shared aquifer. Movement seems to be away from a strict sovereignty approach, but even a limited sovereignty approach would still guarantee Palestinians in a West Bank State or entity entitlement to substantial portions of the water resources originating in their territory, and which can be utilized by them, were it not for the enforced restrictions. The forcible exploitation of these resources by the Israeli authorities, does not create for them rights therein, nor does the enforced low utilization of these resources by the Palestinians negate their legal rights to their fair share of such resources.

5. The Third Approach: Equitable distribution

A third and most constructive approach to this conflict is built on seeking agreements based, not on brute force, nor on sovereign rights held in an adverserial zero-sum context, but in a reasonable attempt to arrive at a fair and equitable solution. Such an approach is increasingly gaining acceptance, and is reflected in the practice of states in a number of disputes. It is becoming codified as a result of the painstaking efforts of the International Law Association, under the name of the Helsinki Principles. These principles have not yet been fully adopted into binding legal obligations and norms, although they are most useful as tools for furthering the prospects of negotiated agreements between contenders for shared resources without the danger of being down in legalistic disputes over contentions texts and controversial political stands. This approach, by contrast is more pragmatic and result - oriented.

Closely related to this approach are the proposals to resolve the conflict by "enlarging the pie" ' that is by importing or creating new water resources from outside the Area, rather than facing the difficult task of making choices, and determinations between differing claims.

The principles outlining this approach are found in the Salzburg resolutions of 1961, entitled The Utilization of Non-Maritime International Waters, adopted by the Institute of International Law, and The Helsinki Rules of 1966 on the Uses of the Waters of International Rivers, developed by the International Law Association.

Article #3 of the Salzburg Resolution states that disagreements will be resoled 'on the basis of equity, taking particular account of the respective needs, as well as other pertinent circumstances". Article 4 requires that no state utilize its water sources in a way which "seriously affect" the possibility of utilizing the same sources by other states".

Article 4 of Helsinki states that " each state is entitled within its territory, to reasonable and equitable share in the beneficial uses of the waters of an international drainage basin". This right comes with the proviso that it does not cause "significant" or "substantial" harm to others, either in terms of the quantity or quality of water left over for the use of other, usually downstream users.

One problem with this approach is that it leaves vast room for interpretation, and opposing claims as to what are "equitable", "reasonable share", "needs" of each party, the potential needs? What constitutes "significant or substantial" harm? What level of development is permitted given a limited resource? Who will be permitted access to easily available sweet water, and who must contend with the expense and uncertainty of importing water from afar or of desalinating brackish or sea water or altering agricultural practices to utilize reclaimed sewage?

In the context of the Israeli Palestinian conflict over water rights, the appeal to equity, and proportionality must avoid the following pitfalls:

1. That this approach be used to negate water rights clearly established under existing legal standards such as the rightful share of surface waters and other riparian rights.
2. Giving weight to the "rights" or entitlements of Jewish settlers in the occupied territories, whose very presence is

illegal.
3. Accepting a false symmetry in assessing potential needs, and population growth between returnees, and refugees returning to their families and homes after a forced exile, and between Zionists making "alia" for ideological or other reasons.
4. Taking as a yardstick the present level of water consumption by Palestinians, when such figures have been artificially frozen at 1967 levels, by force and coercion, and even reduced by drilling deeper Israeli wells next to Arab springs.
5. Taking as a yardstick the present level of water utilization by Israelis, to the extent that that level of use resulted from mining Palestinian sources, and illegally overpumping shared aquifers while prohibiting Palestinians from normal utilization.
6. Neglecting to provide Palestinians compensation for the decades of illegal exploitation of their resources, which is also a form of "affirmative action" to enable them to compensate for past deprivations.
7. Granting legitimacy to previous violations by accepting a "prior use" approach.

It must be noted here that if Equity and Equitable principles are followed, no weight or recognition can be given to advantage obtained by illegitimate means . Equity requires clean hands, and water usage arrived at by coercion and force of arms does not give rise to any "equitable " claims.

6. Conclusion

There are sufficient principles for resolving water issues between Israelis and Palestinians; but they must be applied in a legal and equitable fashion. Otherwise, they will degenerate into a scholarly and judicial cloak for naked aggression and justification for the lawless domination of the strong over the weak. The inevitable outcome of such neglect of Palestinian rights would be undermining the possibility of wider regional cooperation on water, and ultimately the absence of security and stability.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Water Situation In The Gaza Strip

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Abstract

Quality drinking water and sufficient resources are essential to Gaza's 800,000 Palestinian inhabitants. However, increasing salinity and an enormous annual deficit in reserves; a result of overdrawing on resources, increasing demand, and increasing population; require the identification of all potential means to conserve and augment water resources and preserve water quality. One such remedy is the implementation of the Gaza Municipal Storm Water Project. Its main objective is to trap the city's rainwater and allow it to recharge the water table. Primarily financed by ANERA, the Storm Water Project is now entering into its third stage and should be completed by 1995.

The Gaza Strip is 360 square kilometers. It has a population of 800,000. It is located on the southeastern coast of the Mediterranean sea between latitudes 31° 16" and 31° 45" and longitudes 34° 20" and 34° 25" East. It is about 1.33% of the total area of mandate Palestine. On the east it is bordered by Israel. On the south Egypt, on the north Israel and on the west the Mediterranean sea. The winter season in Gaza starts officially in November and ends in march causing the precipitation that constitutes the major source of fresh water and aquifer recharge. The temperature mean is 21°C, but the average annual humidity is 65 with a peak of 97 % during August and September.

The strip comprises:

Built up areas	70,000 dunums
Jewish settlements	38,000 dunums
Cultivated land	168,000 dunums
Sand dunes	89,000 dunums

In 1948 the strip had a population of 50,000 inhabitants and 6,000 dunums of citrus trees. The influx of refugees in 1948 raised the population to about 350,000 which increased progressively until it reached 800,000 at present. The 10,000 citrus dunums went up to 75,000. As the water salinity increased the area of citrus decreased. It is now 40,000 dunums. Maximum produce reached 250,000 tons which realized an income of $20,000,000 - annually. This of course contributed to the quick consumption of the fresh water strata.

The Gaza Strip lies on top of two water carrying strata. The upper is fresh water carrier, the lower carries the saline water. Salinity ranges from 250 ppm in the north to 1500 ppm in the south. In some places it exceeded 1500. The slope of the aquifer is from east (30 m below sea level) to west (110 m below sea level). At a depth of 400 m below sea level there is geological sediment dating back to senomonian and upper cretaceous ages containing large quantities of brackish water of very high salinity ranging from 3000 - 5000 ppm.

From a demographical point of view Gaza represents one of the highest densely populated areas. The average population per square metre is over 2200. If we left out the Jewish settlements and sand dunes the average population in 233 square meters becomes 3423 persons per square kilometre. In other words every person has 0.290 square metre to live on.

The annual consumption of water at present is in the vicinity of 100,000,000 cubic metres of water. The aquifer gets a replenishment of some 60% water leaving a deficit of 40,000,000 cubic metres.

The overdrawing of water has caused drying up of the fresh water strata. The alternative was to dig deeper into the lower saline strata where we entangled the brackish water. In addition to replenishment rain water, creates pressure on the brackish water preventing the sea water from crossing through the brackish water, contaminating it and rendering it unsuitable for human consumption. There are some pockets in the upper strata with fresh water scattered in the strip from which inhabitants get their drinking water.

Chemical and bacteriological characteristics of Gaza Water:

1. Samples of water unfit for human consumption which contain more than 400 parts per million of chloride were found to be 34% of artesian water wells used by the city dwellers.
2. Samples of unfit water containing more than 900 parts per million of sulphur was found to be 10 % in city wells.
3. Samples of unfit water containing more than 1.7 ppm of florid was found to be 16%.
4. a. Samples of unfit water containing more than 50 mg/liter of nitrates (10mg/liter of nitrogen) was 77%.
   b. Samples of unfit water containing more than 100 mg/liter of nitrates was 44%.
5. Samples contaminated with bacteria are 12%.

A study by the Gaza Health Department Research Center revealed that the florid level in drinking water in the whole of the Gaza strip averages between 0.8 and 3.8 parts per million. The normal ration allowed in drinking water in accordance with WHO recommendations is 0.7 to 1.2 parts per million.

As if the situation does not lend itself to sufficient danger to the general health of the population particularly the children, the question of sewers in alliance with these hazards is leaving its mark on the children population. The estimated number of physically handicapped children exceeds 16,000. Other factors contribute to the situation E.G. family inter marriage, mal-nutrition, ignorance among mothers,... etc.

Until 1967 the water situation did not show much effect on the population, nor any signs of waning. However, the Israeli occupation authority issued a series of military orders restricting water testing, monitoring or research without permission of the military governor general of the Gaza Strip. Furthermore new orders followed imposing stringent conditions whereby no one was allowed to bore a new water well without permission. The order prevented repairs and/or rehabilitation of wells as well. In 1968 a new military order No.291 was issued declaring all water resources to be owned by the military government. The latter was issued in pursuance to the Government of Israel Water Law of 1959.

Serious work began in 1977 when the loss of the fresh water strata became apparent. The military governor issued an order restricting and metering irrigation water according to the type of crop per dunum. Strict preventive measures were stipulated including high fines and jail. There has been very little need to apply the law as the water allocated for irrigation was adequate.

Drinking water is the responsibility of municipalities and UNRWA. In the middle area of the Gaza Strip the Israel National Carrier dug wells in settlements near Deir El Balah in the middle of the Gaza Strip where some of the best quality water exists. They pump the water into their national carrier lines, but sell water to the population in the middle area where the lines pass.

20 wells of 20" bores were also dug around the green line surrounding the Gaza Strip. All these, pump water continually into the Israel National Carrier. " When in operation each well pumps 200 cubic meters per hour".

Wadi Gaza which flows during the winter season, originating from the Hebron mountains in the east and ends at the sea shore south of Gaza, has been blocked by Israel. Several dams were built all along the way preventing the water from flowing into the Gaza Strip which otherwise would have provided a valuable source of water to be used for irrigation and for compensation for the lost pumped out water. There are no known figures of the amount of water this wadi brings, but it would have been a great help to the irrigation in the middle zone of Gaza.

The estimated domestic consumption in the Gaza Strip during 1991 was 40 million cubic metres. This did not include the Israeli settlements in the Strip. The consumption is slated to reach 59 million cubic metres in the year 2010 where the population is expected to reach 1.025 million citizens. At present the per capita consumption for domestic use is 107 liters per day. This figure is expected to rise to 160 by the year 2010. Again this does not include figure for Israeli settlements.

The water deficit with the increased usage is expected to rise to some 70 million cubic metres by the year 2010 without taking into consideration Israeli settlements which consume much more water for irrigation than the Arabs. It is known that Israelis consume twenty time as much water as the Arabs.

This much for the situation reflecting the present trends and problems. As to possible solutions, the options are not readily accessible nor are they easily obtained. Some suggestions which were put for study are:

1. Reuse of sewer water by treatment and recycling. The Gaza Strip produces about 35 million cubic meters of sewage water which up to this moment has not been utilized. It could save immensely on irrigation water.
2. Building small dams in Wadis.
3. Storm water preservation projects in several towns and localities. The American Near East Refugee Aid Society (ANERA) carried out such project in Gaza where all rain water falling on the city is channelled into an artificial lake to help replenish the aquifer. This project is estimated to inject some 1.5 million cubic metres into the aquifer.
4. Reverse Osmosis where brackish water could be turned to fresh water usable for drinking.
5. Desalination by distillation of sea water. This no doubt is the most expensive way of obtaining fresh water.

A UN expert by name KRAFT (WHO) conducted a study on the water situation in the Gaza Strip. He estimated that Gaza Strip should run out of drinking water in the next 10 years.

A preliminary study for the construction of a sea water desalination plant was undertaken by UNDP in 1990. The study proposed the construction of a dual purpose power and desalination plant consisting of steam turbine power units with net production of 50 Mega Watts coupled with a (Multi Stage Flash) desalination unit to be constructed in two stages. First stage is to provide 18 million cubic meters of fresh water per year at a capital investment of $ 180 million. The estimated cost of one cubic metre of water would be $ 1.00 (one dollar) at the plant. A second unit was proposed to be constructed at a later date at the same cost and the same yield. The total cost in the end will be $ 360 million. Both stages will produce 36 million cubic meters of water;

a. at a very high cost.
b. still short of present needs, let alone the projected increase of inhabitants to one million by the year 2000.

An alternative project was suggested by I.D.E. Technologies Ltd. in 1990. The proposed construction of a dual purpose plant consisting of medium speed diesel generators to provide 50 Mega Watts of electricity coupled with Multi Effect Desalination units providing 18 million cubic metres of fresh water per year. The fresh water yield costs 48 cents per cubic metre. A second unit to be constructed at a later stage assuring same capital investment and capital required to produce the total of 36 million cubic metres of fresh water per year at $ 315 million with a considerably lower cost per every cubic metre of water than proposed by UNDP.

To implement such long range projects is costly and takes a long time to complete. However it would be economically desirable to avoid using high cost desalinated sea water as long as any other lower cost source may be available.

In view of the existing acute shortage of potable water in the Strip and in view of the ever increasing need in the coming years for both drinking and irrigation water, some intermediate solution must urgently be exploited. Such short term solution may be achieved through desalination of brackish ground water by the method of Reverse osmosis technology. The Gaza Strip has abundance of brackish ground water a salinity ranging from 500 to a little over 1000 mg. of chloride per liter. Of course this is not a final solution as it will no doubt lower the level of the underground water table, but it could be used safely until the big funds are available to implement the sea water desalination.

The cheapest solution in my opinion, which is not impossible, though very difficult is for peace to abide in the area. Then a joint committee to include all parties should take the responsibility of distributing water. They should even be authorized to buy water from outside sources should they find this necessary.

GAZA MUNICIPAL STORM WATER PROJECT

The Gaza city lies in the middle of the Gaza Strip in the midst of arable area all planted with citrus trees. Gaza is the largest city in the Gaza Strip. Its population is over 250,000. It extends 5 kilometers on the shores of the Mediterranean.

The Gaza Strip lies on top of two water stratas; the upper strata has the fresh water; the lower the salty or brackish.

The water crises in the Gaza strip in general, and the specific water quality and quantity crises within the municipal area of Gaza coupled with over drawing caused by a tremendous increase in population and need for irrigation (population jumped from 50,000 in 1948 to close to 800,000 at present. A similar boost in citrus planted areas jumping from 10,000 dunums to 75,000) created a big demand on water consumption causing depletion of most of the upper fresh water carrying strata. Except for the extreme north of the Gaza Strip, an area consisting of some 60 square kilometers, the fresh water was almost completely used up. This resulted in the need to dig deeper into the brackish water strata. We should know at this stage that Gaza Strip annual consumption of water for both domestic and irrigation usages amounts to some 1,000,000 cubic meters of water. The natural replenishment from rain is around 60%, leaving a deficiency which has to be replenished one way or another. This affected the entire population of the Gaza city, over 250,000.

It has been estimated that there were some 2,195 boreholes in the Strip in 1986, of which 2,150 were used for agricultural purposes. Approximately 1,600 agricultural boreholes were located in the inner Gaza area and some 350 by the sea. The inner Gaza Wells are between 25 and 90 m. deep, with a water quality of 250-1,000 p.p.p. The wells in the vicinity of the sea are of good quality water, ranging between 20-80 mg./cl. and sunk to a depth of 4-20 m.

In the pre-1970 period, there was inadequate control in the provision of permits for water drilling. As a result, the number of boreholes increased markedly, farmers drilled and used as much water as they wanted.

In light of these conditions, restrictions were imposed in the mid 1970's against the digging of new wells, and these controls have limited the amount of water available to Palestinian farmers. But permits continue to be granted for the extraction of drinking water. Piped water has been provided for 90 per cent of the population of the cities. In the small towns and villages, some 60 per cent of the residents receive water.

In the Gaza region farmers are allocated water on the basis of soil conditions and the specific crop cultivated. The allocations are as follows:

citrus	1,000 cu.m./dunum/year
vegetables	700 cu.m./dunum/year
strawberries	1,000 cu.m./dunum/year
olives/almonds	300 cu.m./dunum/year

The deficit caused by overpumping led to both a drop in the water table by an average of 15-20 cm. per annum and increasing salinization of wells (15025 cm. chlorine per liter per year). The sea water seepage has extended some 1.5 km. into the sweet water aquifer. These factors brought about a deterioration in the quality of the regional water supply, estimated quantitatively at some 60 per cent, with 400 mg. chlorine per liter. The deterioration of the water used for irrigation has had a damaging effect on the agriculture of the region.

The presence of undrained standing water in large areas of Gaza city during the rainy season constitutes a serious problem for the residents, certainly, apart from the structure of the underlying political problem itself, few conditions represent a more demoralizing blotch in the day to day quality of life of Gazans than the mudhole impression of winter life in the city. The standing water damages streets and other property, precludes development of certain areas of precious land, causes health hazards, overloads the normal sewage system, and regularly distributes or blocks transportation flows within the city.

Two kinds wells are affected by the encroaching salt water, drinking water wells and irrigation wells. The 14 municipal drinking water artesian wells are harmed the most due to their proximity to the sea. The 40 irrigation wells are also affected; they often nearly dry up during the summer and fall. The wells average 19 to 20 meters in depth.

The pressure from the sea water had to be stopped lest it pollutes the brackish water upon which human beings as well as plantation became dependent. Rain slowed down during the last 20-30 years while consumption of water increased. This prompted serious thinking.

In 1977 the late mayor Shawwa of Gaza in consultation with the American Near East Refugee Aid (ANERA) conducted a feasibility study to make utmost use of rain water of which the greatest part went to the sea or evaporated without being able to make use of. The study resulted in designing of a project to preserve almost all rain water which fell on the city and give it a chance to be absorbed into the fresh water aquifer, thus increasing the rate of compensation of the fresh water strata and creating pressure over the brackish water strata to stop the encroachment of polluted sea water into the aquifer. The study proved that the cost of the project was prohibitive in as far as the municipal resources were concerned. The Mayor lost no time. He travelled to Saudi Arabia and the nearby Gulf State of Abu Dhabi where he was able to raise funds. These were to be used partly for the improvement of the water situation and partly for the other urgent projects in an attempt to improve the social status of the population.

Benefits of the Water Conservation Project:
The project may be analyzed against the following:
1. Waste of extensive rainwater will end, and storage for use in a chronically dry, densely populated urban area will began in a proposed artificial lake.
2. Nearby citrus groves, which provide major income for the Gaza Strip, will have access to new irrigation water from the artificial lake.
3. Water infiltrated downward through soil layers will recharge water-table, raising the level and thereby increasing underground water reserves.
4. The rising water-table level will protect the quality of underground water reserves, preventing contamination by sea water which is unavoidable, given needs for fresh water, during the seasonal low level of water table without infiltrated fresh water rainwater.
5. Eliminating major urban traffic dislocation, damage to municipal and private property, and potential health hazard from longstanding accumulation of seasonal heavy rainfall in low laying densely populated residential and business sections of the eastern catchment area.

A specialist company H.G.M. assisted by (A.I.D) specialists was engaged to do the actual survey and planning work. The study and plans crystallized in the early eighties. It was planned for four stages. As Gaza is built on ridges with four main depressions. The project was based on four phases. The plan was to excavate an artificial lake in the lowest point in the city, then build underground culverts with gullies leading from the main catchment areas through the underground culverts into a "Sand Trap" where solids and sand settle before flowing onto an artificial lake excavated in an area of 34 dunums with a capacity of 400,000 cubic metres. The plan provided for eight bore holes where 20" perforated pipes may be inserted through which water can be injected into the aquifer.

The four stages comprised mid city culverts, sand trap, artificial lake and Saladin Street which crossed Gaza from north to south coming from Jaffa-Tel Aviv through to Rafah and on to Egypt. As the project was divided into phases and as prices fluctuated from year to year, it was decided to budget for the stages one at a time.

In response to the mayor's request ANERA entered into discussion (ANERA, Civil Administration and municipality) resulting in a written agreement in early 1984 between ANERA and the municipality whereby ANERA would contribute an amount not exceeding $ 1,000,000.00 matched by the municipality by an equal amount for the implementation of the first stage (dollar for dollar). Project beneficiaries would be the residents of Gaza city, neighboring Jabalia, and farmers in a 5 to 7 kilometers radius from the artificial lake.

There was a fifth area the project of which the municipality carried out on its own under the city Development Budget. ANERA contributed towards this project an amount of $ 150,000. This was named stage I. Plans for stage II now ready was tendered in November 1984. Gaza being an old city and the area in which excavations were to take place happened to be in a very crowded residential area with intricate underground services, e.g. water lines, sewer lines, telephones ...etc, bidders were given 12 weeks to study their offers before bidding. The project included inter alia, digging and building culverts of 2x2x2 meters in a length of 1700 metres.

In January 1985 the project was awarded. There were many difficulties and obstacles to overcome. Finally in mid April the ground was broken and work officially started with utmost care in order to avoid disruption of services.

The award for stage II was estimated at an initial cost of $2,000,000.00. It was completed in September 1990 at a cost of $2,200,000.000. Stage III now being prepared for work when the winter season is over, will cover deepening the artificial lake by some 1.5 meters, make eight bore-holes inserting 20" perforated pipes to a depth of 8-10 metres, lay "Reno mattress", a kind of special cloth over which graded "Gabions" with a slope 1/1 will be laid. The Gabions, I am sure, are known to many people. They are cage like made of thick galvanized chicken wire like filled with shingle. This proved solid and settles well on inside walls giving a chance to water to seep sideways as well. This stage was estimated at $1.8 million dollars. The figure may exceed the 2 million. On completion and with steady normal rainfall this lake is supposed to filter in some 1.5-2 million cubic metres of water. Its capacity is 400,000 cubic meters, but with the injection and seeping facilities it is calculated that some two million cubic metres should be absorbed through it. The work on the lake includes enclosure of some 100 dunums as reserve with trees planted around it to make it as a park in future.

When work is completed within 12 months as planned, then the final stage of excavating and building culverts connecting the remaining parts of the city, namely the northern entrance and the southern entrance roads to the city which covers some six kilometers of underground culverts through which rain water falling on the eastern hill of Ali Al Muntar and the surrounding heights will start. These culverts will connect with the sand trap and finally into the lake.

However with completion of stages I and II some 40 % of the city has been cleared and made it easier for vehicles and pedestrian to pass through to the west. When the final stage is completed, the city should be 100 % cleared. The estimated final cost may by the time scheduled for completion in 1995 be 12-15 million dollars.

The impact as previously pointed out is expected to be great on movement, industry and commerce, building industry as a result of clearing many dunums of land which are normally flooded with water during the winter season. It will also ease maintenance work on roads which will save good amounts of money for municipal projects, otherwise spent on road maintenance and projection of threatened houses.

It should be noted that there are no known feasible alternatives to this system for recharging fresh water into the sweet water aquifer. Fresh water supply alternatives such as a pipeline from the Nile river or sea water desalination are deemed highly problematic besides the prohibitiveness of such a technology for the relevant cash-starved Palestinian institutions. The other option of using the Israeli national carrier, the only short-term solution, will become increasingly problematic as well, given politics and Israel's own looming water supply crisis and growing dependency on West Bank aquifers.

Although the project is mainly financed by the American Near East Refugee Aid, it will be handed over to the city who will be responsible to maintain and keep in good working shape.

Professor Thomas Naff in testifying on water use in middle East countries in Congress on 26th of June, 1990 said, "If the crisis is not eased, it will result in a significant rise in the probability of an out break of warfare..." He added "It is water, in the final analysis, that will determine the future of the occupied territories...and by extension, the issue of conflict or peace". Professor Naff finally said, "The Gaza Strip aquifer is readily deteriorating. There is already water encroachment from the Mediterranean, and if that aquifer goes, that will have a very serious impact not only on the Gaza Strip but it could have an impact on the coastal plain aquifer within Israel itself because there is a strong probability that there is an interchange between the two. There is serious deterioration in the aquifer and it is reaching what is known as the red line".

N.B. Figures obtained from Department of Agriculture - Gaza and Health Department - Gaza.

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THE GAZA STRIP WATER PROBLEM - AN EMERGENCY SOLUTION FOR THE PALESTINIAN POPULATION

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Abstract

The Gaza Strip suffers from a permanent water shortage, and the available water is of substandard quality for human use as well as for many agricultural crops. The per capita consumption of water for domestic purposes is between 40-45 cm per annum (depending on which population estimate is accepted). In comparison, the annual per capita consumption in Israel is 90 cm. In view of the serious water situation, it is proposed that a desalination plant using distillation technology be urgently erected on the shore of the town of Gaza. This plant will produce 46 mcm annually. The cost of the desalinated water (without interest) would be 82 cents/cm. The reclaimed water emanating from the distilled water could be used in agriculture, and would be available at lower prices. Simultaneously with the building of the desalination plant, the sewage system has to be renovated.
There is no other feasible solution in sight.

1. THE GAZA STRIP WATER PROBLEM

The Gaza Strip suffers from a permanent water shortage, and the available water is of substandard quality for human use as well as for many agricultural crops.

The per capita consumption of water for domestic purposes is between 40-45 cm per annum (depending which population estimate is accepted). In comparison, the annual per capita consumption in Israel is 90 cm.

The water used for domestic purposes is of very low quality. In 1991 seventeen wells supplying 27 mcm/year of water to Gaza City had, on average, a chloride content of 568 mg. per liter. In water of adequate quality for domestic use, the chloride content should not be higher than 250 mg. The nitrate content, by which pollution severity is measured, reached 116 mg. per liter in October 1991; though nitrate content should not be higher than 45 mg. per liter. In Gaza, only 45% of the water supply was within these limits (see table).

Gaza City Water Wells October 1991

No.	Well		Discharge cu.m./hr	Salinity mg. chloride/ liter	Nitrates no. mg.	Distance from sea m.
1.	Sheikh Raduan	1	200	231	165	1,600
2.	Sheikh Raduan	2	160	1708	84	1,200
3.	Sheikh Raduan	3	180	189	150	1,700
4.	Sheikh Raduan	4	200	182	100	1,600
5.	Sheikh Raduan	5	200	1500	-	pumping discontinued
6.	Sheikh Raduan	6	200	1561	145	1,600
7.	Sheikh Raduan	7	200	427	230	2,300
8.	Sheikh Raduan	8	180	84	68	1,700
9.	Sheikh Raduan	9	180	84	78	2,050
10.	Sheikh Raduan	10	190	70	30	2,500
11.	Sheikh Raduan	13	200	371	200	2,300
12.	Sheikh Aglin	1	160	665	125	600
13.	Sheikh Aglin	2	120	483	86	1,400
14.	Safa	1	220	490	280	4,500
15.	Safa	2	180	371	249	4,500
16.	Safa	3	86	819	142	4,500
17.	Safa	4	220	567	88	4,500
			3,076			

Yousef S. Abu-Maila from Gaza University, described the water quality problem (in "Area 1991; 23,3) as follows:
"...intensive pumping has lowered the water table throughout Gaza. Around Beit Lahiya in the north and in the area west of Deir el-Balah in the centre of the Strip, the water table is now approximately at sea level at the coast. Around Jabaliya in the north and south of Deir el-Balah, the water table is about 1 metre below sea level at 1 to 2 kilometres inland. In the east of the Gaza Strip, the water table is only 2 to 4 metres above sea level. These prevailing low water table levels inevitably result in seawater intrusion into the acquifer for distances up to 1-5 kilometres inland." "Data from about 200 water samples from 50 wells in the Gaza Strip have been plotted against the geohydrological characteristics of the aquifer (Figure 1).

The deeper aquifers in the east have the greatest salinity, while the superficial aquifers of the west tend to have the lowest salinities. The high salinities (exceeding 1,500 ppm chloride) east of Khan Yunis and south east of Rafah in southern Gaza are probably a function of the low rainfall compared to that of the north of the Strip where levels are around 100 ppm chloride. However, the values may also be a function of the entry of groundwater from the east and southeast with salinities in the range of 600-1,500 ppm chloride (Schwarz 1982). A small area north of Wadi Gaza experiences inflow salinities in excess of 2,000 ppm (Figure 1). The increase of salinity with depth may be due to the migration of inflow waters or to leakage of water through faults from the Cenomanian aquifer at 350-400 m depth and to the nature of the stratigraphy of the aquifer complex (personal communication, hydrogeology engineer, Gaza 1989). The salinity of water being extracted from the aquifer has increased over the eight years since 1980 by 20 to 200 ppm chloride. If pumping continues at the present rate of 95 to 105 Mm3 per year, the water table will drop at a rate of 12 to 20 cm per year, while the salinity will increase to 300 ppm chloride. The increasing salinity of irrigation water will continue to have an increasingly serious impact on Gaza's agriculture, especially on the citrus crop.[1]

On account of the sanitary system in Gaza consisting predominantly of cesspits, sewage disposal is considered both a source of water pollution and a major health problem. Leakage of sewage leads to rapid penetration of the shallow aquifers of the sandy soils and soil strata. Seventy per cent of the people in Gaza City are served by the sewer system, in Jabiliya, 20 per cent, and in Rafah only 2 per cent. The fifteen other towns and the remaining population in these three centres all rely on cesspits for sewage disposal.

The situation in the crowded refugee camps is no better. Sewage is discharged into open drains which run past houses parallel to the road. The drains carry the waste into open pools and percolation pits are often located just outside the camps. Water from these pools and pits easily percolates into the ground and reaches the aquifers. Some of the water from these liquid wastes is used to irrigate vegetable gardens, and the produce is then sold in local markets. The possibility of health hazards is a direct consequence of the shortage of groundwater needed for irrigation. However, the use of wastewater is likely to increase if nothing is being done to augment the adequate safe water supplies.

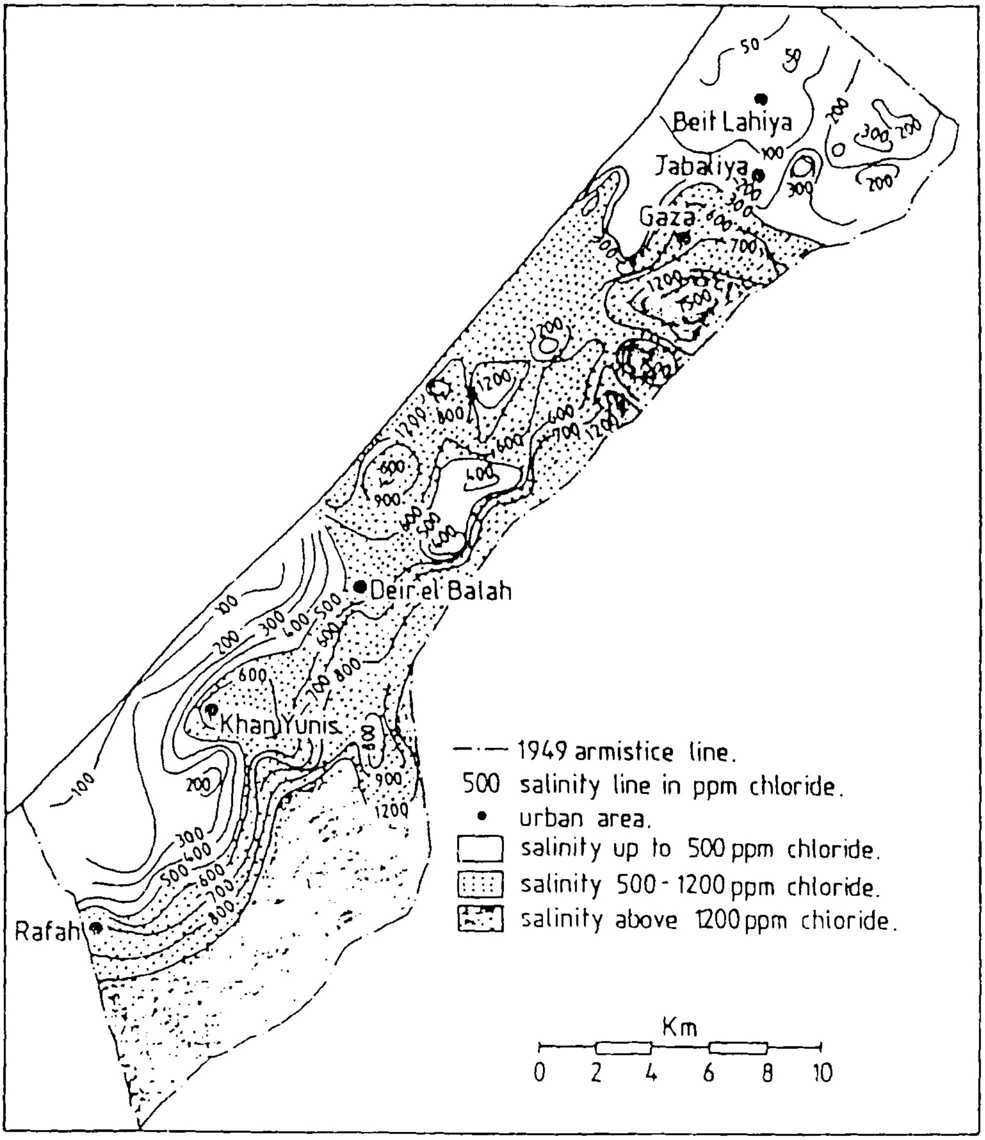

Figure 1: Salinity in the Gaza Strip, 1987–1988

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 salination should be between 130-250 mg. In Gaza about 30% of the water has a higher chloride content. The result is the drying up of agricultural products, in particular, of Gaza's major crop--citrus fruits."

2. TOTAL ANNUAL WATER USAGE IN THE GAZA STRIP

The local aquifers, from which the water is pumped through numerous wells, are the source of water for the Gaza Strip.

The total amount of water used in the Gaza Strip is estimated at 90-126 mcm, 30 mcm thereof for domestic purposes and 60-96 mcm for agricultural purposes. The lower of the estimates for agricultural purposes is based on the actual water consumption; the higher estimate was made by Abdel Rahman Tamimi,[2] who multiplyed quantities of irrigated land per major crop groups, by amount of water needed per dunam of each crop group. (As this is a theoretical and not an empirical calculation, we prefer the lower estimate, which has been gathered administratively and is used in most project oriented papers).

In contrast to the use of 90 mcm annually, the net annual replenishment by precipitation is only 65 mcm. Thus there is annually a shortfall of replenishment of at least 25 mcm. As a result, the water table in the wells and aquifers is lowered by 12-17 centimeters. This causes the accumulating salination of the water, as has been explained above in the citation from Abu-Maila's article.

There are four main reasons then for the low quality of the water in Gaza:

1. The low precipitation.
2. The overdraft of water of about 25 mcm pumped annually, which lowers the water table in the wells and thereby leads to salination by sea water intrusion from the west, and of salinated ground water from the east.
3. The very intensive soil use on the Gaza farms.
4. Pollution of the water by seeping of the free-flowing sewage into the soil.

In conclusion, it is obvious that in Gaza:

1. The domestic water supply is very low.
2. The quality of water for domestic purposes is of sub-standard quality, and apparently is already causing various diseases such as kidney diseases and dysentery among the population.
3. The water for agriculture is also sub-standard for this kind of use and has already inflicted grave damage, in particular, to the all important citrus crops and industries, and to other water-intensive crops, as well.
4. Without drastic intervention, the water situation in the Gaza Strip will steadily worsen, and with it, the human health risks, as well as the damage to agriculture and therefore to the economy of Gaza, since it is based largely on agriculture.

5. The sewage disposal system in the Gaza Strip is dismal, leading to pollution of the aquifers and the soil.

3. THE QUANTITY OF WATER NEEDED IN THE GAZA STRIP UNTIL THE YEAR 2000

To gauge the quantity of water needed annually the following factors must be taken into consideration:

1. The amount of water needed to prevent further deterioration through salination of the Gaza aquifers-which means each year supplying the quantity of water needed to eliminate the existing annual shortfall. An additional 25 mcm of water will have to be supplied annually.
2. The additional quantity needed for domestic use, consumption due to rapid population increase will amount to 8 mcm by the year 2000, assuming an increase of 200,000 persons.
3. Additional quantities of water will be needed to increase domestic consumption from 40-45 cm per capita annually, to 60 cm. This would bring the consumption per capita to about 2/3 of the Israeli level. (This is an arbitrarily chosen target level and smaller or larger quantities may be suggested. To accomplish this, the additional water supply would have to be increased by about 13 mcm.
4. For all the above purposes, the supply of water for domestic use will thus have to be increased by about 46 mcm per annum to a total of 76 mcm.

The additional water supply would increase the potential to reclaim water for agricultural purposes by about 10-12 mcm. In addition, there still remains a latent potential to reclaim water for agricultural purposes of several mcm. Considerably improved quantity and quality of water will also improve the health and sanitary conditions of the population of Gaza, in particular in the refugee camps, and enable a partial rehabiliation of the agriculture. The impact on pollution would be more complex. If additional water is not reclaimed and flows freely, pollution could even become more widespread. If the water is reclaimed, the level of pollution should decrease.

4. OPTIONS FOR ADDITIONAL WATER SUPPLY TO THE GAZA STRIP

The main possibilities for creating additional water supply to the Gaza Strip are as follows:

(1) Supply by Israel
(2) Supply from the Nile
(3) Reclaimed sewage water
(4) Improvement of brackish water

(5) Drilling of some additional small wells in the vicinity of Gaza City
(6) Desalination of sea water.

The Choice of the Desalination Option

The first two options are not feasible given the present political situation. They are also complicated by legal problems as far as water from the Nile is concerned, and by expected shortage of water in Egypt and chronic water shortage in Israel. Reclaiming sewage water is possible and even important in order to reduce water pollution, but unless the water supply is increased, this measure cannot be expected to provide more than 12 mcm of additional water for agricultural purposes only.

The advantage of drilling of some additional small wells is that this can be done in a short period of time, thereby providing quick partial relief to the main urban population. However, it will provide only a short period of having slightly improved water supply, and it is difficult to establish apriori whether this will lower the water table in other wells, thereby increasing salination and pollution. The military administration is, however, apparently in an advanced stage of planning of this project.

The remaining possibility is desalination. The advantage is that a desalination plant can be erected in a relatively short period of time, and it is most likely that the Israeli authorities would approve the project.

5. THE CHOICE OF DESALINATION TECHNOLOGY OPTIONS

At present there exist two main desalination technologies:

(a) Reverse Osmosis (RO), yielding desalinated water of 350-500 TDS (ppm), and 400-1000 ppm chlorides.
(b) Distillation, yielding almost salt free water (5-20 ppm). Mixing the two sorts of water yields a medium salinated water mixture, or use the water produced by the RO technology for agricultural purposes.

The advantages and disadvantages of the two possible approaches to desalinate water are:

The distillation process is considerably more expensive and requires a larger investment per cm of water than the RO process. Even the lowest content of chlorides - 400 ppm - is on the borderline of acceptable quality of water for human consumption. Water produced by RO technology could be used for agricultural purposes.

Desalinated sea water containing 20 ppm chloride can be also used to considerably dilute the salinity of water pumped from wells, bringing both chlorides and nitrates content to low and acceptable levels. The sandy shores of the Gaza Strip will require expensive pre-treatment of the sea water prior to be processed by the RO plant.

Sewage emanating from households using low TDS (ppm) water, produced by distillation technology is of relatively high quality and after treatment could be of much better use for agricultural purposes, than the sewage emanating from water treated by the RO technology.

Taking into consideration all the pros and cons, experts are generally of the opinion that the RO process should not be the only technology used in the case of the Gaza Strip. There are, however, divisions among the experts as to whether to use the distillation process exclusively or a combination of both technologies. Weighing the pros and cons, it is the opinion of the authors of this paper that only the distillation process should be employed.

There are several versions of distillation plants: LT-MED which is a low temperature, multi-effect distillation, including a series of evaporative condensers and head rejection condensers. It can be used where low-temperature heat or low measure steam are available and is dependent on an adjacent power station.

There are two versions of the LT-MED technology: Multi-Stage Flushing (MSF) and the Multi-Effect Distillation (MED). In the MSF technology, pre-heated sea water is poured over chills and condenses the vapors, which then turn into desalinated water. The main disadvantage of the MSF technology is that it needs an adjacent power station and construction and operating costs are high.

The MED distillation technology also requires an adjacent power station, and its construction period is relatively long. Its advantages are that the capital costs are relatively low and the requirements for quality of the sea water to be distilled, are minimal. The quality of the desalinated water is high, similar to the product yielded by the MSF technology.

The last major distillation technology is mechanical vapor compression (MVC). Its main disadvantage is higher energy consumption than that of desalination plants using either the MED or RO technologies. However, it can work with electricity supplied from an electric grid and is not dependent on an adjacent power station. As a result, the capital costs of its erection are considerably lower than those of the distillation plants based on the other technologies, and a considerably shorter construction period is needed. At a later stage it can be adapted to receiving power from an adjacent power station. The quality of the desalinated water is as high as that produced by the other distillation processes. Its operating costs are higher, partly because in the cost of supplying the electricity includes the capital cost of erecting the electricity station--but this is probably offset by the lower capital costs incurred since it is not necessary to build an adjacent power station.

The rest of the paper will assume the use of the MVC distillation technology.

6. THE SOURCE OF ENERGY

There are in principle three possible sources of energy for the desalination plant.

(1) A power station built specifically for the desalination plant in Gaza.

(2) Electricity from a power station now being built by Egypt at El-Arish.
(3) Electricity from the Israeli power station at Ashdod.

Receiving energy from an existing power plant (including the one being built by Egypt) would save the major part of the large investment in the supply of energy. However an adjacent power station would generate electricity at a lower cost than supplied energy, because it would work at base load.

A Gaza power station, if connected to the Egyptian one at El-Arish or to the Israeli Ashdod station, could serve as a back-up for each of them and also receive backing from the power station to which it is connected. In that case partial investment by Egypt or by Israel and also by third parties interested in furthering Middle East cooperation might be forthcoming.

7. THE COST OF INVESTMENT IN A MVC DESALINATION PLANT AND LENGTH OF ERECTION PERIOD:

(a) Cost of erection of desalination by distillation by a MVC plant for 46 mcm of sea water is $ 90 mn

Total investment does not include the electricity plant or connection to an electricity grid, the water distribution pipeline, regional pools, and water collection pipelines from the aquifers, or wells for mixing the two kinds of water.

The erection of the desalination plant is expected to take 2-2 1/2 years.

8. THE COST OF 1 CM OF WATER (NOT INCLUDING THE ITEMS QUOTED ABOVE):

(1) Cost of 1 cm of water from distillation of sea water:

Energy: 6 cents kwh x 7.5kwh/cm	45 cents
Other current expenses (chemicals, operation maintenance)	20 cents
Replacement cost, assuming a 20 year lifetime	17 cents
Total with interest	82 cents
Interest at 7%	63 cents
Total with interest	145 cents

If the investment in the desalination plant were extented as a grant, interest would not be a cost from the point of view of the grant recipients and therefore the cost of water from the distillation plant would be 82 cents/cm.

For comparative purposes, the cost of 1 cm of water in Israel is calculated at 25 cents.[3]

9. CONCLUSIONS

(1) It is proposed that a desalination plant using distillation technology be erected on the shore of the town of Gaza.

(2) The cost of the desalinated water (without interest) would be 82 cents/cm. The reclaimed water emanating from the distilled water could be used in agriculture, and would be available at lower prices.

(3) The total investment needed for the erection of the desalination plant would amount to about $ 90 mn. In order to make the water affordable for human consumption, the investment should be made by grants, because otherwise the cost to the consumer would be very high (145-193 cents per cm) according to the interest rate used - 7 percent or 12 per cent.

(4) The building of the desalination plant would take 2-2 1/2 years. However if electricity would have to be supplied from an adjacent power station built specifically for the desalination plant, the beginning of the supply of desalinated water from the plant would be delayed considerably. The required investment would also be very much higher. Therefore it would be advantageous to first connect the desalination plant to the electricity plant in El-Arish or Ashdod while building an electricity plant in Gaza, which on completion could takeover the supply of electricity. In the long run, the power stations could back up each other. Additional quantities of water for agricultural purposes should be supplied only from reclaimed water, because water from any other source should either increase the prices of agricultural products to an extent which would make them non competitive on the markets, or they would have to be heavily subsidized.

Development of agriculture in the Gaza Strip should in general be restricted to the amount of relatively cheap water available, or to products which could be marketed in spite of their high prices, such as some out of season crops, or rare products.

(5) Simultaneously with the building of the desalination plant, the sewage system has to be renovated and enlarged to gather most of the sewage in a way that would prevent it from polluting the aquifers and endangering health. This sewage water would then have to be reclaimed and made available for agricultural uses.

In addition, also the fresh water pipeline system has to be renovated to prevent leakage and extended to most of the consumers which are not yet connected.

NOTES

1. The vicious circle phenomena will become acute: irrigation with saline water causes soil salinity to increase due to evaporation and to concentration of salts in the soil.

2. Abdel Rahman Tamimi, "Water, A Factor for Conflict or Peace in the Middle East," Israeli-Palestinian Peace Research Project - Working Paper Series, No. 2, 1991/92.

3. It should be noted that the cost items of distillation were provided to me by a reliable source, who prefers not to be quoted. Calculations must be regarded as approximations and will depend on the location and conditions on the actual site.

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SECTION IV
Developing alternative water sources

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Contribution of Water Imports to Israeli-Palestinian-Jordanian Peace

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Abstract
To help meet the projected growth in demand for water and shortages in available domestic sources of supply in the Palestinian-Israeli-Jordanian region, imports from neighboring countries have been proposed. Before resorting to imports, countries should give first priority to conserving and more efficiently utilizing existing supplies. Current efforts and the difficulties in instituting reforms are discussed. Various proposals for conveying water from Egypt, Lebanon and Turkey by pipelines, canals or vessels (tankers or "Medusa bags") are described and assessed in terms of their technical feasibility, economic viability and political acceptability. Some suggestions are presented for institutional mechanisms to insulate these projects from political disputes and help surmount the legacy of mistrust between suppliers and recipients and other riparians in the region.

IMPORTS AS SUPPLEMENT TO CONSERVATION

Large-scale schemes for importation of water have been criticized on the ground that they are at best only a temporary solution, that suppliers may prove to be unreliable for political or other reasons, and that such schemes are the lazy politician's escape from the hard political and economic decisions needed to enforce conservation and set realistic prices for domestic supplies. Imports should be considered *as a supplement and not as an alternative* to more efficient and rational utilization of domestic resources.

Jordanian officials have indicated that much of the water pumped to consumers in Amman never comes out at the tap because it is lost through leakage in the old pipes.[1] Replacing the pipes is a worthwhile, but capital intensive project. Jordan has already significantly cut down on water loss through evaporation by replacing much of the original open channel East Ghor Canal system with enclosed pipes. Foreign as well as Israeli and Arab experts have advocated lining canals to prevent seepage, more rational allocation of water to agriculture, charging realistic prices to all users, recycling of treated sewage, and other water-saving technologies, such as sprinkler and drip irrigation, development of crop varieties that require little water or can grow in brackish water, and installation of water saving shower and toilet facilities in homes.

But conservation can go only so far. Consequently many analysts in the region believe that to change the equation from a zero sum game of intense competition among riparians will also require imports of water from outside sources. Although desalination is regarded by many as the ideal long-term solution, under present technology and fuel costs, desalination remains prohibitively expensive for most uses in energy-poor countries such as Israel and Jordan. Even assuming that there may be a technological breakthrough in the next 10 to 20 years, imported water sources can play a crucial role in the interim period to bridge the gap between the limited locally available supplies and increasing projected needs for growing populations and rising standards of living under peacetime economic development.

Israel, Jordan and the Palestinian-inhabited territories of the West Bank and Gaza District, with their rapid rates of population increase, are already utilizing virtually all available water supplies.[2] In fact, Palestinians in Gaza and Israelis in the coastal plain have seriously overpumped the aquifers. In January 1991, Israel State Comptroller Miriam Ben-Porat issued a scathing critique of Israeli officials for what she termed "irresponsible water management for 25 years," which had resulted in overpumping and deterioration in the country's water quality. By the end of 1990, she wrote, Israel had an "extremely serious water deficit" of 1.6 billion cubic meters (BCM), equal to an entire year's normal supply.[3] 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.[4]

DIFFICULTIES IN IMPLEMENTING REFORMS

But implementing drastic reforms and cutting entitlements is easier said than done. In Israel and the neighboring states -- no less than in France or the United States -- agricultural interests are a well entrenched and powerful lobby.[5] Moreover, the Palestinians' deep attachment to their familial lands and the Zionists' pioneering ethos of "return to the land" still resonate in both cultures and evoke broadly based nationalist feelings that transcend the strictly economic value of agricultural production. In Israel, a major national security motivation behind the costly project to bring water to the arid Negev to sustain new immigrant agricultural and industrial communities was Prime Minister David Ben-Gurion's desire to disperse the population away from densely populated coastal plain. It should be noted that Israeli agriculture and animal husbandry got their major impetus to develop when the Arab Boycott cut the Jewish state off from its traditional sources of supply in the neighboring Arab countries. Under conditions of peace, sharing of technology and better coordination of Israeli, Palestinian and Jordanian agricultural production might result in saving water.

A perceived national security interest in achieving self-sufficiency in food production and a desire to reduce the migration of farmers to the cities, help explain why Jordan and other Middle East countries continue to give a high priority to agriculture. Oil-rich Saudi Arabia continues to grow wheat, at a cost that is reportedly six times what it would cost to purchase it on the world market! Finally, not all uses of water can be subjected to a cold economic calculus. Forests and parks have environmental benefits and improve the quality of life. Indeed, who can set a dollar value on how high the human spirit is lifted by the sight of blossoming trees, flower gardens and pools of clear water? Such oases are especially important in the semi-arid Middle East.

As the severe drought in Israel continued into the summer of 1991, the government took some unpopular draconian measures, such as the stopping of cotton cultivation. The 50 percent cut in water allocations to agriculture and the rise in prices even led some to uproot citrus groves. Some of these restrictions have since been eased under pressure from the farmers and the exceptionally heavy rainfall and snow of the winter 1991-92 season. This suddenly and dramatically transformed the level of Lake Tiberias (Kinneret) from the lowest in this century to overflowing. Lack of adequate storage facilities caused flood damage in Israel and the territories, and much precious water ran unused into the Dead Sea or the Mediterranean. The 1992-93 winter may again be one of above average rainfall. This may result in additional flood damage and loss of uncaptured runoff. The Jewish National Fund is developing improved "water harvesting" and storage techniques in Israel, including special plastic-lined reservoirs, and floodwater dams that cause the water to slowly trickle down and recharge the groundwater rather than being swept away through flash floods. The Jordanians have also begun to consider such water-storing techniques.

Meir Ben-Meir, a former Israeli water commissioner, sharply disagrees with the State Comptroller's sweeping criticism, pointing out that the Kinneret (Sea of Galilee/Lake Tiberias) and the mountain and coastal aquifers, when fully recharged, together can hold only 2.5 billion cubic meters, or little more than one year's average rainfall. During his tenure, he increased the capacity of the Kinneret by about 160 MCM by lowering the lake's minimum level by a meter. But it can not be reduced much further, since the pressure of the sweet water on top prevents saline water at the bottom from rising and causing irreversible damage to the water quality.[6]

There is a natural tendency of governments -- as of individuals -- to focus on a problem only when it reaches crisis proportions. All Middle East governments should learn from the long-range planning policies of the Biblical Joseph, who carefully gathered and stored Egypt's grain surpluses from the seven years of plenty to provide a vital reserve for the seven lean years that followed. One does not have to be a prophet, but only a student of the Middle East's climatic history, to know that in the future there will again be years of drought in the Arab-Israel region.

THE DEMOGRAPHIC TIME BOMB

While the amount of rainfall will fluctuate, the population in the region is likely to continue its inexorable upward movement. The only question is how rapid the growth rate will be. Dr. Al-Weshah notes that Jordan's natural rate of growth of 3.8 per cent is "one of the highest growth rates in the world."[7] Dr. Rami Abdulhadi of the Palestinian Center for Engineering and Planning assumes an average annual net growth rate of 3 percent for Palestinians in the Nablus, Jerusalem and Hebron districts and a 3.5 percent growth rate for the Gaza district, giving current (1990) estimates of Palestinian population of 908,000 in the Nablus and Hebron districts of the West Bank, plus 584,000 in the Jerusalem region and 773,000 in the Gaza District.[8] In a report prepared for the World Bank, Dr. Joshua Schwarz, manager of the comprehensive planning division of TAHAL Consulting Engineers, Ltd., projects that by 2010 the Arab population of the West Bank alone, excluding Jerusalem, will reach 1,300,000.[9]

Forecasts for Israel's population growth are affected not only by natural increase (averaging 1.6%), but also by the migration balance. For example, the projections published by the Central Bureau of Statistics in 1989 for the year 2010 ranged from 5.7 million to 6.5 million. But with the sudden arrival of more than 200,000 immigrants from the Soviet Union in 1990, a new projection was prepared, which estimated that Israel's population would spurt up to 6.5 million by the year 2,000 and to over 8 million by 2010.[10] While Jewish immigration from the Commonwealth of Independent States (CIS) did not reach the million projected last year, the figures have again increased and more than 64,000 arrived 1992, for a total of over 414,000 since 1987. Some 15,000 others have come from Ethiopia, strife-torn former Yugoslavia and other countries. If economic distress and political turmoil increase in the CIS and/or peace is established between Israel and it Arab neighbors, the combination of push and pull factors will likely result in additional immigrants being attracted to Israel.

The Hashemite Kingdom of Jordan's high rate of natural increase in recent years, estimated at between 3.5 and 3.8 per cent, is similar to that among the Palestinians in Gaza. It should be noted that this is nearly twice the world average (1.8%).[11] The pressure on Jordan's limited water resources has recently been compounded by the return of more than 300,000 Palestinians/Jordanians who fled or were expelled from Kuwait and Iraq following the Gulf War of 1990-91. This alone has increased Jordan's population by 9 percent.[12] Unless population growth and water supply can be brought into equilibrium, the increasingly critical shortages within the next decade threaten to exacerbate tensions in the area and will act as a major obstacle to achieving Arab-Israeli and Israeli-Palestinian agreements.

CRITERIA FOR SUCCESSFUL WATER IMPORTS

For any water import scheme to win general acceptance it must meet four criteria:

1. It must **cause no appreciable harm** either by reducing the supply to established users or by causing environmental damage.

2. It must be proven to **be technically feasible**.

3. It must **be politically acceptable**. Facilities must be physically secure and the agreement must be structured so as to insulate the scheme as much as possible from disruption or cancellation in case of political changes in the policies of the supplier country or of transit countries.

4. It must **be economically viable**.

Projects that are commercially structured to pay for themselves and produce revenue for the supplier country have the best chance of success. Of course, economic viability can also be achieved if individual donor countries or international agencies subsidize the cost through loans or grants as part of their efforts to promote peace, stability and economic development in the region. Yet even subsidized projects must be subjected to rigorous economic analysis to make sure that sufficient funds will be available not only for construction, but also for annual operations, including maintenance, debt service and possible increases in costs of water and other inputs, such as for fuel to pump water through pipelines or to power tankers or tugs to ship the water.

Lebanon and Turkey are the only two countries in the region currently with significant surplus supplies of water available for export.

During the peace negotiations with Israel in 1979, President Anwar Sadat proposed piping Nile water to Israel, in exchange for Israeli concessions on Jerusalem. The plan was quickly dropped. Prime Minister Begin's government found the Egyptian demands on Jerusalem unacceptable, while the export of Nile water encountered strong opposition within Egypt and its upstream neighbors. Dr. Elisha Kally[13] continues to recommend piping Nile water to El Arish to meet the needs of Gaza and possibly Israel's Negev, arguing that technological improvements provided and paid for by Israel could produce a net saving in water for Egypt, exceeding the estimated 100 MCM per year conveyed to Gaza/Israel.

Unfortunately, in all my recent discussions with Dr. Boutros Boutros-Ghali, who headed the Nile riparians Undugu group before becoming UN Secretary-General, and other knowledgeable Egyptians, the idea continues to be dismissed as politically unacceptable, since Egypt would need approval of the other eight Nile riparians. Relations with Ethiopia and the Sudan are already strained over water issues. They also reject the argument advanced by Dr. Kally and Professor Hillel Shuval[14] of the Hebrew University that Egypt has a moral obligation to supply water to the Palestinians since much of the overpumping of the aquifers occurred during the nineteen years of Egypt's administration of Gaza.

A. PROSPECTS FOR LEBANESE-ISRAELI-PALESTINIAN COOPERATION

There have been various proposals to divert part of the Litani River directly into the Jordan for use in Palestine/Israel. There are no technical difficulties in carrying out this project. According to Professor Joseph Eaton of the University of Pittsburgh, this was first proposed a century ago by the Swiss engineer Bourkardt. It was revived in the Lowdermilk plan of 1944. It is also economically viable. Depending on where the water is used, Israel might also furnish some electricity to Lebanon (about 7 percent of its needs) generated by hydropower installations taking advantage of the drop in elevation from Lebanon to Israel. The Litani could be diverted by a short tunnel into the Hasbani and thence flow into the Jordan and be stored in Lake Tiberias for West Bank and/or Jordanian use. At present some 236 MCM of Litani water is diverted through the Markaba Tunnel to the Awali River to produce hydroelectric power. Professor John Kolars estimates that some 500 MCM of Litani and Awali water flow annually into the Mediterranean.

Kolars found "no significant removal of water from the lower Litani by human means at the present time," contrary to persistent Arab charges of clandestine Israeli diversion. He notes, however, that 100 MCM per year disappear in the last downstream segment, which he attributes to the water charging "a large synclinal aquifer which may deliver water to the Dan Spring and Hasbani River on the Jordan River."[15] This supports the idea that from a hydrological point of view the Litani is naturally connected to the Jordan River's sources. Presumably unaware of this fact, Ambassador Eric Johnston in the mid-1950's rejected the Israeli view that the Litani be included and accepted the Arab view that the Litani be removed from consideration of regional development of the Jordan-Yarmuk River Basin, on the ground that the Litani flowed exclusively within the territory of Lebanon.[16]

The end of the civil war, which had effectively shelved most Lebanese development plans since 1975, as well as projected population growth mean that demands for water will increase. The key questions are: how long will Lebanon have surplus water and how can Beirut assure itself of adequate supplies for the country's future domestic needs? Most experts believe that "the country's total water availability (4,380 MCM/year stream flow and 600 MCM/year ground water) greatly exceeds projected water demands." These were estimated as reaching between 1,450 and 1,985 MCM/year by the year 2000, according to a 1987 World Health Organization study and a 1989 article by Mamdouh Shahin.[17]

Dr. Selim Maksud, who heads the Litani River Administration and is currently engaged in a three-year World Bank reconstruction program for Lebanon, says that one of their objectives is to obtain accurate data on water resources and use. Based on currently available data, he believes that "we will have a surplus of water for some 25 years, beyond that, based on projected increase in population and the country's development, we will need all our water." Although during the summer months parts of Lebanon are short of water, in winter the surplus flow is as high as 700 MCM in some years, while in others it is only 200 MCM, depending on precipitation. He estimated the average surplus as between 400-500 MCM. Dr. Maksud stated that Israel and the West Bank Palestinians were Lebanon's natural downstream markets, adding that Lebanon could certainly use the additional revenue from water sales.

Dr. Maksud pointed out that Lebanese officials are worried, however, that once they had agreed to sell the water -- and even if the contract stipulated that they were only selling it on an annual basis with no guarantee of future supply -- the Israelis and West Bank Palestinians, who had become dependent on this water for field crops and orchards, would have world pressure exerted on Lebanon to keep selling them the same quantities of water. The downstream users would argue that they had acquired a legal right to the water on the basis of prior use, requiring the Lebanese to find other, more expensive sources to meet their own needs, e.g. through desalination.

As a way to shield Lebanon from such political pressures, Dr. Maksud proposes creation of an international water bank in Tiberias, along the Sea of Galilee/Kinneret, which would accept surpluses, crediting the account of the supplier, and sell the available water to those who had a deficiency. While the details had not yet been worked out, he assumed this would involve some international agency to supervise the inputs and withdrawals from Lake Tiberias.[18]

Several papers prepared for the Zurich conference should prove particularly instructive for the negotiators who will be grappling with this issue. These include the concept of "Capacity sharing" as a new way of defining and allocating rights of water in a reservoir drawing water from various sources described by Dr. Norman J. Dudley of the Center for Water Policy Research at the University of New England, Australia in his paper "An Innovative Institutional Arrangement with Potential for Improving the Management of International Water Resources," and the paper on "International Trading in Water Rights in the Mediterranean Region" by Professor Mordechai Schecter of the University of Haifa. At the Zurich conference Bernard Zamaron of the Robert Schuman Center for Europe proposed that the European Coal and Steel Community that first linked long hostile Germany and France after World War II, might serve as a model for shared water resource management among Arabs and Israelis. Hanan Bar-On, former deputy director-general of Israel's Foreign Ministry, had already in 1991 referred to the Schuman plan as a paradigm for managing Israeli-Palestinian cooperation on their shared water resources.[19]

The original Johnston Plan of the mid 1950's had proposed an international *Watermaster*, but the Johnston Plan was never ratified for political reasons. Syria refused to cooperate in any water arrangement that implied recognition of Israel's legitimacy as a riparian state. Israel, while prepared to store Arab water in the Kinneret, was unwilling to relinquish its exclusive sovereignty over the entire lake. In discussions during 1952 the Syrians demanded a redrawing of the Armistice Demarcation Lines to have the Syrian border with Israel run lengthwise down the middle of the Jordan River and the Sea of Galilee. Some Israeli officials were prepared to consider the idea in the context of a formal peace treaty, but the Syrians refused at the time to consider normalizing relations with Israel.[20]

Unless there is a fundamental change in the Syrian position toward full formal peace and cooperation with Israel, no joint Israeli-Lebanese water project will be politically feasible, even if the Israelis and Palestinians manage to reach an agreement with the Lebanese on an international water bank and other issues. Syria has an effective veto over any such development plans under the May 1991 Syrian-Lebanese Treaty of Brotherhood, Cooperation and Coordination. The 35,000 to 40,000 Syrian troops still stationed in the country further assure that the fragmented Lebanese government will not adopt any policy inimical to Syria. Thus, for example, Beirut has thus far followed Damascus's lead in boycotting the multilateral peace conference's water group discussions. Syrian officials have insisted that any discussion of regional cooperation with Israel must wait until Israel has agreed to withdrawal from the occupied territories.

B. TURKEY: A MAJOR SOURCE AND A WILLING SUPPLIER

This leaves Turkey as the only realistic option for the near future. According to the 1992 report of the General Directorate of State Hydraulic Works -- *Devlet Su İşleri* (DSI) in Turkish -- the total discharge of Turkey's 26 river drainage basins averages 186.05 Billion Cubic Meters (BCM) of water annually. Dr. Özden Bilen, Deputy Director of DSI, told me that they estimate that of this sum 96 BCM can be effectively utilized. To get a sense of the vastness of this figure in the context of our area of concern, the available water in a good year for all of Israel, the West Bank and Gaza reaches only about 2 BCM. In other words, Turkey has 48 times as much water. Yet Turkey's population is only 8 times as large. It is true that Turkey's population is growing rapidly, at a current rate of 2.4 percent, which is expected to drop below 2.0 percent after 2000, as a result of the continuing urbanization and industrialization of the population. Even assuming that Turkish Government forecasts are correct and the population will increase from 58 million to 83 million by 2010, the *potentially* available supplies will still furnish a generous 2,350 cubic meters per person per annum, as against 3,471 cubic meters in 1990. In actual fact, only about 450 cubic meters per capita per annum is currently being used, but even this is still nearly 5 times the quantity (91 cubic meters) DSI engineers consider adequate for domestic consumption when designing facilities for Turkey's large cities.[21]

According to Professor John Kolars of the University of Michigan, Jordan's available water per capita is expected to drop from 255 cubic meters to 100, and for the Palestinians in the West Bank and Gaza it will fall from 153 to 65 by 2020. (By way of comparison, Kolars estimates that in 2020 Turkey will still have 1,245 cubic meters available for every man, woman and child.)[22] For the nearer term, Kolars estimates that even after all future needs for irrigation, industrial and domestic use have been deducted, Turkey will have "an available surplus of nearly 43 Billion cubic meters sometime after the year 2000."[23]

Turkey's main water supply problem is one of distribution. The economically most developed regions, such as the Marmara and the Aegean, which include the major metropolitan centers of Istanbul and Izmir, lack sufficient water for their burgeoning populations, especially during periods of drought and in the summer. Future development plans include the transporting of surplus water from the rivers flowing into the Mediterranean to the western cities, to growing tourist sites near Antalya and also possibly to the nearby Greek islands and the Turkish Republic of Northern Cyprus. Depending on economic cost and technical feasibility, retro-fitted oil tankers, giant plastic balloons (the Medusa Bags described below), or pipelines will be utilized.

Jordanian officials are eager to obtain Turkish water since the Hashemite Kingdom faces a looming crisis. In December 1990 Minister of Irrigation and Water Resources Dawud Khalaf estimated that current Jordanian consumption of 730 Million Cubic Meters (MCM) would rise to 1,120 MCM by the year 2005. This estimate did not include the 300,000 to 350,000 Palestinians and Jordanians who fled or were expelled from Kuwait and have since returned to Jordan. Moreover, according to a paper prepared for the World Bank in June 1991 by Abu Taleb, Deason and Salameh, even if political agreement is finally reached on the long-delayed Al-Wahdah (Unity) Dam at Maqarin on the Yarmuk and other projects are completed, Jordan will only have a total annual water supply of 862 MCM. This means an annual deficit of 268 MCM.[24]

Adnan Abu Odeh, Jordan's ambassador to the United Nations, told me that he believed very deeply that "Turkish supply of water is imperative" to the region of historic southern Syria, which today encompasses Israel, Palestine and Jordan. [25] He expressed the view that the Syrians might modify their present opposition if they realized that if there was no assured water for Israel from Turkey, Israel would not consider withdrawing from the Golan Heights and southern Lebanon. The Israelis point out that in addition to its strategic importance, the Golan Heights also controls major water sources of the Jordan-Yarmuk River System, including the Banyas and Wazani springs.[26]

Ambassador Abu Odeh has been a close advisor to King Hussein and an active advocate of peace with Israel and efforts to open up the political process and liberalize the society in Jordan. These policies of modernization and liberalization are under challenge from Muslim fundamentalists. Ambassador Odeh told me he saw benefits to greater Turkish involvement that transcended even the value of providing additional water supplies. Because Turkey was a Middle Eastern country with a well established political system that was "more on the secular side," he believed Turkey's involvement in the sphere of cooperation in supplying water would indirectly help other countries move closer to secularism. This would help promote peace, because, in his view, militant Islamic rejectionism was the biggest threat to the Mideast peace process.

TRANSPORTING TURKISH WATER TO ARABS AND ISRAELIS

I. Turkish President Özal's "Peace Water Pipeline."

This is the most ambitious of the various plans under discussion. According to a feasibility study prepared by Brown and Root for the Turkish government, some 6 million cubic meters per day would be conveyed from the Ceyhan and Seyhan Rivers via two pipelines to eight Arab states including, Syria, Jordan, Saudi Arabia and other Gulf states. When the $21-billion project was first proposed in 1986 by then prime minister Turgut Özal, Israel was included. In the face of Arab objections, Ankara announced that extension of the pipeline to Israel would have to await Arab-Israeli peace. In their preliminary study, Brown and Root assumed that the Syrian cities of Aleppo, Hama, Homs and Damascus would receive a combined total of 1,100,000 cubic meters daily and Amman 600,000. The western Saudi cities of Tabuk, Medina, Yanbu, Jeddah and Mecca would receive 1.5 MCM. The eastern, or Gulf pipeline, would provide 2.5 MCM for Kuwait, Saudi Arabia, Bahrain, Qatar, the United Arab Emirates and Oman.

This project has been shelved since the Saudis and other Gulf states expected to help finance it have been cold to the idea even if Israel is excluded. Among their objections are that gas-fueled desalination is cheaper, that they do not want to be vulnerable to supply interruptions by Turkey, Syria or others along the line, and finally because there is still a residue of resentment of 400 years of Ottoman rule. Syria and Iraq also complain that before Turkey begins selling water to others, Ankara should first increase the supply to them from the Euphrates and Tigris, which they fear will be diminished as the Atatürk Dam and other installations in Turkey's vast South East Anatolia (GAP) project are completed. (The first meeting of Turkish, Syrian and Iraqi water officials since the Gulf War, held in Damascus September 28-October 2, broke up without reaching agreement, after Turkey rejected an Iraqi request to increase the flow at the Turkish-Syrian border from 500 to 700 cubic meters per second.)[27]

II. The "mini-pipeline."

Professor Kolars of Michigan and Professor Hillel Shuval of the Hebrew University have suggested that a more modest Turkish "mini-pipeline" to Syria and Jordan with an extension to the West Bank, would be of great benefit to Syrians, Jordanians and Palestinians. Such a pipeline would provide Aleppo, Homs, Damascus, and Amman with an assured steady, pure supply of water, which has been threatened during years of drought. Even if water from the pipeline were not initially made available to Israel itself, by extending it to the West Bank and possibly also to Gaza, it could make a tangible contribution to increasing the quantity and restoring the quality of the water available to the Palestinian Arab population. While technically feasible, this project also depends on overcoming the suspicions and hostilities among the countries involved and finding donors prepared to contribute to the estimated $5 billion cost.[28]

III. Direct shipment of water from Turkey's Manavagat River.

This project is the closest to realization. Work is already underway to construct the necessary facilities in Turkey, with completion expected in 1994.[29] Since the water will be shipped directly from Turkey to Israel in supertankers or in plastic balloons towed by tugs, there is no need to obtain approval from any other countries. According to Dr. Bilen, Deputy Director of DSI, the Manavgat River, which is in the Antalya Basin along the Western portion of Turkey's Mediterranean coastline, has an outflow at the rate of 140 cubic meters per second, or 4.7 BCM per annum.

What about future Turkish domestic demand? Dr. Bilen assured me that since the area was mountainous and covered with forests, the area slated for irrigation was small, currently only 10,500 hectares, with development limited to an additional 5,000 hectares. Thus total Turkish water usage was projected at only 135 MCM per annum. Since the tourist hotels in the region were all along the Mediterranean shore, they would not degrade the high quality of the water for export, which would be taken by pipe from a reservoir at the Oymapinar Dam 11 kilometers upstream. The initial planned capacity is for 183 MCM per year. This would be conveyed in two pipes, one carrying specially treated water, and the other untreated river water, with a combined capacity of 500,000 cubic meters per day. The pipelines would be extended for about a kilometer into the sea and linked to a single point mooring system for tankers or plastic balloons to be filled. DSI prepared the contracts, arranged the bidding, and supervises the work of the Turkish private contracting firms Aydiner-EMT group who are doing the work within the framework of the Turkish Public Partnership Administration (PPA). The facility is to be transferred to the Public Participation Fund (PPF), which has already provided some construction funding. The PPF was created to supervise the privatization of Turkish state enterprises.

The marketing of the water will be undertaken by a separate agency to be established, which may have foreign as well as Turkish shareholders. The idea is to create a structure that will insulate the Turkish Government from Arab criticisms that Ankara is officially selling water to Israel, while also reassuring Israeli buyers that the future supply of water will not be subject to interruption by Arab political pressure or possible domestic political changes within Turkey itself. Moreover, Israel will not be the only consumer. There is sufficient surplus water in the Manavgat and the nearby Köprüçay river to expand the export facilities to meet the needs of Turkish cities in the West, the tourist areas around Antalya, the nearby Greek islands and possibly Northern Cyprus and the Sinai Coast at El Arish.[30]

The Turkish approach is that their terminals will be like gas filling stations, which serve all customers without any political discrimination. Moreover, like a filling station that provides a choice of regular or premium gasoline, the two Manavgat terminals will offer a choice of regular or specially treated water. There has been considerable interest in Israel in importing water from Turkey. Tahal conducted a pre-feasibility study and a report prepared by engineer Abraham Shemtov in June 1990 estimated that 250 MCM in the first stage and 400 MCM in the second stage could be delivered into Israel's National Water System for 22.3 US cents per cubic meter, utilizing extremely large plastic bags (1.6MCM capacity) towed by tugboats from the Manavgat or other sources.[31]

The project has not yet been implemented, however. One reason has been the concern expressed in the past by Israelis, including former Water Commissioner Dan Zaslavsky, over the dependability of Turkish supply over the 10 to 20 year period necessary to make the cost of constructing the Israeli terminal worthwhile. Ambassador Collette Avital, Israel's consul general in New York, recently expressed the view that Turkey was a major constructive force for peace and that Israel had no reason to question Turkey's reliability as a source of water. Among the positive changes are that Turkish-Israeli relations have been raised to the ambassadorial level and bilateral cooperation in tourism and other areas is openly developing, the fact that Jordan and the Palestinians are interested in obtaining Turkish water, and Arab objections have been undercut by the fact that Ankara can point to the fact that direct Arab-Israeli peace negotiations are under way.[32] However, the heavy rains of the past two seasons have lessened the sense of urgency in Israel and the Labor Government of Yitzhak Rabin and Minister of Agriculture Ya'akov Tsur and Water Commissioner Gideon Tsur, have not yet determined their water import policy.

A decisive factor will be whether Turkish water is in fact cheaper than water from desalination. The cost of the Turkish water depends not only on costs of construction, interest rates and the Turkish royalty, but also on whether large-scale Medusa bags will perform as projected. James A. Cran, President of the Medusa Corporation of Calgary, estimates the first 250 MCM could be conveyed to Ashkelon and pumped into the National Water Carrier at a cost of 17 cents per cubic meter, while additional quantities would be at 9 cents. He contends this compares very favorably "to desalination at $0.75-$1.25, supertanker transport at $0.70-1.10 or the Turkish pipeline to Jordan at $0.60." He estimates that 10 months and $1.5 million are needed to complete technical development, construction and testing of a 100,000 ton prototype.[33] Mr. Yüksel Erimtan, the Turkish contractor involved in the Manavgat project, estimates that utilizing retro-fitted oil tankers, the total cost of supplying the water to Israel would be between 65 and 70 cents per cubic meter.

Turkish Water's Potential Contribution to Peace

Mr. Cran suggested in a recent discussion with the author how Turkish water could tangibly contribute to Jordanian/Palestinian-Israeli peace: Some 250 MCM of Turkish water would be delivered to Israel and connected by short pipeline with the National Water Carrier. For each cubic meter received, Israel would release a cubic meter from the upper Jordan or the Kinneret for Jordanian (or Palestinian) use. This would save the cost of conveying the Turkish water to Jordan's East Ghor Canal and would also save Israel the energy cost of lifting water into the National Water Carrier from the Kinneret. Linking the two projects could help overcome Arab opposition to Turkey's supply of water to Israel: "Since Israel is unlikely to admit Jordan's right to 200 MCM, the compromise is for Israel to give 250 MCM annually to Jordan conditional on an equivalent quantity being brought from Turkey to Israel." Additional projects using the Medusa bags could carry a total of 1880 MCM of Manavgat water to terminals at various other ports along the Mediterranean and Red Sea.

In response to Arab and Israeli fears that political factors may disrupt Turkish water supplies, President Özal and Prime Minister Süleyman Demirel have repeatedly stressed that they seek to develop a network of mutually beneficial economic relations among Turkey and all its neighbors. For example, pipelines would convey oil and gas to Turkey and in exchange Turkey would provide water and hydroelectric power to its neighbors. This growing interdependence and the obvious fruits of cooperation, they say, are the best guarantee against disruption. The financial and technical support of outside industrial nations and of international agencies for such water sharing projects can make a tangible contribution to a more peaceful and prosperous future for all the peoples of the region, including the Israelis and the Palestinians.

ENDNOTES/REFERENCES

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Schiller, (Special Issue of the *Canadian Journal of Development Studies* published jointly with International Water Resources Association, 1992), 153-71, at p. 160. Radwan Al-Mubarak Al-Wesheh estimates Jordan's loss at 25 percent, noting this equals loss rates in British municipal systems but is less than Boston's, which was only cut from 43 to 33 percent from 1980 to 1988. ("Jordan's Water sources: Technical Perspective," *Water International*, 17 (1992) 124-32, at. p. 130.)

2. John Kolars, "Water Resources of the Middle East," in *Sustainable Water Resources Management. . .*, cited in note 1 above, pp. 103-119, provides an overview of water resource availability as against consumption and population growth in Israel, Jordan, Lebanon, Syria, Iraq and Turkey.

3. "The Water Crisis: 25 years of bad management," text of the official summary of the State Comptroller's report, *Jerusalem Post*, May 25, 1990.

4. George E. Gruen, *The Water Crisis: The Next Middle East Conflict?* (Los Angeles: Simon Wiesenthal Center, 1991) pp. 19-20 and 35-38, provides a summary of the recommendations being made by officials in Israel and in neighboring Arab countries to conserve water.

5. See for example Paris dispatch by Alan Riding, "Europe's Farmers Stage Big Protest--Thousands Throng Streets of Strasbourg in a Rally Against Trade Accord," *New York Times*, December 2, 1992, and Keith Bradsher dispatch from Asbury, Missouri, "How Trade Pact Plays on the Farm: Emerging details suggest U.S. soybean growers may suffer," *ibid*, January 13, 1993.

6. Conversation with the author, Zurich, December 13, 1992. Ben Meir recommends reducing the level of the lake as much as possible by the end of summer to provide for maximum winter storage. If rainfall proves inadequate, priority in periods of drought must be given to domestic users, "the inelastic demand," and cutbacks made in allocations to agricultural users, "the flexible demand."

7. Al-Weshah, "Jordan's Water Resources: Technical Perspective," cited in n. 1, p. 126.

8. Rami S. Abdulhadi, "Water Resources for the State of Palestine," unpublished Background Paper provided to the author in June 1992. His total Palestinian population estimate of 2,265,000 is considerably higher than that given by the Israelis, who exclude Jerusalem from West Bank statistics.

9. Joshua Schwarz, *Israel Water Sector Review: Past Achievements, Current Problems and Future Options*, prepared by TAHAL Consulting Engineers Ltd. for the World Bank, Tel Aviv: December 1990, p. 10-8.

10. *Ibid*. pp. 10-4 and 5 and Fig. 10-2. Tahal's Master Plan gave a slightly high projection than the 1989 CBS estimate.

11. Population growth rates from "Middle East Country Profiles Summary" in *Water in the Sand: A Survey of Middle East Water Issues*, draft prepared by U.S. Army Corps of Engineers, Washington, DC, June 1991.

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15. Kolars, "Water Resources of the Middle East," cited above, pp. 109-111.

16. On the Johnston negotiations, see George E. Gruen, *Water and Politics in the Middle East: An Analysis of Arab, Israel and International Efforts to Develop the Jordan River System* (Reports on the Foreign Scene, December 1964, No. 5, published by the Institute of Human Relations of the American Jewish Committee, New York).

17. The International Drinking Water Supply and Sanitation and Sanitation Decade: Review of Mid-Decade Progress (as of December 1985) , Geneva: World Health Organization, September 1987, and Mamdouh Shahin, "Review and Assessment of Water Resources in the Arab Region," Water International 1989, vol. 14, pp. 206-219. The quote is taken from the forthcoming study by the U.S. Army Corps of Engineers, Water in the Sand, cited above n. 11. Kolars in Table 10 of "Water Resources of the Middle East," cited above n. 2, estimates the unused available reserve, based on mid-1970's annual water consumption figures, at 2,859 MCM.

18. Conversation with the author in New York, November 23, 1992.

19. In a conversation with the author, cited in Gruen, *The Water Crisis*, rev. ed., p. 30. The Tennessee Valley Authority and the Saint Lawrence Seaway Authority are some other possible institutional models.

20. The abortive 1952 Syrian-Israeli negotiations are summarized in a recent article by Moshe Zak, "Heed B-G's advice on Syria," *Jerusalem Post International Edition*, week ending December 5, 1992, based on the volume seven of *The Documents on the Foreign Policy of Israel*, edited by Dr. Yehoshua Freudenlich.

21. The above statistics on water availability and population are based on discussions with Dr. Bilen in Ankara on September 24, 1992 and on the *1992 Diary* issued by the

Turkish Republic, General Directorate of State Hydraulic Works, and from Tables 5.1 and 5.2 in Özden Bilen and Savaş Uskay, *Comprehensive Water Resources Management Policies and Issues: A Report to the World Bank* (June 1991). I am also indebted to Professor Ilter Turan of Istanbul University, with whom I met on September 18, for sharing with me the draft of his forthcoming article on "Turkey and the Middle East: Problems and Solutions."

22. John Kolars, "Population and Water in Two Middle East Basins," unpublished table provided the author in June 1992. The figures do not comment on agricultural needs or plans.

23. Kolars, "Water Resources of the Middle East," p. 117.

24. Cited in Gruen, *The Water Crisis*, revised edition, pp. 19-20. Many American and Middle Eastern analysts doubt the dam will ever be built, since the Syrians have already methodically and unilaterally reduced the flow of the Yarmuk to Jordan and Israel by construction of some 30 small diversion dams.

25. Conversation with the author, New York, July 21, 1992. Support for the idea of bringing Turkish water to Jordan was also expressed to me by Dr. Jawad al Anani, director of the Center for Economic and Technical Studies in Amman. (Conversation in New York, June 18, 1992.)

26. See map "The Golan Heights: Room for Maneuver?" accompanying Ehud Ya'ari's dispatch from Hong Kong, "Lessons from the East," *Jerusalem Report*, November 5, 1992, pp. 25-26. Mr. Boaz Wachtel has proposed solving both the water and the security problems by means of a pipeline from the Ataturk Dam that will feed a broad canal along the Israeli-Syrian Golan front to serve as an anti-tank barrier and provide water and hydropower to Syria, Jordan, Israel and the Palestinians. Aside from the plan's economic feasibility, which has not yet been fully calculated, the project faces many political hurdles since in addition to Syrian-Israeli agreement, it would require Turkish, Syrian and Iraqi approval to divert 1 billion cubic meters of water annually from the Euphrates. (Boaz Wachtel, "The Peace Canal on the Golan," *The Turkish Times*, March 1, 1992, p. 11.)

27. Agence France Presse dispatch from Baghdad, October 9, 1992, quoting Iraqi Deputy Agriculture Minister Abdel Sattar Hussein.

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29. Lale Sariibrahimoglu, "Manavgat Project Underway," *Turkish Daily News*, December 2, 1992.

30. Mr. Yüksel Erimtan, chairman and CEO of EMT, a Turkish consulting and construction company, has plans for dam construction and power generation projects on the Köprüçay River, which would provide more than 1 billion cubic meters of water for export, in addition to the water available from the Manavgat. (Conversation with the author, Ankara, September 21, 1992.)

31. James A. Cran, "The Medusa Bag and Middle East Projects"(mimeographed), 13-pages, contains a detailed description of the technical aspects of the project. Copies are available from the Medusa Corporation, 625 Sifton Blvd. S.W., Calgary, Alberta, Canada T2T 2K8, Tel. (403) 243-3640, Fax. (403) 244-1675.

32. Author's conversation with Ambassador Avital, January 6, 1993.

33. As stated in the August 17, 1992 letter Mr. Cran wrote to Allen Kieswetter, Chief Negotiator, Multilateral Working Group on Water Resources, Department of State. (Copy given me by Mr. Cran.) The lower cost figures are based on an interest rate of 7.5% rather than the 12% of the Tahal study. (Telephone conversation with the author, December 7, 1992.) Unitor, a Norwegian maritime supply company, which has patented the "Unitor Oil Bag," for collecting oil spills, has also begun to experiment with polymer coated fabric containers for transporting fresh water. However, the company recently suspended work, because of "major engineering obstacles" that Unitor did not feel able to tackle on its own. The Oslo-based company is seeking to attract support from governmental or major corporate entities to resume the research. (Author's conversation on January 18, 1993 with Christopher P. Constantine, U.S. representative of Unitor Ships Service, Inc.)

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COSTS OF INTER-REGIONAL CONVEYANCE OF WATER AND COSTS OF SEA WATER DESALINATION

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Abstract

Costs of water conveyed from abroad into Israel, Jordan and the Occupied Territories were calculated. Recent costs of Nile Water conveyed to the Gaza Strip are between 20 ¢/m^3 to 82 ¢/m^3. Costs of conveying water from the Syrian Euphrates to Israel are between 36 ¢/m^3 to 82 ¢/m^3 The conveyed water costs are compared to those of desalinated sea-waters.

1. GENERAL

This paper refers to the "costly water" of the two following types:

(a) Inter-Regional Conveyed Water, and
(b) Desalinated Sea Water.

The above subjects are dealt with on the background of that the cost of these waters is to be a major factor regarding the real possibility to be incorporated into the system. The following subjects are elaborated here:

(a) The updated cost of Nile water conveyed to the Gaza Strip by a canal system.
(b) The cost of conveyance of water by pipelines from various sources in the Middle East to several destinations in Israel, the Territories and Jordan.
(c) Updated sea water desalination costs.
(d) Water exchange: Turkish Euphrates water in the Syrian Euphrates Dam - in exchange for the Yarmouk water used by Syria.

2. COST OF NILE WATER CONVEYED TO THE GAZA STRIP

2.1 General

The cost of the Nile water in the Gaza Strip is the combination of the following:

(1) the value of the water at the source,
(2) conveyance cost through the Sinai (along with the planned Egyptian "El Salaam" Project (E.S.P.) Route),
(3) conveyance cost from North Sinai up to the Strip,
(4) treatment of the water towards either direct use in irrigation or artificial storage in the Strip's aquifer.

The values of the above four components were updated and elaborated for a 100 MCM/yr project out of Publication 2.1 Data as detailed below.

2.2 Price Change

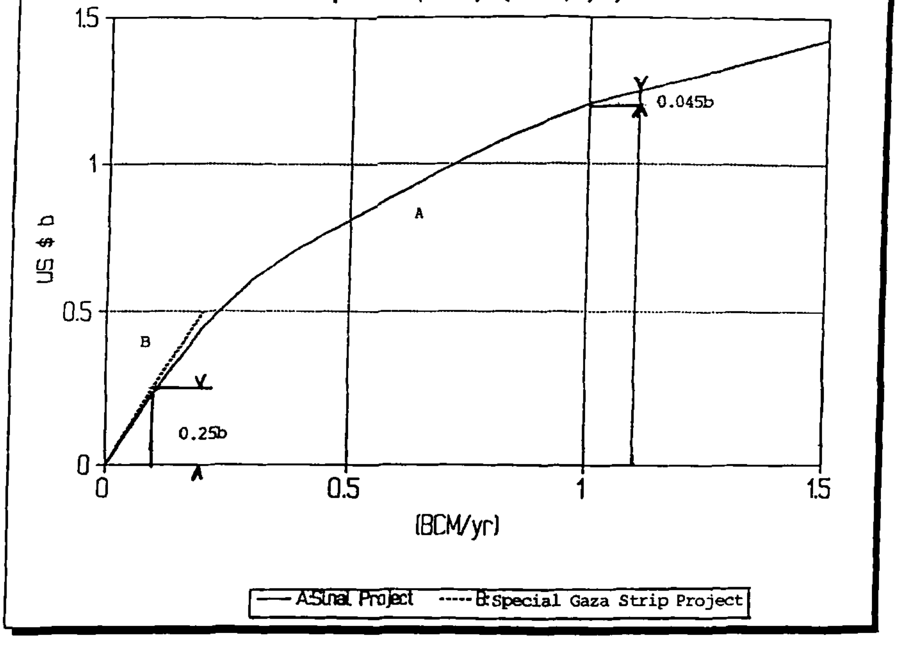
Reference 1 Prices are 1985 ones. The price change between 1985 and 1992 was taken as the average between:

(a) the U.S.A. Construction Cost Index as published by the ENR Journal (price change ratio: 1.179),

(b) the findings of Reference 2 regarding a similar structure price change (Two Seas Project, between 1982 and 1991), which gives the corresponding (Israeli) dollar price change as: 1.125.

The resulting average which is to be used hereafter is 1.15.

Fig 1.Investment Cost (US $ b) Vs Project capacity (BCM/yr)



2.3 The Investment Cost of the E.S.P. Route Part

This cost refers to the route of the Egyptian "El Salaam Project" (E.S.P.) starting from the Damietta Nile branch up to South El Arish, 200 km from the Suez Canal.

The conveying system cost as a function of its capacity is shown in Fig. 1.

The cost of this conveying system depends on the way of its cost sharing with the Egyptian Project as follows (refer to Fig. 1):

(a) the cost of a marginal 100 MCM/yr project over the basic ESP 1BCM/yr, is: $45M,

(b) the average cost in a common 1100 MCM/yr project is:

$$1205 \times \frac{0.1}{1.1} = \$110M,$$

(c) the cost of an independent 100 MCM/yr project (not related to the E.S.P.) is $250M (refer to Fig. 1). This leads to the following project cost (Table 2).

Table 1 - 100 MCM/yr Project Cost
(In Million Dollars)

Cost Share Form	The E.S.P. Route Part	The Sinai-Gaza Route Part	Total
Marginal	45	64	109
Average	110	64	174
Independent	250	64	314

2.4 The Water Cost

Water cost components apart from the investment ones (updated Publication 2.1 Costs) are:

a.	Value at the source:	¢4.6 /m^3
b.	Power (by 6/kwh):	¢4.6 /m^3
c.	Operation, maintenance & treatment:	¢4.0 /m^3
	Total	¢13.2/m^3

These components added up to the investment cost result in the following water costs:

Table 2 - Water Cost, ¢/m³

Form of Cost Share with the E.S.P.	Investment Interest Rate 6%	12%	Other Costs (Source, Power, O&M and Treatment)	Total Interest Rate 6%	12%
Marginal	7.2	13.2	13.2	20.4	26.4
Average	11.5	21.1	13.2	24.7	34.3
Independent	20.8	38.1	13.2	34.0	51.3

This table's data shows:

(a) The cost share form has a crucial effect on the water cost.
(b) The interest rate affects the water cost significantly.

3. COST OF WATER CONVEYANCE BY PIPELINE

3.1 General

Eight origin points and six destination ones were referred to (see Table 4 and Map 1).

Among these points, 15 routes were defined, for which water conveyance costs were calculated.

These costs are conveyance (horizontal and vertical) only and do not include other possible functions like: storing and treatment which regularly may cost between 5 to 20 ¢/m³. The value of the water at its source is also not considered here.

For the horizontal conveyance cost, optimal diameter was calculated by the following basic data. Vertical lift cost was taken as 2.5 ¢ for 100 m.

3.2 Optimal Diameter and Horizontal Conveyance Unit Cost

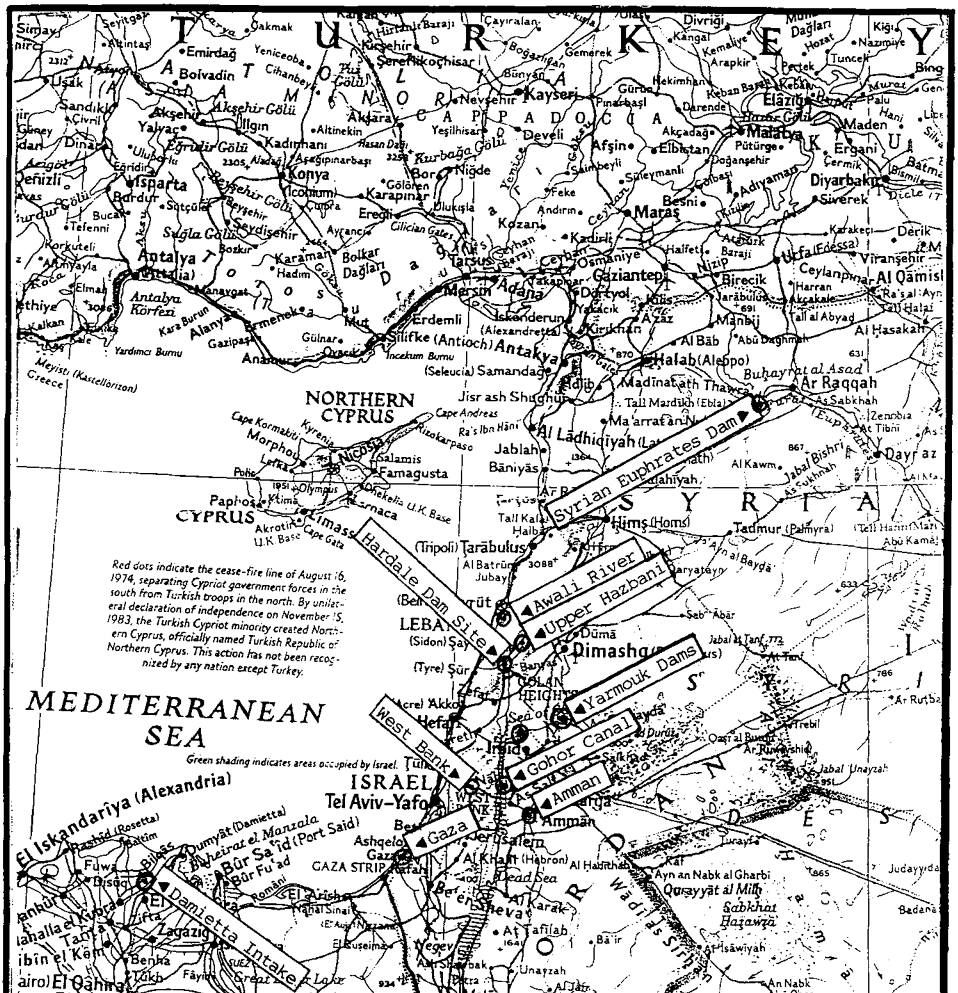
A. General Input Data for Optimal Diameter Calculation

Pump Efficiency (%):	85.00
Interest Rate (%):	12.00, 6.00
Life Span (yrs):	40.00
Pump Cost ($/kw):	850.00
Annual Maint. Cost - pipe:	0.75% of the investment cost
Annual Maint. Cost - pump:	3.00% of the investment cost

Annual Changes of Flow

Year/Percent of final flow:	1:100.00
Year/Percent of final flow:	40:100.00

MAP 1 CONVEYANCE SOURCE AND DESTINATION POINTS



Pipe Definition

Pipe Diameter (mm):	1400.00	Pipe Diameter:	800.00
Pipe Cost ($/m):	740.00	Pipe Cost:	220.00
Pipe Friction*:	140.00	Pipe Friction:	140.00
Pipe Diameter (mm):	1600.00	Pipe Diameter:	1000.00
Pipe Cost ($/m):	870.00	Pipe Cost:	400.00
Pipe Friction*:	140.00	Pipe Friction:	140.00
Pipe Diameter (mm):	1800.00	Pipe Diameter:	1200.00
Pipe Cost ($/m):	1000.00	Pipe Cost:	580.00
Pipe Friction*:	140.00	Pipe Friction:	140.00
Pipe Diameter (mm):	2000.00	Pipe Diameter:	1400.00
Pipe Cost ($/m):	1120.00	Pipe Cost:	740.00
Pipe Friction*:	140.00	Pipe Friction:	140.00

Hourly Rates

Number of Hours:	8000 (in a year)
Rate (¢/Kwh):	6.50

B. **Optimal Diameter and Unit Cost of Horizontal Water Conveyance**

The data of (A) above result in the following optimal diameters and costs. [The optimal diameter is the least cost one (among the commercial diameter selection), considering both investment and power costs, all by (A) data of paragraph 3.2 above.]

Table 3 - Optimal Diameters and Costs

Interest Rate		12%			6%	
Annual Flow, MCM/yr	50	100	200	50	100	200
Hourly Flow m^3/hr	6250	12500	25000	6250	12500	25000
Optimal Diameter, mm	1200	1600	2000	1200	1800	2000
Cost ¢/m^3/km	0.184	0.145	0.110	0.117	0.091	0.078

3.3 Conveyance Costs

Tables 5 and 6 show the 15 routes' water conveyance cost. Tables 7 and 8 show the pipeline investment costs for the above routes. Note that investment costs, as such, are not dependent on interest rate but through that the optimal diameter-does.

3.4 Notes

The following notes refer to the numbers in brackets on the Tables.

(1) The three conveyance cost figures in each square include vertical rise lift costs and refer to 50 MCM/yr (upper), 100 MCM/yr and 200 MCM/yr
(2) This dam is planned and not yet existing.
(3) Lake Tiberias can serve as the Yarmouk flood water storage instead of the Yarmouk Dams. The Dams can store these waters efficiently hydraulically but not economically which make them not practical for this purpose. This subject is dealt with in Reference 1.

* "Friction": Friction coefficient by Hazen Williams

3.5 Cost of Interregional Water Conveyance by Pipeline - Conclusions

3.5.1 Calculation Subjects

1. Within the project, interregional water conveyance cost was calculated. The calculation referred mainly to pipeline pressure conveyance (due to the topographical circumstances).

2. The water costs were calculated as follows:

   2.1 Flows of 50, 100 and 200 MCM/yr were referred to.
   2.2 Optimal diameters were calculated under a set of assumptions (8,000 hours pumpage in a year, 6 ¢/Kwh, fixed flow through the project lifetime.
   2.3 A matrix of 8 origin points and 6 destination points were set and 15 routes of interest were defined on it for which costs were calculated (1992 prices).
   2.4 Conveyance and pipeline investment costs were calculated for 12% and 6% interest rates respectively.

3.5.2 Conclusions

1. Limiting agriculture water cost to some 25 ¢/m (which is about the maximum product value of water), leads to that international water transition can mostly be suitable for urban uses only (if not heavily subsidized).

2. Taking into account that water conveyed to the Yarmouk dams or to Lake Tiberias is to be further conveyed to final destinations, makes most of the international conveyance too costly even for urban uses (compare to sea water desalination).

3. The conveyance cost in the Nile (Damietta branch)-Gaza Strip route resulted in 74 ¢/m for 50 MCM/yr, 12% I.R. In this route, canal system can replace the pipeline economically and reduce the conveyance cost to about a half (38.1 ¢/m). Additional significant cost decrease can be achieved here if this project is combined with the Egyptian "El Salaam" Project (21 ¢/m in the "proportional" cost sharing).

4. The route Gohor Canal-West Bank is of special importance. It is the updated version of the "West Branch" of the Gohor Canal Project - the yet uncompleted part of the whole Yarmouk-Gohor Project.

   This project is the twin project of the Gohor-Amman one and its justification from both economic and water -balance points of view - is well established.

5. The too-high conveyance cost of the Euphrates water leaves place for water exchange: water is to be bought (by the Territories, Jordan or Israel) from Turkey in the Syrian Euphrates Dam and be given to Syria in exchange to the Yarmouk Water used by Syria. The exchange rate of such a deal will, most probably, be more Euphrates water for less Yarmouk one, yet, still it may be worthwhile.

TABLE 4 – WATER CONVEYANCE BY PIPELINE – BASIC DATA: SOURCE AND DESTINATION LEVELS ABOVE SEA LEVEL AND PIPELINE LENGTH (KMS.)

Destination \ Origin	Awali River +0	Gohor Canal -300m	Hardale Litani Dam(2) +220m	Lake Tiberias(3) -210m	(3)Makarein Yarmouk Dam(2) +190m	(3)Muheiba Yarmouk Dam(2) -40m	Nile's Damietta +0	Syrian Euphrates +200m
Aman +800m	210 kms.							580 kms.
Gaza Strip +100m							390 kms.	
Upper Hazbani River +300m	40 kms.		8 kms.					430 kms.
West Bank +800m	180 kms.	40 kms.	140 kms.	70 kms.	90 kms.	70 kms.		580 kms.
Yarmouk Makarein Dam(2) +190m								485 kms.
Yarmouk Muheiba Dam(2) - 40m								495 kms.

TABLE 5 – WATER CONVEYANCE BY PIPELINE. WATER COSTS AT 12% INTEREST RATE FOR: 50 MCM/YR.
100 MCM/YR.
200 MCM/YR.

Destination \ Origin	Awali River	Gohor Canal	Hardale Litani Dam	Lake Tiberias	Makarein Yarmouk Dam	Muheiba Yarmouk Dam	Nile's Damietta	Syrian Euphrates
Aman	58.6 ¢/m^3 50.5 ¢/m^3 43.1 ¢/m^3							121.7 ¢/m^3 99.1 ¢/m^3 78.8 ¢/m^3
Gaza Strip							74.3 ¢/m^3 59.1 ¢/m^3 45.4 ¢/m^3	
Upper Hazbani River	14.9 ¢/m^3 13.3 ¢/m^3 11.9 ¢/m^3		3.5 ¢/m^3 3.2 ¢/m^3 2.9 ¢/m^3					81.6 ¢/m^3 64.9 ¢/m^3 49.8 ¢/m^3
West Bank	53.1 ¢/m^3 46.1 ¢/m^3 39.8 ¢ m^3	34.9 ¢/m^3 33.3 ¢/m^3 31.9 ¢/m^3	40.3 ¢/m^3 34.8 ¢/m^3 29.9 ¢/m^3	38.1 ¢/m^3 35.4 ¢/m^3 33.0 ¢/m^3	31.8 ¢/m^3 28.3 ¢/m^3 25.2 ¢/m^3	33.9 ¢/m^3 31.2 ¢/m^3 28.7 ¢/m^3		121.7 ¢/m^3 99.1 ¢/m^3 78.8 ¢/m^3
Yarmouk Makarein Dam								89.0 ¢/m^3 69.1 ¢/m^3 52.1 ¢/m^3
Yarmouk Muheiba Dam								83.0 ¢/m^3 65.8 ¢/m^3 49.6 ¢/m^3

TABLE 6 - WATER CONVEYANCE BY PIPELINE. COSTS AT 6% INTEREST RATE FOR: 50 MCM/YR.
100 MCM/YR.
200 MCM/YR.

Origin / Destination	Awali River	Gohor Canal	Hardale Litani Dam	Lake Tiberias	Makarein Yarmouk Dam	Muheiba Yarmouk Dam	Nile's Damietta	Syrian Euphrates
Aman	44.6 ¢/m^3 39.1 ¢/m^3 36.4 ¢/m^3							82.9 ¢/m^3 67.8 ¢/m^3 60.2 ¢/m^3
Gaza Strip							48.1 ¢/m^3 38.0 ¢/m^3 32.9 ¢/m^3	
Upper Hazbani River	12.2 ¢/m^3 11.1 ¢/m^3 10.6 ¢/m^3		2.9 ¢/m^3 2.7 ¢/m^3 2.6 ¢/m^3					52.8 ¢/m^3 41.6 ¢/m^3 36.0 ¢/m^3
West Bank	41.1 ¢/m^3 36.4 ¢/m^3 34.0 ¢/m^3	32.2 ¢/m^3 31.1 ¢/m^3 30.6 ¢/m^3	30.9 ¢/m^3 27.2 ¢/m^3 25.4 ¢/m^3	33.4 ¢/m^3 31.6 ¢/m^3 30.7 ¢/m^3	25.8 ¢/m^3 23.4 ¢/m^3 22.3 ¢/m^3			82.9 ¢/m^3 67.8 ¢/m^3 60.2 ¢/m^3
Yarmouk Makarein Dam					29.2 ¢/m^3 27.4 ¢/m^3 26.5 ¢/m^3			55.5 ¢/m^3 42.9 ¢/m^3 37.0 ¢/m^3
Yarmouk Muheiba Dam								48.5 ¢/m^3 39.0 ¢/m^3 32.6 ¢/m^3

TABLE 7 - WATER CONVEYANCE - PIPELINE INVESTMENT COST (US$M) AT 12%[1] INTEREST RATE FOR: 50 MCM/YR.
100 MCM/YR.
200 MCM/YR.

Origin / Destination	Awali River	Gohor Canal	Hardale Litani Dam	Lake Tiberias	Makarein Yarmouk Dam	Muheiba Yarmouk Dam	Nile's Damietta	Syrian Euphrates
Aman	$122 M $183 M $235 M							$336 M $505 M $974 M
Gaza Strip							$226 M $339 M $437 M	
Upper Hazbani River	$ 23 M $ 35 M $ 45 M		$ 5 M $ 7 M $ 9 M					$249 M $374 M $482 M
West Bank	$104 M $157 M $202 M	$23 M $35 M $45 M	$ 81 M $122 M $157 M	$41 M $61 M $78 M	$ 52 M $ 78 M $101 M	$41 M $61 M $78 M		$336 M $505 M $974 M
Yarmouk Makarein Dam								$281 M $422 M $543 M
Yarmouk Muheiba Dam								$287 M $430 M $554 M

TABLE 8 - WATER CONVEYANCE - PIPELINE INVESTMENT COST (US$M) AT 6% INTEREST RATE FOR: 50 MCM/YR.
100 MCM/YR.
200 MCM/YR.

Origin / Destination	Awali River	Gohor Canal	Hardale Litani Dam	Lake Tiberias	Makarein Yarmouk Dam	Muheiba Yarmouk Dam	Nile's Damietta	Syrian Euphrates
Aman	$122 M $210 M $235 M							$336 M $580 M $974 M
Gaza Strip							$226 M $370 M $437 M	
Upper Hazbani River	$ 23 M $ 40 M $ 45 M		$ 5 M $ 8 M $ 9 M					$249 M $436 M $482 M
West Bank	$104 M $186 M $202 M	$23 M $40 M $45 M	$ 81 M $140 M $157 M	$41 M $70 M $78 M	$ 52 M $ 90 M $101 M	$41 M $70 M $78 M		$336 M $580 M $974 M
Yarmouk Makarein Dam								$287 M $485 M $554 M
Yarmouk Muheiba Dam								$287 M $495 M $554 M

4. DESALINATION COSTS

4.1 General

Desalination costs of sea water are updated here in 1992 prices. Works done in 1990 and 1986 (see References List) are the data source of this cost updating. The construction cost dollar inflation rate is based on the data detailed in Chapter 1. According to this, the relevant construction cost inflation rate from 1986 up to 1992 is 1.1 (considerably lower than the general American Consumer Price Index Rate).

4.2 Seawater Desalination

Some of the main characteristics of the two above-mentioned desalination methods are summarized in Table 9. The resulting water costs are shown in Table 10.

Table 9 - Characteristics of Sea Water Desalination Methods
(8,000 m^3/h Plant)

Characteristics	Method Multi Stage Distillation (M.S.D.)	 Reverse Osmosis (R.O.)
Lead Time: Decision-Operation	6 years	4 years
Annual Operation Hours	5,800 (depending on electricity demand hours)	8,000
Typical Plant Area, m^2	50,000	5,000
Product Water Salinity, PPM of TDS	50	500
Initial Investment $M	136	126 (membrane not included)
Operation Costs $M/yr	4.8	23.0 (incl. membrane replacement)
Power Demand Kwh/m^3	7.0	4.2

Table 10 - Desalination Annual Expenses and Water Costs
(8,000 m³/h Plant)

Method	M.S.D. (46.4 MCM/yr) (life time: 25 years)				R.O. (64.0 MCM/yr) (life time: 20 years)			
Interest Rate	IR 12%		IR 6%		IR 12%		IR 6%	
Power Cost ¢/Kwh	6	4	6	4	6	4	6	4
Investment $M/yr	16.0		10.6		16.9		11.0	
Operation and Miscellaneous $M/yr	4.8		4.8		23.0		23.0	
Power $M/yr	19.5	13.0	19.5	13.0	16.1	10.8	16.1	10.8
Total $M/yr	40.3	33.8	34.9	28.4	56.0	50.7	50.1	44.8
Water Cost ¢/m³	86.8	72.8	75.2	61.2	87.5	79.2	78.3	70.0

Notes

(1) The above water costs do not include conveyance and storage costs neither do they include general infrastructure (roads, power network, etc.). Plant land cost is also not included but this may be negligible.

(2) The cases of 12% I.R. and power cost of 6 ¢/Kwh may be regarded as real market price costs while the other represent subsidization.

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Replenishment of Palestinian waters by artificial recharge as a non-controversial option in water resource management in the West Bank and Gaza Strip

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Abstract

Naturally occurring water resources in the Occupied Palestinian Territories (OPT) and the demand on their useage is becoming a critical political, economical and technical issue. Palestinian water useage and conservation is a top priority strategy that must be freely developed during the proposed interim peace period and thereafter.

Providing funds are made available, artificial groundwater recharge is suggested as a possible non-controversial method for water reclamation and conservation for use by Palestinians in the OPT. There should be no logical Israeli objections to Palestinian programs in implementing this technology. The various techniques of groundwater recharge could be applied in the OPT with the proper appropriate infrastructure and site development which could become an integral part of both the present and future master plan for water resource management in the area.

Applicable methods of artificial groundwater recharge using Palestinian water pumped into Palestinian wells or infiltrated into Palestinian land will be presented along with the benefits and disadvantages of this technology. Constraints will be pointed out.

1. INTRODUCTION

Artificial recharge of groundwater is an example of the alteration or acceleration of a natural process. Fundamentally, artificial recharge means placing water in the ground to supplement existing groundwater. The practice of supplementing the natural recharge of aquifers by artificial means is not new. (The practice of artificial recharge was first used in 1890 for the water supply of Gothenburg, Sweden and has been used in Israel since the late 1950's.)

Since artificial recharge is a logical process that can be used to replenish depleting wells and springs, it is a possible immediate, non-controversial, partial solution to the water resource problems of some areas of the OPT in which outside aid could be used immediately. It is really a local solution which can be done by individual well owners if funds are provided and the Israeli military authorities allow the Palestinian people to use the equipment and monies made available to them. However, the current Israeli military orders are an obstacle where, for example, laying pipes of any size over 2 inch (about 5 centimeters) for over 200 meters needs a military permission.

Artificial recharge has been used all over the world to :

(a) maintain or augment the natural groundwater in order to preserve aquifers as a continuing economic resource,
(b) to combat adverse conditions, such as intrusion of sea water and local saline waters,
(c) to provide subsurface storage for local or imported surface water, or both,
(d) to provide a subsurface distribution system, and
(e) to reduce the rate of land subsidence due to the extraction of fluids, whether it be water or oil or gas.

In general, recharge water comes from rain and runoff from rain. Areas of recharge are deposits of high porosity and permeability along the slopes of mountains and areas of discharge are in the form of seepage surfaces above and below (or both) rivers, lakes and oceans. In general, all major aquifers change from open to confined as they extend from the area of recharge to the area of discharge. (The slope of important aquifers is normally small, seldom in excess of 12 meters per kilometer.)

The critical need for recharge projects is apparent. The variable nature of rainfall both seasonly and yearly mandates storage of excess water supplies underground by artificially recharging water (either excess spring flow, collected runoff or treated wastewater) into the groundwater system in low demand winter months and recovering this water in the summer.

1.1. Brief historical review

Artificial recharge was first practiced in J. Gus Richert in 1890 for the water supply of Gothenburg, Sweden. In fact, in Sweden at least 50% of the water consumption in cities is from groundwater and of this quantity 50% has been created by artificial replenishment. The first recorded case in the United States was in 1889 when a Denver water company spread water over a gravel outcrop in order to avert a potential "water famine" and as early as 1900 spreading of water on debris cones was practiced in southern California. These early systems were designed to increase the amount of water percolating to the water table by spreading water over a larger surface area than occurred naturally.

2. PRINCIPLES BEHIND USING WATER RECHARGE

The argument is often presented as to why pour water into a well only to pump it up again - if there is water to spare, why not keep it on the surface? Underground storage eliminates the high water losses in surface storage due to evaporation and transpiration and it keeps the water stored in a clean form or even cleaner because it is filtered before being recharged and sediments settle as it is stored, while surface water may be contaminated from various fall out substances and dead organisms. Therefore, it must be emphasized that the purpose of recharging an aquifer artificially is not only to restore the potentiometric surface to normal levels, but to provide intermediate storage of surplus water for withdrawal as future needs dictate.

In artificial recharge, the objective is to store and retrieve water of good quality. To be practical, recharge must be done in a permeable lithologic unit at an economic rate and one should be able to predict movement and the chemical reactions and physical changes that could take place while the clean, stored water is in the underground reservoir.

This method is really an example of the alteration or acceleration of a natural process in the service of the people. It consists of utilizing some form of excess water which is placed in the ground to augment or supplement an existing form of groundwater. Indirect reuse through artificial recharge of aquifers offers great potential as a reclamation and conservation tool. (However, there are complications in the artificial recharge process which will be pointed out.)

3. METHODS OF GROUNDWATER RECHARGE

Artificial groundwater recharge is accomplished by two basic methods: -

(1) * spreading water over the land surface, and

(2) ** injection through wells either into unconfined aquifers, or into confined aquifers by penetrating the confining strata.

Examples:

*(1-a) as occurs naturally in Balou in El-Bireh/Ramallah in the central hills of the West Bank which is located exactly in the small valley between the West Bank Water Department and the West Bank Drivers' Education Department and near the entrance of the Israeli Military Headquarters for the West Bank

*(1-b) There is also natural recharge through the large water area of the seasonal Lake Sanour near the village of Sanour in the northern Jenin District of the West Bank and near Azzoun in the Nablus District.

**(2-a) as Israel is doing now in the coastal areas and should be done soon as possible in the Gaza Strip.

There are several general techniques of artificial recharge :

Water spreading (by construction of dikes or small dams) :
(1) basins,
(2) flooding,

Water spreading (by excavations) :
(3) basins
(4) ditches and furrows,
(5) pits and shafts,

Use of Wells :
(6) pumping to induce recharge from surface water bodies.
i.e., stream channels or ponds, pools, lakes.
(7) injection wells.

4. THE GROUNDWATER RECHARGE PROCESS

Obviously, the geological characteristics of the aquifer will be the primary controls in the choice of a particular artificial recharge method, the key factors being:

location, extent and nature of the aquifers,
as well as the availability and quality of the potential recharge water.

Efficient economical artificial recharge requires the logging of soil and stratigraphic characteristics and a knowledge of the relationship of these characteristics to infiltration and the subsurface storage and movement of water.

An aquifer is any body of rock which will yield water to wells. An aquiclude is a body of rock which confines the water in an underlying aquifer under artesian pressure. The terms are relative, i.e., aquifers may yield little or much water, and few aquicludes are entirely impermeable.

The permeability caused by the openings in rocks is said to be primary if these openings are inherent in the nature of the rock and have been formed by the same process and at the same time as the rock was formed, e.g., the spaces between the grains of sand or sandstone or the gas cavaties in lava. It is called secondary permeability if the openings have been caused by some later or unrelated process, such as the fracturing resulting from earth movements or the removal of calcium carbonate by solution. Some rocks possess both primary and secondary permeability.

The classification of aquifers is based upon the properties of rocks which affect ground water. In any region the rocks may be consolidated or unconsolidated. They may be uniform in lithology, or they may consist of alternating layers of different llithologies. They may have been tilted, or altered in various ways since their formation.

Consequently, the occurrence of groundwater depends not only on the fundamental nature of the rocks but also on their geological history. The groundwater may be found under confined (artesian) or unconfined (water table) conditions. The permeability of an aquifer may be uniform, or it may vary in some regular way, or it may be very irregular because most of the water is in secondary openings.

Only a small fraction of the annual precipitation percolates downward to the water table. A large proportion of precipitation runs overland to streams or is discharged by the process of evapotranspiration before it reaches aquifers. The amount of precipitation that reaches the zone of saturation depends on several factors. Among these are :

- the character and thickness of the soil and other deposits above and below the water table,
- the topography,
- the vegetal cover,
- land use,
- soil moisture content,
- depth to the water table,
- the intensity, duration and seasonal distribution of rainfall, and
- the air temperature and other meteorlogical factors (humidity, wind, etc.).

Recharge direct from precipitation and by infiltration of surface water involves the vertical downward movement of groundwater under the influence of vertical head differentials. Thus, recharge involves vertical leakage of water through deposits. The quantity of vertical leakage varies from place to place and is controlled by

- the permeability and thickness of the deposits through which leakage occurs,
- the head differential between sources of water and the aquifer,
- and the areas through which leakage occurs.

Thus, the hydrology of groundwater recharge depends upon the physical and chemical characteristics of both soil and water. These characteristics must be measured and related to subsurface storage space and water movements to determine the feasibility of a site for recharge and to select appropriate methods and systems of recharge; only then may water be efficiently stored underground to be used independently or conjunctively with releases from surface storage reservoirs.

Withdrawal of water from the ground at rates greater than those at which it is replenished results in lowering the water table and an increase in pumping cost. (This is what Israel is now causing to the West Bank aquifer systems by their huge amounts of water withdrawals.) In coastal areas, an overdraft may reverse the normal seaward gradient of the water table and permit salt water to move inland and contaminate the aquifer. (This is what is happening in the Gaza Strip now.)

An aquifer undisturbed by pumping is in approximate equilibrium. Water is added by natural recharge and removed by natural discharge. In years of abundant water, the water table rises and in years of drought the water level declines, but rates of recharge and discharge tend to remain in approximate balance.

When a well is put into operation, new conditions are created. Water may be removed from storage in the aquifer or "mined" in the sense that other minerals are mined. The depression in the water table caused by the well may induce increased recharge or may decrease natural discharge. The concept of "safe yield" has been used to express the quantity of groundwater which can be withdrawn without impairing the aquifer as a water source, causing contamination, or creating economic problems from increased pumping lift. (The concept of "safe yield" and equitable water rights is what the Palestinians must insist upon from Israel during "peace" negotiations.)

Actually, safe yield cannot be defined in truly practical and general terms. Determination of safe yield is a complex problem in hydrology, geology and economics for which each aquifer requires a unique solution. The general type cases are :

(a) aquifers in which safe yield is limited by the availability of water for recharge,
(b) aquifers in which safe yield is limited by the transmissibility of the aquifer,
(c) aquifers in which safe yield is limited by potential contamination.

If the rate of recharge of a reservoir-type aquifer is increased, the safe yield is also increased. If an aquifer of low transmissibility can be recharged close to the point of withdrawal, the safe yield may also be increased.

Artificial recharge is commonly carried out in conjunction with some sort of surface storage or reservoirs in which excessive flows can be impounded temporarily. Controlled releases of water from surface reservoirs can then be diverted to spreading areas, shafts, pits or wells for groundwater recharge. The aquifer then serves as a distribution system and eliminates the need for surface pipelines or canals.

The most widely used method for artificial recharge is spreading which usually entails diversion of water from a stream or reservoir to shallow basins, ditches or pits. Spreading (which is similar to various systems of irrigation) diverts water to land thereby increasing the amount of water infiltrating into the soil by reason of a greater wetted surface. In this method, the water is usually recharged by infiltrating through the bottom and sides of the basin or ditch and through the unsaturated zone until it reaches the water table.

Tests indicate that highest infiltration rates occur on areas with undisturbed vegetation and soil covering. The economy of water spreading for recharge hinges upon maintenance of a high infiltration rate. Typical rate curves show a pronounced tendency to decrease with time. The initial decrease in infiltration is attributed to disperson and swelling of soil particles after wetting. A subsequent increase of infiltration occurs with elimination of entrapped air by solution in passing water. The final gradual decrease results from microbial growth clogging the soil pores.

Generally, recharge rates decrease as the mean particle size of soil on a spreading area decreases. Efforts to maintain soil pores free for water passage have led to additions of organic matter and chemicals to the soil as well as to vegetation on a spreading area. Alternating wet and dry periods on a basin generally furnish a greater total recharge than does continuous spreading, in spite of the fact that water is in contact with the soil for as little as one half of the total time. Studies in small ponds have confirmed that infiltration rates are directly proportional to the head of water. Where less pervious strata lie below the surface stratum, the recharge rate depends on the rate of subsurface lateral flow.

Surface spreading is practicial only where surface and subsurface soils are suitable. Injection wells are used where impermeable strata or layers overlie the principal waterbearing deposits, a condition that renders surface spreading unfeasible. Also, recharge wells may have merit where land values are too high to set aside sufficient area for surface reservoirs. Recharge wells permit water to be injected into an aquifer where it is most needed. In fact, recharge wells are essentially the same physically as producing wells, and during an off season producing wells can be used for recharge purposes. Injection wells may be fed water by gravity or, in order to increase the recharge rate, the water can be pumped under pressure if the subsurface conditions are amenable.

As mentioned previously, the argument is often presented as to why pour water into a well only to pump it up again - if there is water to spare, why not keep it on the surface? Water used for recharge purposes is always temporary surplus water - either water that has been used for some purpose or water from high flow periods of a spring or river which is not needed for use at exactly that season. Such water, if not stored in surface or groundwater reservoirs, would just run down to the sea or to the nearest river or wadi. Underground storage also eliminates the high water losses in surface storage due to evaporation and transpiration. Therefore, it must be emphasized that the purpose of recharging an aquifer artificially is not only to restore the potentiometric surface to normal levels, but to provide intermediate storage of surplus water for withdrawal as future needs dictate. In addition, the benefit from the practice of artificial recharge should outweigh the potential constraints of public health safety, economics, maintenance and public acceptance.

5. GROUNDWATER RECHARGE IN VARIOUS PLACES IN THE WORLD

Artificial groundwater recharge has been practiced successfully in various countries for many years as a water management tool to help meet regional water requirements. In Germany, Australia, Switzerland, and The Netherlands, basins and canals for infiltration are used in most cases. The situation is the opposite in Great Britian, Japan, Israel and Jamacia where wells are more often preferred. The two systems are used almost equally in France, Sweden and the United States, where very often wells and basins are used both at the same time in the same installation. The choice between the various techniques is, of course, influenced by geological formations.

5.1. Groundwater recharge in Israel

In Israel, underground water storage is an integral part of the country's water supply system. Part of the artifical recharge is connected with flood water utilization and waste water reclamation. The majority of the recharge operations are directed towards replenishing over-exploited aquifers, thereby preventing sea water intrusion and providing seasonal and perennial water storage in the national water system. In general, climatic and geological conditions make surface storage unsuitable in this area. An economic analyses of the two methods of artificial recharge - surface spreading and well injection - has shown that when water of drinking quality is used for recharge, well injection should be preferred.

Recharge operations in Israel are applied to two main aquifers :

(a) the coastal plain aquifer - sandstone formation of the Pleistocene.
(b) the foothill aquifer - limestone and dolomite of the Turonian-Cenomania Age.

In Israel, recharge rates into sandstone wells range between 200 to 500 cubic meters per hour. Rates for limestone wells are 500 to 2000 cubic meters per hour.

In the late 1950's, artificial recharge volumes in Israel ranged between one-half to one million cubic meters per season. Projected recharge rates in Israel are 200 MCM through about 150 wells and spreading grounds by the year 2000.

It should be noted that Israeli officials announced as recent as October 1992 that they are placing a fourth large pump on Lake Tiberias (which is partially owned by Syria and now occupied territory) to control and utilize the available large quantities of water at the Dejania Dam entrance in order to increase the recharge output of their water carrier pipes to the underground wells in Israel (which system of recharge has been in operation for over two decades.)

6. PROBLEMS ENCOUNTERED DURING RECHARGE

There are many complications in the artificial recharge process related to the ability of the aquifer to transmit the injected water and these problems include the following :

(1) injection of fluid containing suspended solids which are often chemical precipitates,
(2) accumulation of corrosion products,
(3) precipitation within the formation as a result of incompatibility of the injected fluid with the connate water of the formation,
(4) injection of insufficiently treated water resulting in bacteriological plugging and/or algae growth,
(5) swelling of mineral constituents in the formation,
(6) rearrangement of soil particles,
(7) silting, and
(8) air entrainment due to undue fluctuation and turbulance of the injected water.

Favorable injection rates have been maintained by the use of chlorinated water free from silt, aeration of the water supply, and by conducting a comprehensive well maintenance program. If a well does become clogged, it must be cleaned or pumped periodically. Studies show that it is advisable to use a recharge well system simultaneously with water withdrawal from pumped wells in order to increase recharge rates. However, even when recharging through pumped wells, rapid declines in intake rates due to the accumulation of silt and slime usually needs to be prevented by pumping the recharge wells for 15-30 minutes per day.

Clogging and contamination processes in limestone are much less pronounced and detectable than in sandstone. In limestone wells, the water enters through fractures and holes that are large compared with the pores of sandy granular or sandstone-consolidated media. Also, surface forces in limestone are smaller than those in the sandstone formations that contain a clay fraction. The filtering out of suspended material in limestone is less effective than in sandstone, and the accumulation of organic solids in close vicinity of the well are smaller.

6.1. Ways and means to overcome groundwater recharge problems in wells

- minimize clogging effects by re-pumpage of small volumes of water for cleaning and re-development; operation of dual purpose wells is thus preferable.

b - recharge wells must have gravel jackets.

c - If recharge water is chlorinated in order to prevent bacterial activity in the pores of the soil or for sanitation reasons, proper precautions should be taken to prevent corrosion of the well casing. To maintain satisfactory recharge rates, the recharge water should be chlorinated to about 1.5 mg/liter.

d - avoid formation of air bubbles during recharge by injecting water at a steady rate.

e - use plastic insert tubing in the well instead of steel to minimize corrosion.

7. ADVANTAGES AND DISADVANTAGES OF GROUNDWATER RECHARGE

7.1. Advantages

- While most water conservation practices are designed to reduce the amount of water used, artificial recharge can be used to stabilize declining water levels and, with an adequate supply of water, replenish dewatered areas, (for example, the natural springs and shallow wells that went dry in the West Bank and Gaza Strip.)

- Losses due to evaporation and transpiration which can be high in surface storage will be largely eliminated by underground storage. (a good application for Tulkarem and Jenin Districts, as well as the Jordan Valley)

- Underground reservoirs have a built-in distribution system, although it is limited in some cases by the transmissibility of the aquifer.

- Wells already drilled in groundwater aquifers can serve as surface distribution systems.

- Salt-water intrusion can be controlled (as should be done in the Gaza Strip in the same way as it is being done by Israel along the coastal plain).

- Adverse salt-water balances can be prevented by the addition of fresh or less saline waters. (Cases are reported of control of high nitrate levels in groundwater by the process of artificial groundwater recharge. This strategy could also be used in the Gaza Strip for nitrates and florides.)

- Land subject to flooding during periods of high rainfall can be drained and put into production (as in the seasonal Sanour Lake in the Jenin District and near Azzoun in the Nablus District).

- Pumping and well construction cost increases can be prevented by maintaining or raising water levels.

- Land subsidence can be reduced or eliminated by pressure injection.

NOTE: - The only agricultural well known to the author that is used for artificial recharge in the West Bank is located in Auja in the Jordan Valley. The well is about 70 meters deep and its normal discharge is 90 cubic meters per hour. During the winter months when the Auja Spring has a high flow rate, filtered spring water is injected through the columns and pump of this well by gravity only at an estimated rate of 100 cubic meters per hour for 30 hours a week for about four weeks, i.e., about 3,000 cubic meters of water are recharged.

A combination basin recharge and well injection project is nearing completion in Gaza City. A large collection pool for city stormwater drainage has a capacity of 400,000 cubic meters and, in addition to surface infiltration, eight 20-inch diameter, stainless steel, perforated pipes will be inserted into the upper aquifer. Water will be recharged by gravity. It is estimated that 2 MCM of water can be recharged per year at this location only.

7.2. Disadvantages

- Water must be pumped from the underground reservoirs for surface distribution.

- Possible chemical change in groundwater quality may occur due to dissolving of soluble materials in underground formations.

- Possible contamination of groundwater could result in cases of excessive surface spills of persistent materials.

- Recreational facilities that would be available with surface storage are precluded.

7.3. Constraints

The following is a list of contraints that currently exist in the occupied West Bank and Gaza Strip with regard to the implementation of water resource projects in general especially water recharge as all of the items below require prior Israeli permission and/or permits from various Israeli military departments in the area.

a - Israeli military orders preventing Palestinians from making any changes in existing wells including cleaning, deepening, lowering pump setting, acid-treatment, pulling casing, or even fixing a pump or motor.

b - Israeli military orders preventing Palestinians from making any changes in water distribution systems, including laying any pipe over 2 inches in diameter (about 5 centimeters) for any length over 200 meters.

c - Israeli military orders preventing Palestinians from cementing dirt water canals.

d - Israeli military orders preventing Palestinians from making any water conservation systems, such as laying of plastic agricultural pools, building earth water holding pools, or cement reservoirs, and any extensive system of water harvesting and earth damming.

e - Israeli military orders preventing Palestinians from implementing the water recharge operation itself, as this involves a change in the well status.

f - Israeli military orders preventing Palestinians from employing any Palestinian engineer and/or technician without an identity card in obvious economic development projects.

g - Israeli military orders preventing Palestinians from taking any actions toward having substantial funds enter the OPT or to be used except with their permission for already approved projects and from their "approved list " of donors.

h - Israeli military orders preventing Palestinians from making any community or group work on water spring development or fixing.

i - Israeli military orders preventing Palestinians from making any transaction for their own import, erection and use of any water equipment related to water withdrawal and distribution from wells or springs.

j - Israeli military orders preventing Palestinians from making any new irrigated orchards and planting any irrigated tree crops without permission.

Since any farmer or person or village committee or village council wanting to carry out any of the above activities must go to the Military Governor's District Office to submit an application and be questioned, Palestinians usually refrain from this step because :

a - each step in the process needs a separate and different permission thus making the application process lengthy;
b - having to deal with collaborators;
c - questioning on source of funds;
d - there are possible tax problems which the Israelis could open-up;
e - their own children being possibly involved with the Uprising (Intifada);
f - waiting to enter after body search and possible humiliation;
g - permission chances are slim and only after months or years of going back and forth;
h - funds cannot be constantly available during the various delays for the various steps of getting permission;
i- a Palestinian going back and forth for permission to the Israeli officer could become a questionable person in the eyes of the public, and
j - in general, farmers do not like dealing with the military, nor bureaucracy.

Lastly, the most severe constraint on any water resource development planning or project implementation is the lack of access to any technical and quantitative water resource data as Israeli military orders classify data about water as "Security".

8. IMPORTANCE OF APPLICATION OF GROUNDWATER RECHARGE TO THE WEST BANK and GAZA STRIP:

In conclusion, groundwater recharge as a method of insuring a more plentiful underground water supply is a well recognized and established method in many countries in the world and is used successfully in Israel. The concept of recharge and storage of water underground needs to be accepted by professional Palestinians and decision makers as a valuable method of water conservation. Use must be made of water runoff down the slopey hills of the West Bank by slowing it down by some means thus giving it a chance to recharge the local springs and underground water supply. (The dry springs in early summer and the decrease in the water pumped out per hour in most shallow wells of the West Bank is the result of excessive discharge down-dip in the aquifer which may be corrected by increasing recharge rates.)

Every possible means should be used to decrease water flow down the hillsides. Not only will hindering water flow prevent soil erosion, but it will also insure that more water will be recharged into the underground. To guarantee recharge of the useable water resources in the West Bank and Gaza Strip, every single ditch, hole and valley should be explored to determine if it could hold more water in the rainy winter season. By increasing the time span that water is kept on a ground surface, the local recharge in the area of the West Bank and Gaza Strip will raise the local water table levels. Furthermore, demonstrations should be made of recharging some existing wells near flowing springs and wadis under the supervision of hydrologists. The more recharge is done, the more the water is saved for the country.

Before a full scale underground recharge program can be initiated, a full hydrological examination of the West Bank and Gaza Strip must take place in order to pinpoint the areas in which recharging of aquifers can be carried out. Once this is accomplished, we can begin to do something concrete toward the conservation, preservation, and maintenance of Palestinian waters.

Recharge is a solution - not another problem - so why did we wait so long?

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POTENTIAL APPLICATIONS FOR DESALINATION IN THE AREA

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ABSTRACT

Four concrete projects which were examined recently in Israel and represent major potential applications for desalination in the area, are described. These projects are

1. Desalting up to 104 million cu. m. per year of marginally brackish waters from the coastal aquifer with combined nanofiltration and reverse osmosis plants. Product water cost will be 27-29 U.S. cents per cu. m.
2. Desalting 40-80 million cu. m. per year of sea water in hybrid reverse osmosis and low temperature multi-effect distillation plants, operating in a total energy scheme with their own independent steam turbine power stations. Product water cost will be 65-70 U.S. cents per cu. m.
3. Desalting 40 million cu. m. per year of sea water in a reverse osmosis plant using hydrostatic potential energy from a Mediterranean Sea - Dead Sea channel. Product water cost will be 55-67 cents per cu. m.
4. Desalting sea water with low temperature multi-effect distillation plants using low grade energy from solar ponds. Product water cost will be 80-116 U.S. cents per cu. m.

INTRODUCTION

Desalination has always been considered by water planners in Israel as a serious potential option for improving the quality and/or increasing the quantity of the country's limited water resources. During the nineteen-sixties it appeared that the competition between scientists and engineers from various countries, supported by their respective governments and/or commercial companies, to bring desalted water costs down through innovation and technical development, was bearing fruits. The gap between the cost of water from newly developed desalting technologies and the cost of water from new marginal natural water sources narrowed continuously.

The sharp rise in the price of oil in the nineteen-seventies and the soaring interest rates of the nineteen-eighties dampened, at least in Israel, all expectations that this gap would disappear in the foreseeable future. Desalination processes are energy and capital intensive, and the reality of the changed economic conditions in effect turned back the clock. Desalination, so to speak, was put on the "back burner". The only projects which materialized in Israel were relatively small local plants, in remote locations not reached by the national water grid.

The desalination industry, however, did not remain idle. Other, larger projects materialized in the world, particularly in the Middle-East, North Africa and the Caribbean Islands, where no alternative water sources existed or the alternatives were costlier. New technologies emerged which were more frugal energy and investment wise. These included the Low Temperature Multi-Effect Distillation (LT-MED) and Reverse Osmosis (RO) processes. LT-MED plants were fabricated from lower cost materials and were capable of utilizing, economically, low grade, low cost energy sources. RO plants utilized improved membranes, reduced operating pressures and incorporated energy-recovery turbines to reduce specific energy consumptions. Operating experience with these plants led to improved reliability, higher availabilities and lower operation and maintenance (O&M) costs. Designs for ever larger plants, modularization and standardization of equipment, led to economies of scale and lower specific investments for projects on a regional scale.

All these developments were watched closely in Israel. In fact, Israeli desalination industry contributed significantly to some of them and benefitted from its efforts through increased exports. Thus, when the country's water supply situation deteriorated over the past few years, due to a continuous drought and increased household and industrial demand, a serious reexamination of desalination options, with uptodate cost and performance figures began.

The objective of this paper is to present four actual projects proposed and studied as part of this government level reexamination of options. All four projects are on a scale large enough to have an impact on the regional water supply equation. One of them, at least, has as much to do with correcting a deteriorating water quality problem and conserving an important water source, as with adding new water.

APPLICABLE DESALINATION TECHNOLOGIES

The potential raw water sources for desalination in Israel have been divided into three groups, according to their salinity levels :

1. Marginally brackish waters, with a total dissolved solids (TDS) content of up to 1,250 parts per million (ppm).
2. Brackish waters with a TDS content between 1,250 and 10,000 ppm.
3. Sea water, with a TDS level of about 39,000 ppm in the

Mediterranean Sea and about 42,000 ppm in the Red Sea.

The processes most relevant today to marginally brackish waters desalination are Nanofiltration (NF) and Brackish Water Reverse Osmosis (BWRO). BWRO is also the most economical process for the higher salinity brackish waters. The processes suitable for large scale sea water desalination are Sea Water Reverse Osmosis (SWRO) and Low Temperature Multi-Effect Distillation (LT-MED).

It is assumed that most participants to this conference are familiar with these processes, but, for the benefit of those who are not, we will briefly describe their characteristics.

NF, BWRO and SWRO rely on pressure driven semi-permeable membranes to separate solutes from their solvent, and can be grouped together under the more general title of "Reverse Osmosis". In all plants utilizing these processes the saline feed is pumped across the membranes and part of it, with a small percentage of salt ions which have not been rejected by the membrane, permeates through the membranes. The difference between the processes is in their membranes' characteristics, particularly those which determine salt rejection and operating pressures. The third basic parameter which defines membrane performance, flux, i.e. permeate flow rate per unit membrane area, is normally kept in the same range of 0.5-0.9 m3/m2/day, to avoid concentrate polarization and membrane clogging with foulants.

NF membranes have good rejections (90-98%) for the larger bivalent salt ions, but only moderate rejections (45-70%) for the smaller monovalent ions. At recovery ratios (permeate to feed ratios) of 50-75% their permeate may not have a lower TDS level than the feed, but the hardness ions (which are bivalent - Ca, Mg, SO4) will be mostly rejected, as will all organics, color, bacterias, viruses and health hazardous contaminants, such as DHP and THM precursers. The product water will, thus, be softened and contaminant free.

The main advantage of NF is that it operates at pressures of only 3-10 bars and has, therefore, a low specific energy requirement of only 0.5-0.8 kwh/m3. The NF process has been called, therefore, also "Ultra Low Pressure RO".

NF plants have been most popular in Florida, for municipal water supplies where the raw feed is of low TDS content but high in hardness and DHP and/or THM contaminants. Softening and contaminant removal NF plants have become the second largest application of membrane processes [1].

BWRO membranes have typical rejections of 96-99% for all salts. Plants using polyamide or composite thin film (CTF) BWRO membranes operate at pressures of 15-17 bars, and are called "Low Pressure BWRO" plants. Plants using tri-cellulose acetate (TCA) membranes operate at 25-30 bars, and are referred to as "high pressure BWRO" plants. The specific energy requirements of BWRO plants range from 1.1 to 2.0 kwh/m3, depending on membrane choise, feed water concentration and plant recovery ratio.

NF and BWRO membrane and total plant costs are almost identical. In the large sized plants of interest for regional projects - above 30,000 m3/day - the specific investments in the plants are on the order of US$ 300-400 per m3/day capacity.

The growing use of NF and low pressure BWRO plants has raised the total number of membrane plants from about 100 plants with a total design capacity of 190,000 m3/day in 1985 to 150 plants with a total design capacity of 1,325,000 m3/day today [1].

SWRO plants require membranes with rejections of 99.6% and above. Operating pressures are in the range of 70-80 bars. Specific energy requirements in large plants which incorporate energy recovery turbines are on the order of 4.5-5.5 kwh/m3. Specific investments for large SWRO plants should be US$ 700-900 per m3/day capacity.

These low specific investment and energy requirement figures, and the positive operating experience accumulated with several large plants (the most important reference plants are in Malta, Jeddah and Las-Palmas) have led to increased use of SWRO for single purpose applications where electric power may be purchased. The recent development of better and larger SWRO membrane modules promises that this trend will continue.

LT-MED is a sea water distillation process which requires heat at only 55-70 degrees C and 0.9-1.2 kwh/m3 of power for liquid pumping. The heat input is recycled in the LT-MED system through repeated steps of evaporation and condensation, so that the latent heat of condensation in each step provides the latent heat for evaporation. Each recycle occurs in an "effect" at a lower temperature and pressure and contributes an additional quantity of product. The specific energy requirements with LT-MED plants depend, therefore, on the heat input temperature, the number of effects incorporated in the plant, and the temperature drop across each effect.

55-70 degrees C heat is low grade, low cost heat. If it is obtained from the thermal discharge of an industrial plant as "waste heat", its cost may even be negative (i.e. discharging the heat otherwise would have involved an expense). Solar and geothermal fields are other potential low grade heat sources. The most common sources, however, are electric generating plants, where the LT-MED plant can operate within "total energy" schemes. Typical specific heat requirements are then about 63 kcal/m3, at 72 degrees C, equivalent to 1.5-1.8 kg fuel/m3 [2]. Due to this low specific fuel consumption, LT-MED plants have been adopted increasingly in fuel importing countries which rely on desalination, e.g. the Caribbean Islands.

The specific investment in large LT-MED plants is US$ 900-1,000 per m3/day capacity.

These are the desalination technologies of choise today. Their economics, at current fossil fuel costs, in large plants of 30,000 m3/day and above, with the three potential raw feed water sources identified earlier, are summarized in Table 1.

Table 1
Desalination processes economics

Raw Water	Process	Specific Investment	Product Cost *
		US$/m3/day	US Cents/m3
Marginally brackish	NF	300-400	25-35
Brackish	BWRO	300-400	30-40
Sea water	LT-MED **	900-1,000	65-75
	SWRO	700-900	70-80

* Based on : Fossil fuel cost of US$ 105/ton
Plant lifetime - 25 years
Interest on investment - 7.5%

** Assuming : Operation in cogeneration with a large new steam turbine power station designed for back-pressure operation on a marginal cost basis.

With desalinated water costs being lowest with lower salinity raw waters, it is clear that as long as such raw water sources are available, and their pumping does not affect potable well water levels, availability and/or salinity (e.g. through sea water intrusion), they should be desalinated first.

It should be noted, though, that the above NF and BWRO water costs assume that brine disposal is not a problem. Should this not be the case, brine disposal costs for an inland BWRO plant could add another 9-15 US Cents/m3 [3].

The four specific projects described below provide a more accurate assessment of the actual costs which may be expected today for incremental water supplied through desalination. The projects' water costs are based on plants sized according to available quantities of feed, indicated water needs and/or special corollary benefits from the project, on anticipated raw feed water compositions, on best available energy sources, on optimized plant configurations, including, in two cases, a combination of processes, and on other real life variables.

Any long range analysis of these figures, however, should take into account that they utilize current fuel and power costs, and these could change over the life of the projects (25 years). Also, capital costs were based on 7.5% interest. One hopes that, given the international support for peace promoting regional water projects, lower cost financing will be made available.

PROJECT A -

Salinity measurements and salt balance calculations have shown that the salinity of the coastal plain aquifer in Israel is increasing steadily. The coastal aquifer extends over about 120 km along Israel's Mediterranean coast, from Mount Carmel in the north to the Gaza district in the south. Its width varies from 3-10 km in the north to 20 km in the south. Its natural replenishment rate is 300-330 million m3/yr [4].

The average chloride level in the aquifer today is about 180 ppm, but in many areas the level is in the range of 300 ppm. The current rate of increase in chlorides is about 2.2 ppm/year. This rate is expected to grow to 3.2 ppm/yr within a few years, when chlorides accumulating in the unsaturated layer above the aquifer starts reaching the saturated layer. At this projected rate, without corrective action, chloride concentration can reach an asymptotic value of 900 ppm. 400 ppm are generally accepted as the maximum allowable level [5] [6].

The main cause for the increase in aquifer salinity has been the curtailment of the natural salt removal mechanism through underground runoff to the sea. Overpumping during the past ten years has lowered aquifer levels to the point where underground runoff, which used to flush out tens of thousands of tons of salt per year, has almost ceased. Resuming runoff at the rate sufficient to restore the aquifer's quality means a sharp cutback in pumping to allow water levels to build up again, and, more significantly, the loss of 100-200 million m3/yr of low salinity runoff water.

Desalination plants, acting as "artificial kidneys", have been suggested as an alternative solution to the problem. The two important questions which remain unanswered are :

1. At which point - time and salinity levels - to start implementing such a desalination program; and
2. Which aquifer waters to desalinate and where to locate the desalination plants.

In the view of some economists, the investments in desalination should be postponed until the aquifer's salinity approaches the maximal allowable chloride level. The quantities of water to be desalinated to remove the excess salt would be then smaller, with unchanged unit costs. Many hydrologists, on the other hand, believe that such a postponement will create irreversible damage through excessive salination of parts of the aquifer and permanent loss of their storage capacity.

Some hydrologists advocate desalinating well water from saline pockets which exist near the eastern edge of the aquifer. This would reduce required plants size, but will present more acute brine disposal problems. Other hydrologists propose desalinating water from a line of shallow coastal wells, just east of the underground seawater interface. Such pumping would resume the westerly flow of all aquifer waters and the salt flushing process, and, as the desalination plants will reject only a fractional amount of concentrate, water losses to the sea and brine disposal costs will be minimal.

These questions still remain in contention. However, some figures which could at least serve as a basis for their resolution were provided in a study prepared recently by ADAN for the Israel Water Commissioner [7]. The study's main concern was reduction of salinity levels in municipal sewage. Most of the municipal sewage (75%) in Israel is treated and used for irrigation. High levels of chlorides in the recycled waste waters are harmful to some important crops. High levels of sodium damage certain soils. The study examined, therefore, among other solutions, the costs of desalinating large quantities of degraded coastal aquifer waters in NF and BWRO plants. The objective was to direct the product exclusively to municipal use. The desalinated water would have lower initial salt levels and its softness would reduce household and industrial salt additions from detergents and water softener regenerations. An added benefit would be the removal from municipal water supplies of all color, organic and other contaminants.

The conclusions of the study were that the best plant for this service would be a two stage NF-BWRO plant. The first stage NF section would desalinate the feed at low pressures, with a lower energy consumption than in an equivalent BWRO section. The NF section's recovery ratio will be limited to the point where the rise in the concentrate's osmotic pressure would reduce the pressure driving force to the lowest practical level. The BWRO section will desalinate the NF section's brine, using a booster pump, to the maximal recovery rate possible without scaling or fouling the membranes.

The rationale for this design can be seen in Table 2, which shows the performance of NF, BWRO and combined NF-BWRO plants with a worst case, high salinity, marginally brackish aquifer feed waters (400 ppm chlorides, 1,250 ppm TDS). The size of the plant was fixed by the required chlorides removal load calculated for the aquifer by the hydrologists's - 51,000 tons/yr [6]. This gave each plant a feed of about 130 million m3/yr. (Starting the desalination program at a chloride level of only 300 ppm would have required desalinating about 173 million m3/yr of feed, i.e. a 33% larger plant.)

A plant using NF membranes only will be able to operate with current aquifer waters (180-220 ppm chlorides, 500-600 ppm TDS) at a reasonable recovery ratio of 75%, and will have a low 0.6 kwh/m3 specific energy consumption. With marginally brackish feed, however, it must operate at a maximal recovery of only 50% to give a potable product. The product will be also soft and free of organics and health hazardous contaminants, but the larger pumping volume will reduce the benefit due to the NF's low operating pressure. Specific energy consumption will be 0.8

kwh/m3. Also, water losses and brine disposal costs with 50% concentrate reject will be higher.

A plant using BWRO membranes only will be able to operate at high recovery ratios, 75-85%, but its product water quality will exceeds requirements by a wide margin. It will be possible to use the high quality BWRO plant product for blending poorer quality waters, but this will reintroduce hardness and, possibly, contaminants. As soon as the aquifer's quality improves, let alone is restored, use of the BWRO plant will become unjustified (an "overkill").

The combined NF-BWRO plant will be suitable for all anticipated aquifer salinities, and will deliver a soft and pure product at a TDS which makes sense. It will operate at the same overall recovery rate as an all-BWRO membrane plant, but its energy consumption will be lower by about 25% . This could be significant in the future, should fuel and power costs rise. As noted in Table 2, the required investment in a 104 million m3/yr NF-BWRO plant will be US$ 125-165 million, and its product will cost US Cents 27-29/m3, excluding feed water costs. Chlorination and distribution costs will remain similar to those with current water sources.

According to ADAN's findings, municipal use of NF-BWRO plant water only will reduce the initial salt levels by 30-130 ppm chlorides, up to 105 ppm sodium, and 100-270 ppm TDS, depending on the specific municipality's present water supply quality. Salt addition due to reduced industrial and household softening requirements and detergent use will be reduced by 48 ppm chlorides, 47-51 ppm sodium, and 95-100 ppm TDS. Total recycled treated sewage salinity levels will drop, therefore, by 78-178 ppm chlorides, 52-156 ppm sodium, and 195-370 ppm TDS.

Table 2.
Desalination of marginal coastal aquifer well water

Plant	NF	BWRO	NF-BWRO
Raw water salinity - ppm			
Chlorides	350-400	350-400	350-400
TDS	1150-1250	1150-1250	1150-1250
Recovery rate - %	50	80	80
Sp. Energy Cons. - kwh/m3	0.8	1.2	0.95
Product salinity - ppm			
Chlorides	220-245	15-30	110-130
TDS	600-650	45-65	300-330
Capacities - million m3/yr			
Feed	130	130	130
Product	65	104	104
Brine	65	26	26
Investment - US$ million	60-80	125-165	125-165
Product cost* - US Cents/m3	25-27	29-31	27-29

* excluding feed and brine disposal costs

PROJECT B

Large scale sea water desalination along Israel's Mediterranean coast, where its major population centers exist, raw water is abundantly available and brine disposal will not be a problem, has always been considered as the ultimate solution to its water problems. Brackish waters, of a salinity suitable for BWRO plants and their economics (Table 1), are of limited supply. Recent surveys have identified a potential of only several million m3/yr which are not due to overpumping and sea water intrusion, and at sites where concentrate disposal costs will not be prohibitive.

The ideal locations for sea water desalination plants are alongside the country's large thermal power stations. These possess already the major infrastructure requirements, a large sea water intake, a brine outfall, and more importantly, are capable of providing adjacent thermal desalination plants with low cost, low pressure steam, after expansion in the station's turbine.

Almost all the large thermal desalination plants all over the world are, in fact, dual-purpose water and power stations, which rely on such a cogeneration scheme. As shown in Table 1, when such cogeneration is based on LT-MED plants, resultant water costs can be lower than SWRO water costs. Thus it was no surprise when the first proposals submitted recently to the Israeli government for large scale sea water desalination were based on combining huge LT-MED plants within the Israel Electric Corporation's (IEC) existing and planned power stations. An internal IEC study [8] showed that combining LT-MED plants with any existing 550 MW coal fired IEC unit, on a base load basis, could generate 65 million m3/yr of distilled water, at a cost of 84 US Cents/m3. The IEC analysis, however, used a high 12% interest rate for capital recovery and charged water production with energy costs at the external distributed price of power. When a more reasonable interest rate of 7.5% is used, and a realistic energy price based on in-station costs is charged, product water costs drop to about 70 US Cents/m3. Furthermore, if the LT-MED plants are combined with a new 550 MW station, designed initially for cogeneration, energy costs are reduced even further, giving a product cost of about 60 US Cents/m3. The IEC, however, was less than enthusiastic about the LT-MED-cogeneration proposals for various reasons, including its reluctance to tie down the operating regime and the loading of its stations to the operating requirements of adjunct desalination plants.

While these proposals were being studied and debated, ADAN Ltd. submitted its own proposal for an alternative approach. The ADAN concept was to build up the country's sea water desalination capacity in phases, with a series of smaller, independent plants, totally divorced from the IEC power generation system. These plants would have their own autonomous energy supply system, consisting of a back-pressure steam turbo-generator. The turbine will discharge its low pressure steam to an LT-MED plant, which will act as its condenser, and will supply its electric power to a SWRO plant. The benefits of a "total energy" scheme will thus be maintained, achieving an overall thermal efficiency of over 80%, based on the caloric value of the input fuel.

There are several other intrinsic technical and operational advantages to the proposed plant :

1. Non reliance on the existing power supply system, or any specific station within it.

   The plant will be connected, nonetheless, to the national grid, which will serve as a backup to its own steam turbine power. This will assure high availability to the plant's SWRO units, which supply 80% of total desalinated water output. On the other hand, the plant's power station will serve as a strategic backup to the regional grid. In case of emergency, or even during peak power demand hours, some or all of the SWRO units can be idled, making power available for export (at profitable peak load tariffs).

2. The coolant reject from the LT-MED unit, which will have been preheated by about 6 degrees C, will be used as feed to the SWRO units. SWRO membranes performance, in terms of flux and/or power consumption will be improved by about 15% as a result of this higher feed temperature.

3. The requirements on the SWRO membranes' permeate quality will be relaxed, to allow over 500 ppm TDS, since it will be mixed with the 20 ppm TDS distilled product from the LT-MED unit. This will enable extending the life of the membranes and reduce replacement costs.

4. If the systems are located adjacent to existing IEC power stations, though still remaining operationally independent from them, they can benefit from their infrastructure (sea water intake, etc.), saving about 10% in investment costs. The distilled product from the LT-MED plants can then be sold to the stations for boiler feed makeup.

Points 2 and 3 show that the proposed combination will bring out, synergetically, the features of both processes, better than had they been operated independently.

ADAN proposed its scheme based on a fixed modular plant design, to save in engineering and fabrication costs. The suggested minimal size of the module was 120,000 m3/day (40 million m3/yr) of total desalination plant capacity (SWRO and LT-MED), combined with a 25 MW steam turbine generator. Beyond this size economies of scale, begin to diminish, though larger modules, with larger power plants will benefit also from improved turbine efficiencies. If power is generated continuously also for export to the grid, even better efficiencies will be possible.

The investment required for putting up each 40 million m3/yr plant was calculated by ADAN as US$ 143 million. An 80 million m3/yr plant (with a 50 MW power station) would cost about US$ 270 million. Water costs for both sized plants, based on a fuel cost at plant limits of US$ 115 per ton, 25 years amortization and 9% average cost of capital, would be 65-70 US Cents/m3.

It is worth pointing out that the size and operating independence of the proposed plants make them amenable to privatization. In fact, an 80 million m3/yr project built around ADAN's concept has already been adopted by a group of private entrepreneurs. They proposed materializing the project on a BOOT basis (Build, Own, Operate and Transfer), with their own financial resources, at any site designated by the government, provided the government agreed to enter into long-range (25 years) water purchase agreements. This financing was, of course, costlier than that available through international development agencies, and this was reflected in offered water prices. Nevertheless, the readiness of the business community to invest in ventures based on this scheme is a vote of confidence in its soundness.

The most logical site for the first plant of this design would be the Gaza area. One plant in the south of the zone and one plant in the north, or one larger plant in the center could solve the acute water shortage in the area and, in the spirit of regional cooperation, also serve the western Negev and, maybe, also northern Sinai. Total water demand in the Gaza area is 85 million m3/yr, 35 million m3/yr for household use and 50 million m3/yr for agriculture. Natural water recharge is only 40 million m3/yr. The huge imbalance has resulted in a sharp drop in underground water levels and salination due to sea water intrusion. The real cost of potable water conveyed from the north to the south-western Negev has been estimated at over 35 US Cents/m3. This cost should be subtracted from the cost of desalted water to arrive at the real cost of desalination for the area. With low cost desalination plant financing, this real cost should be acceptable.

Asides from Gaza, a series of other plants can be erected, in sequence or in parallel, along the Mediterranean coast, starting with Ziqim, just south of Ashkelon. Ten such plants could provide most of Israel's urban population with all its water needs in 2010, 400 million m3/yr. The quality of this water will ensure the same health and water reuse advantages for as described for Project A.

PROJECT C

The plans to construct a Mediterranean to Dead Sea conduit to stabilize the receding level of the Dead Sea and to generate electric power utilizing the height difference, have raised the possibility of combining also a SWRO plant and benefitting from the same potential pressure difference.

The conduit project, including its desalination aspects, was examined in detail by the Israel Ministry of Energy and Infrastructure (MOEI). Though we do not believe that it will materialize in the near future, at least not as long as the current relatively low fuel prices persist, we felt it appropriate that we mention it, albeit briefly, in this conference. First because the product, generated 400 m below sea level, could best be utilized regionally, along the Jordan Valley, on both sides of the border. Also, the recent talk of an alternative Red Sea to Dead Sea conduit, as a possible regional joint Israeli-Jordanian project, seems to indicate that international support may be available to such a project.

The project, as conceived by the MOEI, would have part of the sea water diverted from the power generation turbines, which are destined anyway to operate only during peak electrical demand hours, to the SWRO plant. The plant's booster pump will pressurize the water from its available pressure of 41 bars to the 60 bars required by the SWRO plant. 120,000 m3/day (40 million m3/yr) of 400 ppm TDS product can be generated from the available flows. The required investment in such a plant has been estimated at about US$ 100 million. Desalinated water will cost 55 US Cents/m3, at the plant's battery limits, and 67 US$ Cents/m3 including product pumping to higher elevations.

PROJECT D

Sea water desalination utilizing non-polluting solar energy has always appeared, on the face of it, to be an ideal solution for the Middle-East. Climatic conditions in the region are conducive to solar heat collection, and the major water consuming population centers are located along the Mediterranean and Red Seas and the Persian-Arabian Gulf.

In a study prepared by ADAN for the Israel Ministry of Energy and Infrastructure [2], various potential combinations of solar collectors and desalination plants suitable for regional projects were examined. A 100,000 m3/day (33 million m3/yr) plant was taken as the reference size for comparison. The preferable system turned out to be the combination of a salinity gradient solar ponds and LT-MED. This was the only system that did not require fuel fired heat backup, and its unit water costs were lowest, 80-100 US Cents/m3, depending on interest rate and local site conditions. Land area requirements, at local insolations, were 40-50 m2/m3/day and overall specific investment was 1,700-2,000 US$/m3/day.

The actual costs for such a system on a smaller scale, 10,000 m3/day, have been determined recently through a concrete commercial offer from an Israeli company specializing in solar ponds to construct and operate such a plant near the Gulf of Eilat (Aqaba). With the solar insolation measured at Eilat, the required solar pond area was 600,000 m2, and total plant cost US$ 21 million. Water costs, within a BOOT contract, i.e. private financing and operation, were quoted at 1.16 US$/m3.

CONCLUSIONS

Desalination offers regional water planners viable options for improving the quality of existing water resources and for adding new marginal quantities of extra high quality water. Municipal use of the resultant desalination plants' product will improve the quality of municipal effluents and enable their ready reuse for irrigation.

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THE ROLE OF RECLAMATION AND REUSE IN ADDRESSING COMMUNITY WATER NEEDS IN ISRAEL AND THE WEST BANK

by

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"Shortage of water is perhaps the most crucial environmental and development problem in Israel" (Israel 1992). Recognizing this problem early, Israel has engaged in large scale water reclamation projects in the Tel Aviv and Haifa regions where about 80 and 30 million m^3 of wastewater, respectively, are annually reclaimed for irrigation of largely industrial crops. This practice releases equal amounts of the limited high quality fresh water resources of the region for urban use.

The purpose of this paper is to suggest that water reclamation and reuse be extended beyond solely agricultural irrigation to urban and industrial uses in communities throughout Israel and the West Bank. The reclamation of wastewater and its reuse for the myriad nonpotable purposes that can be met by water of less than potable quality has proven to be an environmentally and economically attractive option for addressing local and regional shortages throughout the United States. While such an approach might have been expected to be widely adopted in the arid and semi-arid areas of the southwestern region of the country, including California and Arizona, for example, it has found appeal in the water-rich regions of the southeast, as in Florida, and in the northwest. The U.S. Environmental Protection Agency has just published Guidelines for Water Reuse which illustrates, inter alia, water reclamation and reuse developments in the U.S. and other countries (CDM 1992). Examples of the practices described in this paper are to be found in the Guidelines.

The advantages of urban over agricultural reuse are:

- Many urban nonpotable water uses, such as toilet flushing, are nonconsumptive, so the water can be reused again.

- New freshwater supplies need to be carried longer and longer distances to serve urban areas because the more local sources have already been fully exploited, or even over-exploited, whereas reclaimed water is generated locally.

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- Because urban and industrial demands are not as seasonally variable as agricultural irrigation demands, seasonal reservoir storage requirements are sharply reduced, thereby reducing evaporative losses.

- The potential for pollution abatement through reclaiming wastewater is greater because urban reuse is not nearly as seasonal as reuse for agricultural irrigation.

- Water in urban use is far more valuable than in agricultural use; costs are more easily recovered than where water is used in agriculture, and they need not be subsidized.

Urban reuse often involves dual distribution systems, one system delivering water drawn from fresh water sources for potable uses and the other drawn from reclaimed wastewater for nonpotable uses. The growth of this practice is evidenced by the publication of a Manual of Practice for dual systems in 1983 (AWWA 1983), with an updated edition to be published in 1993.

Two objections nearly always arise when dual systems are proposed:

1. Cost. The visualization of two separate reticulation systems induces reactions that tend to dismiss their economic feasibility. However, where the marginal costs for additional water resources for a community are increasing, as they are almost everywhere, dual systems have often proven more economical, even in humid regions. In the Middle East, where the only alternative may be desalination, dual systems may be substantially less costly. While costs are much lower when dual systems in streets and dual plumbing in buildings are introduced during initial construction of settlements, retrofitting in existing communities has been found to be economically attractive in the U.S. in both the west and the east.

2. Cross-connections. Public health professionals cringe at the thought of two water systems under pressure, one potable and the other nonpotable, in the same street or in the same building. Structural safeguards are required to prevent cross-connections but, should a cross-connection occur, or should the nonpotable water be inadvertently ingested, there would be no infectious disease risk because the microbiological standards are much the same as for drinking water. The chronic diseases that dominate drinking water regulations in industrialized countries today result from the health risks of the long-term ingestion of chlorination byproducts or the trace concentrations of synthetic organic chemicals that originate in urban areas and industrial settings. These are of no concern where exposure is short-term.

The Development of Dual Systems

The principle for water reuse was established by the United Nations Economic and Social Council in 1958: "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade." (UN 1958) Many urban uses can be served by waters of a lower grade.

Water reclamation and nonpotable reuse developed differently in the United States and Japan, the two leading countries practicing urban reuse. In the U.S., the impetus in the southwest grew as a result of a need for additional water supply or to delay heavy investments in new water resources. The value of the reclaimed water was appreciated from the outset (Okun 1973). Services were metered and the unit prices ranged from 60 to 70 percent of the price of the potable water. Initially the major uses were for landscape irrigation but applications have extended to a myriad of other uses including toilet flushing in high-rise buildings in Irvine, California.

In Florida, in the southeastern U.S. with annual precipitation of about 1300 mm, urban irrigation was perceived initially as a lower cost method of wastewater disposal, being less costly than treatment for discharge into rivers and coastal waters. The reclaimed water services were unmetered and charges for the water were nominal. Today, however, the greater value of reclamation has been perceived as the conservation of water resources. The Southwest Florida Water Management District has adopted a rule which states that "Before a consumptive use permit (for water abstraction) is issued...if it is determined that the applicant can use a lower quality water (and) such water is available...the permit will be issued only for the lower quality water." (Southwest Florida 1985)

St. Petersburg, with the largest dual system in the U.S., is an example of these changes in approach. The city has been growing substantially, but the gradual introduction of a dual system beginning in 1977 has resulted in no increase in demand on the limited groundwater available to the city (CDM 1992). It is now beginning to retrofit meters and the many new dual systems in Florida incorporate metering at the outset.

Reuse developments in the U.S. that do not involve dual systems are exemplified by the delivery of Baltimore, Maryland secondary effluent in a 2.5-meter diameter pipeline to a nearby steel mill (Okun 1973) and the sale of all of the Phoenix, Arizona secondary effluent to the Palo Verde nuclear power installation for cooling. Agricultural applications are, of course, widespread.

In Japan, urban reuse initially began with dual plumbing in large buildings, where the reclamation facilities were in the buildings. As the need for reclaimed water grew, however, economics dictated the construction of municipal reclamation facilities. Their commitment to urban reuse can be characterized by a Tokyo regulation obligating all buildings with more than 10,000 square meters of floor space to use reclaimed water for toilet flushing (Murakami 1989).

The lessons from these experiences should be clear in the Middle East where multifamily residences and high rise buildings are the norm for future urban development and where significant water conservation can be achieved through water reclamation for landscape irrigation, cooling, toilet flushing and many other nonpotable uses.

Urban Uses of Reclaimed Water

Urban irrigation was the major application in early reuse projects in the U.S. In regions where irrigation is required to sustain greenery, reclaimed water was found to be a useful substitute for fresh water and, in the U.S., is the largest urban use today. (On the other hand in Japan, where dual systems are being introduced widely, urban irrigation is not a major use.) Parks, recreation fields, roadway boundaries and median strips, fountains and pools, public and private lawns, and garden nurseries are among the many landscaping uses now being served with reclaimed water. Reclaimed water is particularly attractive for urban irrigation because of its high nutrient content which promotes rich vegetation. Households, golf courses and other establishments eager to maintain greenery often contract for reclaimed water as insurance against being restricted in fresh water use during drought periods.

Cooling in thermal power plants and in air conditioning systems is another major use of reclaimed water. Cooling towers for power plants have often been the first major use in an urban area, providing the base load, prior to the construction of an urban reclaimed water distribution system. Air conditioning units in large buildings are commonly served from the distribution system.

Toilet flushing is a major nonconsumptive use which is particularly appropriate for commercial buildings, multifamily residential units and the like. Widely practiced in Japan, toilet flushing has just recently begun to be introduced in the U.S. It offers the very best potential for fresh water savings in communities such as those that characterize the new developments in Israel and the West Bank.

Cleansing of all types, including particularly vehicle washing, offers an attractive reuse application.

Construction and dust control in the Middle East generally, where cement is widely used, offers significant potential for conserving scarce fresh waters.

Garden crops grown commercially or for subsistence in and near communities can use reclaimed water effectively with far less health risk than where wastewaters are used directly.

Groundwater recharge, while not an urban reuse application, may be considered as part of water reuse management in urban areas. Recharge may be used to retard salt water intrusion and land subsidence resulting from excessive groundwater withdrawals. Depending upon aquifer configuration, recharge may provide quality enhancement. Recharge of reclaimed water into suitable aquifers provides better long term storage than is provided by surface storage which results in losses due to evaporation and quality deterioration. Abstractions of such groundwater for potable use is being practiced to a limited extent, but questions of public health risk from the long term ingestion of such waters have not yet been resolved. Restriction of reclaimed water drawn from underground storage to nonpotable use, namely agricultural, in Israel has certainly been the prudent course in the face of public health uncertainties.

Water Quality for Urban Reuse

Where only a single use for reclaimed water is envisaged, such as for irrigation of industrial crops or for cooling tower make-up, the quality requirements can be adapted to the use. For unrestricted nonpotable urban reuse, because of the potential exposure of large numbers of people in landscape irrigation, in industry, in toilet-flushing and in many other uses, a hazard must not be presented to people who might be exposed to the water or who might inadvertently ingest it. The oldest and most tested standards are those developed in California (California Administrative Code 1978), although some 22 other states now have their own (CDM 1992). There are no Federal standards in the U.S. The most important quality objective is that the water be adequately disinfected, so a chlorine residual should always be present in the distribution system. Also, the water must be clear, colorless and odorless or it would be aesthetically unacceptable. To achieve this quality, the water must have a low chlorine demand. Experience and research by the Los Angeles County Sanitation Districts at Pomona (Los Angeles County Sanitation Districts 1977) have demonstrated that a high quality secondary effluent, treated with small doses of coagulant and/or polymer, direct conventional sand filtration, and chlorine disinfection can easily and continuously provide a satisfactory product. Figure 1 shows a typical flow diagram.

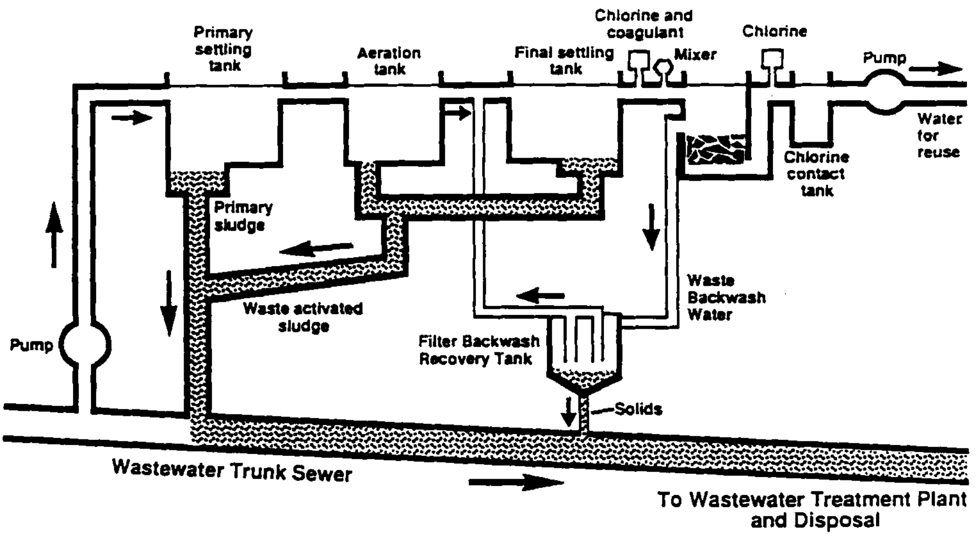

Figure 1. Typical Flow Diagram for Los Angeles County Sanitation Districts Reclamation Plant

Reclamation plants differ from treatment plants, which are intended only for disposal of effluent to receiving waters, in several ways:

- The location of the plant is influenced by potential markets for the reclaimed water rather than by disposal and receiving water requirements;

- The output is a salable product; continuous reliability of quantity and quality are important if customers are to be satisfied;

- Only that much water as needs to be reclaimed is treated at the reclamation plant, the rest going to another plant for treatment and disposal; and

- The sludge produced is not necessarily treated at the reclamation plant; it may be returned to the trunk sewer for treatment and disposal at the terminal plant.

Reclamation plants are designed for reliability with duplicate units, standby power sources, continuous monitoring of effluent turbidity and chlorine residual, as well as monitoring for chlorine residual on the distribution system. The design, operational and quality parameters that have been adopted in California are shown in Table 1 (California Department of Health Services 1988).

Current suggested guidelines, developed from comments and reviews of some 75 individuals drawn from local, state, national and international operational, regulating and educational agencies, are summarized in Table 2.

Where large users on a reclaimed water system may require water of higher quality as, for example, low phosphorus for cooling towers, low solids for boiler feedwater, low color for high quality paper making, the user is generally required to provide the additional treatment.

Application of Nonpotable Urban Reuse in the Middle East

Where reuse is contemplated, planning should be initiated at the earliest possible date because the location of the reclamation plants and the necessary sewerage systems with the interceptors, trunk sewers and outfalls would be substantially different from conventional practice. Ordinarily, wastewater treatment plants are located at the lowest points in the service areas to permit collection of as much of the wastewater by gravity as possible. If urban reuse is being planned, much of the market for the reclaimed water may well be at higher elevations, requiring that the reclaimed water be pumped back up. Location of the reclamation plants at higher elevations may be more economical.

Table 1

California Criteria for Reclamation for Urban Nonpotable Reuse*

(Basic process includes treatment of a high-quality secondary effluent by coagulant addition, mixing, filtration, and chlorination.)

Coagulant (e.g. alum, polymer)	Required unless effluent turbidity <5 NTU
Rapid mix	High-energy
Filter media	Anthracite - sand
Media, effective size	Anthracite 1.0-1.2 mm Sand 0.55-0.6 mm
Filter bed depth	0.92 m (3 ft)
Filter loading rate	12 m/hr (5 gpm/sf)
Chlorine residual	Minimum of 5 mg/L after 2 hrs
Chlorine contact time	2 hrs
Chlorine chamber	40:1 length to width or depth
Coliform bacteria, MPN	
7-day median	2.2/100 ml
maximum	23/100 ml
Filter effluent turbidity	
24-hr average	2 NTU

*Adapted from California Department of Health Services (1988). Also, sand alone can be used, of somewhat larger size but with greater bed depth. Coagulant choice and dosages and filtration rates are best determined by pilot studies.

Table 2

Guidelines for Unrestricted Urban Reuse*

Treatment:	Secondary (biological) wastewater treatment; $\leq$30 mg/L BOD_5 & SS. Filtration through natural undisturbed soils or filter media. Disinfection.
Quality:	pH = 6-9 BOD_5 $\leq$10 mg/L Turbidity (prior to disinfection) $\leq$2 NTU average Fecal coliform - not detectable in 100 ml (7-day median) $\leq$14/100 ml in any sample Total chlorine residual after 30 minutes $\geq$1 mg/L
Monitoring:	pH and BOD - weekly Turbidity and chlorine residual - continuous Coliform - daily
Other Requirements:	Clear, odorless and nontoxic; specific limits recommended for heavy metals and other constituents for irrigation uses; chlorine residual $\geq$0.5 mg/L in distribution system; specific recommendations for reliability

*Source: (CDM 1992)

The situations in Jerusalem, Haifa, the West Bank and Amman are not much different from Los Angeles and the many smaller communities in southern California. All are desperately short of water and water reclamation and nonpotable reuse is widely practiced in California. In the California situation, final disposal is to the ocean, with treatment plants located near the ocean outfalls. The markets for the reclaimed water are at much higher elevation inland. Accordingly, the wastewater to be reclaimed for urban reuse is often pumped from a trunk sewer, treated at an upland reclamation plant for distribution to users in the vicinity. Wastewater that is not reclaimed continues down the trunk sewer to the terminal plant for treatment and disposal. An important feature of this approach, as shown in Figure 1, is that the waste sludge produced in the reclamation plant is returned to the trunk sewer, to be treated and processed for disposal at the terminal plant. This means that the reclamation plant can be much smaller and need not be aesthetically offensive because sludge is not handled there. Many of the California reclamation plants are located in high-value residential areas.

This approach holds considerable promise for the Middle East generally, and for Jerusalem and the communities in Israel and the West Bank in particular. The substantial quantities of wastewater generated can be reclaimed at the high elevations for use there, with excess reclaimed water flowing by gravity to communities at lower elevations. A centerpiece would be a reclamation plant or plants in Jerusalem with smaller reclamation facilities at other communities in the region.

Several options are available and can be evaluated to minimize total capital and operating costs. One option would be to have Jerusalem and each community in the region reclaim its own wastewaters for use in its own service area. Another option would be to build regional reclamation plants to serve clusters of communities. A third would be to establish a reclaimed water system in the region in the fashion of the Dan project.

Whatever scheme is adopted, no distinction can or should be made between Jewish and Arab settlements in treatment of wastewaters or in allocation of fresh or reclaimed water. The very process of examining the options, including the responsibilities for construction, operation and maintenance, meter reading of potable and reclaimed water services, and management of excess wastewater would oblige cooperation in the common interest at the community level. Deliberations are apt to be much more fruitful where decisions are to be made in allocation of adequate resources than in allocation of water in the face of extreme scarcity.

Conclusion

Reclamation and nonpotable reuse, based upon experience elsewhere, offers promise of alleviating shortages in urban settlements in Israel and the West Bank. While this approach may not be adequate in the long term in the face of rapid urban growth rates in the region, it can provide resources pending the provision of other resources that will need to be developed for the future: import of water from the north and desalination. Furthermore, addressing water issues at the local level by Palestinians and Israelis together will lay the foundation for cooperation in the long term.

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Reuse of Waste Water for Irrigation in the West Bank: Some Aspects

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Abstract

West Bank considered to be semi Arid Region, since the average rainfall is 500 mm. Rainfall is the main source of recharging the aquifers where water can be obtained mainly from ground water for both irrigation and domestic use. Attention should be paid to irrigation since a great percentage of citrus, vegetables, and others are produced from irrigated agriculture.

In all cities and villages sewage water is either collected and discharged to the wadi, resulted in dangerous environmental problem through the seepage of this not treated sewage to the ground water or being a source of insects and bacteria. Only few major cities are supplied with sewage collection, and other few cities are implementing sewage collection now. There is only one waste water treatment in Ramallah city operated from 1975.

Due to the absence of sewage treatment there is a ground water pollution mentioned in three areas, even some diseases (skin rash) have been appeared due to this pollution. Further pollution might appear clearly (diseases) in the near future. Waste treatment should be for minimizing ground water pollution and eliminated other environmental problem. Furthermore, this waste treatment can be used to irrigate restricted crops such as alfalfa.

The total water that can be saved from major cities for irrigation purposes is 8 M.C.M.,/year which can irrigate 12,000 dunums. Where this 12,000 can be increased to more than 15,000 dunums by implementing storage reservoir. This 15,000 dunums represent %13 of all irrigated land in West Bank.

Introduction

The West Bank is considered to be a semi-arid region. Rain fall is the main source of water which recharges the ground water, and the ground water is the main source of water for both agricultural and domestic use. In the West Bank, the irrigated area does not exceed 110,000 dunums (5%) from all the cultivated area, while in Israel, the irrigated area reached 44% (See Table No. (I.) One-sixth of the cultivated area in the world is under irrigation which produces half of the whole world food.

Table (1)

Basic land and water indicators for Israel and the occupied Palestinian and other Arab territories

(1 dunum + 1,000 m²)

	West Bank	Gaza Strip	Israel
Total area (dunums)	5,573,000	360,000	20,000,000
Population (1988)	900,000	600,000	4,300,000
Area of land cultivated (dunums)	2,100,000	214,000	4,250,000
Area of land irrigated (dunums)	110,000	120,000	1,850,000
Percentage of total land cultivated	38	59	21
Percentage of total land irrigated	5	56	44
Annual water consumption for irrigation (million m^3)	95	80	1,320
Annual water consumption for households (million m^3)	27	21	325
Annual water consuption for industry (million m^3)	3	2	125
Total annual water consumption (million m^3)	125	103	1,770
Total per capita water consumption (m3)	139	172	411
Per capita water consumption per household (m^3)	30	35	75
Per capita water consumption for industry (m^3)	3.3	3.3	29
Per capita water consumption for irrigation	106	133	307

Source: Israeli land and water policies and practices in the occupied Palestinian and Arab territories, unpublished study in Arabic (Economic and Social Commission for Western Asia, Baghdad, 1990), p.8.

Therefore, efforts should be made to increase the irrigated area in the West Bank for its positive impact on the national income.

There is a vast area in the West Bank planted only in the winter season as rainfed crops due to the lack of water. (For example, there are more than 15,000 dunums in Al Auja left annually without planting due to the lack of water.) There are a number of solutions that can be adopted to increase the water for both agricultural and domestic use and among these solutions is the recycling of waste water.

1. WASTE WATER TREATMENT AND REUSE

It has to be clear that waste water treatment is a must, since now all of this waste water flows into the wadis and then infiltrates down to the ground water aquifers which can or will pollute this ground water. If this happens, everyone will lose the main source of water in the area, and regrets will not help anything.

While the flows of treated waste water cannot be a problem, yet before treatment this waste water should be collected and treated, but unfortunately most of West Bank cities and all villages, lack a sewage system which is clear in Table Number 2. Furthermore, running water in dwellings exists only in 62% of the households in the West Bank. (World Bank).

2. WASTE WATER PROBLEMS IN THE WEST BANK

There is only one waste water treatment plant in the West Bank which is located in Ramallah and owned by Ramallah Municipality. This treatment plant was established in 1975 and this treated waste water flows freely to the wadi. In all the remaining cities in the West Bank, the waste water is collected and flows into wadis which then infiltrates in the West Bank down to the ground water along with all of its content of bacteria and virus resulting in dangerous environmental health problems. This scenario even takes place if the sewage collection system is through sewer pipes or in pits, an example of this is:

2 a. Zbeidat Village (North of Jericho):

The village is located 30km north of Jericho. The total population of this village is 1000. The villagers depend totally on irrigated agriculture. The amount of irrigated area used by the villagers is 600 dunums, while the number of dunums that could be irrigated and planted is 2000 dunums. Prior to 1967 2000 dunums were irrigated depending on water from the Jordan River. Now they are limited to 600 dunums due to two reasons:

1. Some of this land is closed by military action.
2. The villagers are prohibited to take water from the Jordan River.

This village is the only village among the few villages in the

Table (2)

MAJOR CITIES POPULATION IN WEST BANK AND THE AMOUNT OF WATER THAT CAN BE REUSED AND NO. OF DUNUMS THAT CAN BE IRRIGATED

City	Population Thousand	Water consumption $1000m^3$/month	%of sewage average available	Amount of water that can be reused for irrigation $1000m^3$/month	No. of dunums that can be irrigated
-Nablus	64	156	100	122	618
-Hebron	73	167	75	140	2333
-Bethlehem	27	64	100 (x)	51	850
-Beit Sahour	12	28.8	100 (x)	24	400
-Ayda Camp	4	6	100 (x)	5	83
-Jenin	16	39	25	30	500
-Tubas	10	24	0	18	300
-El-Bireh	30	72	70	57	1000
-Am'ary Camp	5.5	8	100 (x)	6.5	110
-Bitunia	8	19	-	15	250
-Deir Dibwan	6	14	-	11	183
-Ramallah	22	52	100	41	683
-Tulkarem	22	52	55	41	683
-Tulkarem Camp	12	19	0	15	250
-Askar Camp	10	15	100 (x)	12	200
-Balata Camp	16	24	100 (x)	18	300
-Halhul	12	28	0	24	400
Total	368.5				11117

(x) means that the sewage system is now under implementation and it is expected to finish the work by 1996. Source Author based on Center of Engineering and Planning.

Jordan Valley that depends on its existing ground water wells for domestic use. Chlorinated water reaches most of other villages in the Jordan Valley by pipeline from Mokerot. So there are no mentioned diseases or water pollution because people do not use that water for domestic use, since all of the waste water from Al Bireh city and Ama'ari Camp and other villages is flowed toward the east (Jericho). So pollution of ground water might exist but symptoms might not appear clearly since the laboratory tests of ground water in Jericho proved that there is contamination . Example: Number of fecal coliform per 100ml is 20 and in some cases is 30.

The people of this village depend totally on the ground water well that is located in the center of the village for both domestic and agricultural use. All of the village houses are supplied with sewage pits which are located near the well. The village people started to use this well water for domestic use since March 1990 and only three months later the people started to suffer from a skin rash (irritation). The laboratory tests proved that the cause of this disease (skin rash) is due to the polluted water from the well. Still the problem is growing and the people cannot find any water source for domestic use. We are worried that this water will become dangerous for agricultural use too since, unfortunately, the main crop that is planted in the area is tomatoes.

2 b. Irtas Village (Bethlehem Region):

The inhabitants of this village totally depend on the existing spring for both domestic and agricultural consumption. The spring is located in the center of the village which is located on a hill. All of the village houses are supplied with sewage pits and so the waste water can easily flow and penetrate down to the ground water aquifers with all its content resulted in dangerous environmental and health problems. Last year, the solid waste could be easily seen with the water and this spring water is completely contaminated. This results in bringing the village people of a dangerous situation since they are using this spring water for domestic use, and now unfortunately they cannot use this spring water for domestic use.

Now the village people are looking for another suitable source for domestic use which is going to be very difficult for them to find. The village leaders have reportedly requested from the military authorities to hook into the Bethlehem piped water system, but they are always turned down.

2 c. Sinjel Village (Ramallah Region):

Again the laboratory tests proved that this spring water is polluted from sewage water and this spring water becomes no more useful for domestic use.

The topography of the West Bank and the presence of mountains, wadis and hills promote the infiltration of this waste water from both pits and sewage system down to the ground water aquifers. Unfortunately, most of this waste water will flow toward the east (Jericho, Jordan Valley), where the ground water wells' depth is in the range of 80 meters and the percentage of ground water wells in Jericho represent about 30 percent of all ground water wells.

3. WASTE WATER TREATMENT AND REUSE FOR IRRIGATION PURPOSES

The idea of waste water treatment and reuse was known long time ago. Example, treated waste water was used for irrigation in Paris in 1868 and in Berlin in 1910, the total quantity of treated sewage water in Paris was 31,000 cubic meter per day. World Bank reports show that 80 percent of the waste water of cities in developed countries is recycled for both seasonal and permanent irrigation. In the West Bank, the first sewage treatment plant was constructed in Ramallah in 1975. The use of raw sewage water for irrigation was known in Silwan village and other areas since the 1930's. Diseases have been spread as a result of this practice, such as typhoid but unfortunately the raw sewage is still being used in different places in the West Bank.

4. BENEFITS OF WASTE WATER TREATMENT

1. To get rid of the waste water which would become a source of insects.
2. To eliminate ground water and surface water pollution.
3. To reduce environmental problems and health hazards.
4. To conserve the soil and the land where the raw sewage used to flow over.
5. To get rid of most micro organisms such as bacteria and viruses from this waste water.

Waste water is considered to be a natural source so we have to take care of it since it is considered as a sword of two sides, if we cannot make use of it to our benefit it will be against us.

5. THE BENEFIT OF WASTE WATER TREATMENT FOR RECYCLING FOR IRRIGATION PURPOSES

1. To get rid of bacteria, helminth and viruses.
2. To keep natural aeration to eliminate bad odor.
3. To ensure that nutrients essential for plant still exist.
4. To get rid of suspended solids to avoid clogging problems of irrigation systems.
5. To keep oxygen content which is required for plants.

Health problems can be eliminated from using treated waste water for irrigation if the followings are achieved.

1. The quality of the water should be appropriate for the type of the crop to be planted according to WHO standards.
2. To restrict usage on planting fodder crops (restricted crops).
3. The right irrigation system should be used. For example, sprinkler system should not be used in order to avoid direct

contact of water and crops.
4. Not to grow any crop to be eaten raw such as tomatoes and cucumbers.
5. Monitoring the treatment plant to ensure good water flow. 6. All workers and farmers should cooperate and understand that this water is waste water and they should wear proper clothing and receive proper vaccinations.
7. Irrigation using waste water should be stopped two weeks before harvesting.
8. A special warning sign should be placed in the farms to indicate that the irrigation water is waste water.

6. THE ECONOMICAL BENEFITS OF WASTE WATER FOR AGRICULTURE

Here I would like to state that recycling of waste water for irrigation is feasibly economical and I do not want anyone to misunderstand that this project is considered as income generator project.

Sewage water contains a great quantity of important nutrients and the estimated content of these nutrients in waste water is as follows:
1. Nitrogen 40 grams per cubic meter.
2. Phosphorus 10 grams per cubic meter.
3. Potassium 30 grams per cubic meter (Shuvall).

So if 1000 cubic meter of waste water is added to the irrigated area in one year, the total nutrients added to that land are as follows:
1. N 40 kg/per dunum per year.
2. P 10 kg/per dunum per year.
3. K 30 kg/per dunum per year.

It is well known that the fertilizers required per dunums are very close to this quantity, so a lot of projects that are irrigated by treated waste water will not need fertilization. There are studies which prove that crops can grow economically without additional fertilizers when irrigated with waste water.

The economical benefit of this treated waste water can be calculated as follows:

6a.

Saving the cost of fertilizers. Assuming that the nutrients (NPK) content in the waste water is equal to half of which is required in fertilizers for agriculture. The cost of the nutrients of 25 kg. as fertilizer of content 20-20-20 NPK is \$20; so the cost of 1 kg. of fertilizer is \$1.2. (Out of 25 kg. of fertilizer, 15 kg. is as main nutrients.
The cost of N fertilizer = 40 x 1.2 = \$48 per dunum/year.
The cost of P fertilizer = 10 x 1.2 = \$12 per dunum/year.
The cost of K fertilizer = 30 x 1.2 = \$36 per dunum/year.
Total = \$96 per dunum per year.

The cost estimate of NPK fertilizers present in waste water is therefore approximately \$50 per dunum since the cost of fertilizer application was not included in the above calculations.

A project like Al Bireh city, the number of irrigated dunums that can be benefited from this project is 1000 dunums, the saving will be estimated to be $50,000 per year. So for 20 years, this saving will amount to one million Dollars.

A total number of dunums that can be irrigated from recycling the waste water from 17 major cities and camps in the West Bank is equal to 11,117 dunums. See Table 2. This is based on the assumption that only fodder crops and others such as Jojoba be planted and the required amount of water per dunum is 60 m3/monthly where the average amount of water required by vegetables per dunum is 120 m3 per dunum. This amount represents 9% of all irrigated dunums in the West Bank. Furthermore, storage reservoirs can be constructed to store this waste water and rainfall water which increase the number of irrigated dunums to 15,000 at minimum. While the estimated number of dunums that can be irrigated from treated waste water from the whole West Bank is 44,000 dunums. The following points must be remembered: 1. Running water in dwellings does not exist in most villages.

2. Sewage collection still does not exist in most cities and all villages. The cost of implementing the sewage collection is very high and considered to be a limiting factor which is estimated to be in the range of $150 per capita.

3. Assume that all West Bank waste water has been recycled and 44,000 dunums of land is brought under irrigation, the 44,000 dunums still cannot be considered to be a big achievement in increasing the irrigated area because the total area that is available for irrigation is 535,000 dunums. See Table 3.

Table (3)
NO. OF DUNUMS THAT CAN BE IRRIGATED AND THEIR DISTRIBUTION IN THE WEST BANK

Location	Dunum
- Plains in Jenin & Tulkarem	99,600
- Mountain area	277,400
- Eastern slopes	64,600
- Jordan Valley	93,500
Total	535,100

Source: Awartani, H. and Jowdah, S.

6b. Saving the Cost of Water for Irrigation:
The cost of fresh water for irrigation is equal to $ .25 per cubic meter while the estimated cost of this treated waste water is equal to $.18. The saving will be $ .07 per cubic meter. For example, in the Al Bireh project, there will be 57,000 cubic meter per month of treated waste water. The amount of saving the cost of water estimated to be equal $ 51,860 per year and over a 20 year period this will be equal $ 1,037,200.

6c.
Another economical benefit is the additional profit that can

be gained from bringing new land under irrigation. The net average profit from rainfed land per dunum is $100 per year, while the net average benefit from irrigated dunums is $200 per dunum per year. The difference of $100 is due to irrigation. So 1000 dunums equal $100,000 additional income per year. This is estimated to be two million dollars per twenty years.

The estimated total additional income of 1000 dunums per 20 years is $ 4.03 million Dollars.

The economical benefit of recycling the projects can be summarized as follows:

1. Saving the cost of agricultural inputs (water and fertilizers).
2. Increase the productivity of agricultural land.
3. Job creation.

7. THE INITIAL ESTIMATED COST OF PROJECT INPLEMENTATION

It is known that for this project the construction of an appropriate treatment of plant is a must, as well as pipelines to carry this treated waste water from the treatment plant to the designated irrigation area. Furthermore, the construction of storage reservoirs will be of a great help to improve the quality of water as well as to store rainfall water.

The estimated cost of treatment plants depends on the type of treatment plants to be adopted. During the last two years since we have seen engaged in preparing feasibility studies for the Al Bireh recycling project, here is some information:

1. Population of Al Bireh is 30,000.

Yearly water consumption is 684,000 cubic meters.

Total water consumption of Al Bireh, Amari camp, and other governmental buildings to be benefited from this waste water treatment plant - 1,000,000 cubic meter.

Due to the existing topography (narrow wadis), waste stabilization ponds have been excluded. So three alternatives were to be discussed:

a. Extended aeration. Estimated cost $3.8 million Dollars.

b. Imohoff tank and biological filter. Estimated cost $4.3 million Dollars.

c. Aerated lagoons. Estimated cost $ 2.5 Million.

Waste stabilization ponds. Estimated cost $.7 million.

It is clear that waste stabilization ponds can be applied easily in other West Bank cities, while the selection among these plants depend on different issues such as quality of the effluent, operation and maintenance cost and others. Let us suppose that these four plants will be distributed among West Bank equally. The average cost of this treatment plant will be $ 2.8 million Dollars. The population of Al Bireh with Al Amari camp is 35,000 so the estimated cost of treatment plant per person equals to $80. If we also include the costs of excavation, electricity connection, and engineering, this will be equal to $100 per capita.

The estimated total cost of constructing treatment plants including the electricity connection and excavation will be $100 x 367,000 = $36700000, for these major cities mentioned in table number 2.

In addition, the capital cost of pipeline and storage reservoirs is estimated to be $20 million Dollars. So the total estimated cost will be at least 56 million U.S. Dollars. It should be mentioned that in some cities like Nablus, two treatment plants are needed and the total length of pipeline to the irrigated area is about 70 km., so the 56 million dollars is a rough estimation.

8. STRUCTURAL ORGANIZATION NEEDED

Reuse of treated waste water for irrigation is new in the West Bank, even waste water treatment is new. An organization or institution should be established in order to manage this program. This institution should have the following components:-

1. Public health division.
2. Environmental engineering.
3. Irrigation engineering.
4. Civil engineering.
5. Mechanical and electrical engineering.
6. Agronomist.
7. Business administration.

This institution could be based in Ramallah, since Ramallah is located in the center of the West Bank, while two branches can be established one in the north and one in the south. This institution should be a branch of the water department in the West Bank, so the running cost of this institution can be minimized. The responsibilities of this institution can be summarized as follows:

1. Responsible for constructing the appropriate waste water treatment plants in the designated cities in collaboration with local municipal engineers.
2. Responsible for constructing the appropriate reservoirs in connection with waste water treatment plants at the appropriate sites.
3. Designation and supervision of the areas to be irrigated by this treated waste water.
4. Monitoring, operating and maintaining waste water treatment plants and the irrigation schemes.
5. Selection of the type of crops to be irrigated from each specific treatment plant, according to the following guidelines:-
   a. The performance of the respective treatment.
   b. The quality of the effluent.
   c. The environment of the area, such as climate, temperature, topography, wind, humidity and soil type (including underlying aquifers).
6. Monitoring the agricultural products by applying regular laboratory tests to ensure that there is no contamination of these crops.
7. Regular monitoring of farmers and workers to ensure their

health.
8. Monitoring the quality of treated waste water to ensure that this water is safe for agricultural purposes.
9. To conduct training programs for both farmers and workers and engineers.
10. To conduct extension program for both consumers and farmers.

Note: Most of these above tasks are required even now without the existence of recycling projects in order to monitor water for both domestic and agriculture use as well as agricultural products.

9. CONCLUSION

The following can be concluded:
1. Most West Bank waste-water is flowing over the ground surface in the wadis and freely percolates down to the ground water aquifers. Furthermore, this waste water will interact with surface water which result in dangerous environmental hazards as well as eliminate the usage of this water. In the long run most of West Bank aquifers will be polluted where this ground water cannot be used easily and safely. Since the topography of the West Bank facilitates the infiltration of waste water down to the aquifers, so treatment of waste water is a must.
2. Waste water treatment plants can be constructed easily and the main constraint is the capital cost to be allocated for that purpose.
3. Qualified staff to run and monitor these recycling projects are available and there is enough land to be irrigated from these projects.
4. Since this waste water is treated, recycling of this water can be achieved easily and cheaply which will play a big role in increasing the availability of water for both domestic and agricultural use.
5. Recycling of treated waste water for irrigation purposes seems to be economically feasible.
6. The total number of dunums that can be irrigated from this treated waste water from these major cities is estimated to be 15,000 dunums. (with implementing reservoirs).
7. The total annual water that can be available from treating waste water estimated to be 8 M.C.M. from the major cities.
8. The cost of constructing treatment plants for these major cities estimated to be $36 million (excluding pipeline and implementing reservoirs).
9. The total number of dunums that can be irrigated from treated waste water is estimated to be only 44,000 dunums, with the availability of reservoirs, while the total area that could be irrigated but lack a water supply is estimated to be about 535,000 dunums. Thus waste water recycling for irrigation purposes will only benefit about 9% of the available land for irrigated agriculture.
10. Some West Bank cities and all the West Bank villages lack sewage collection pipes.

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Fossil water under the deserts of the Middle East: A safeguard against strife

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Abstract

While the demand for water in the Middle East grows as the population continues to expand and demands more food, there are more articles in newspapers and journals forecasting that this discordance between need and supply will be the cause for the coming war. Experts advise that a solution to the conflicts, regarding water resources, must be found before the nations of this region will turn to arms as a solution to the disagreements between them regarding the rights to utilize these depleting resources.

The present shortage may even become worse once the forecasts predicting a "warm world" come true. The semi-arid parts of the northern belt of the deserts of the Middle East will become more yellow rather than green if the "Greenhouse Effect" materializes.

Below all the Middle Eastern countries bordering the Saharo-Arabian deserts, extend thick layers of sandstone that contain thousands of billions of cubic meters of water. One can visualize it as a tremendous sponge, made up of sandstone, saturated with water. The water under many areas is fresh and good, under others brackish and even salty. Under some areas it is at a shallow depth, under some areas deep drilling is needed to tap the water bearing layers, and in some areas it comes up to the surface and flows as artesian wells or springs.

It is, thus, suggested to create a think-tank within the already existing Water Resources Center of the Jacob Blaustein Institute for Desert Research belonging to the Ben-Gurion University of the Negev. This think-tank would come up with solutions based on the development of the resources under the deserts. This think-tank will be comprised of a group of experts who will investigate the problems and alternative solutions.

INTRODUCTION

There is a growing gap between demand and supply of water resources in the Middle East. This has recently caused conflicts between the countries of the region on the questions of sharing common water resources. Experts in the field of political sciences advise that a solution to these conflicts must be found before the nations of this region begin using arms to solve disagreements on the rights to utilize these depleting resources [1]. The present shortage may even worsen, once the forecasts for a "warm world" become fact. The semi-arid parts of the northern belt of the deserts of the Middle East will become even more yellow rather than green if the "Greenhouse Effect" materializes.

Most articles currently published refer to a shortage in surface water, namely water flowing in the rivers and streams. A few articles also touch on problems concerning over exploitation of ground water. Very few touch on the water contained in regional aquifers extending under all the Middle Eastern countries bordering the Saharo-Arabian deserts. These aquifers are composed of thick layers of sandstone, (referred to as The Nubian Sandstone or *Continental Intercalaire*) and contain thousands of billions of cubic meters of water. One can visualize it as a tremendous sponge, made up of porous rocks and saturated with water. Under many areas the water is fresh while under other areas brackish and even salty. Under some areas it is located at shallow depths and other areas deep drilling is required in order to tap these water bearing layers and in some areas it comes to the surface as artesian wells or springs.

This water infiltrated and accumulated in the subsurface tens to a few thousands of years ago, when high latitude areas of the globe were covered by glaciers, and the low latitude deserts enjoyed more rains, turning the deserts into huge savannas in which wildlife and man prospered [2-6].

Many countries have already started using this water. Libya has tried but failed. Potential settlers, whose income was guaranteed in greener areas, have been reluctant to immigrate and settle in new regions to grow conventional crops that have been subsidized. The alternative solution is a tremendous system of wells, pumps and pipes that brings water to coastal areas. It is undoubtedly a daring technological enterprise. Whether it can also be regarded as a sound economic solution is still dubious [3, 7].

The Egyptian Government initiated "The New Valley Project". Its success is murky. Salt marshes have encroached upon the sown land due to the failure of the Egyptian *fellah* to adapt to a new environment and use different methods than what they were accustomed to in the Nile Valley.

In the Arava Valley in Israel, which extends from the Dead to the Red Seas, this resource is utilized by irrigating summer crops in winter, such as melons, tomatoes and flowers. The farmers in some places utilize the natural warmth of the water to warm the inside of the plastic tunnels in which the plants are grown. These crops are then exported to markets in Europe. In some areas salinization of soils due to over irrigation can be observed. The Dead Sea Works and the Phosphate Mining Company also benefit from this water for product processing.

Above the sandstone aquifers containing fossil water in many regions one finds limestone aquifers containing semi-fossil water. The age of this water is in the order of magnitude of a few thousands of years. Salinity ranges from fresh to brackish. In most cases the part containing fresh water is replenished annually. The storage capacity of these aquifers is enormous, to the effect that new contemporary water replenishing these aquifers does not change the average ancient age of the water. A case study of such an aquifer, which will be discussed in the present paper, is that of the Judea limestone aquifer found under central and southern Israel.

The water from fossil and semi-fossil aquifers as an economic asset

The first question to be raised when this resource is suggested as a remedy for water shortage problems is: How can people depend on a vital resource which is not going to last forever? The answer to this question is: water for irrigation and industry is not a vital resource but an economic asset, such as oil, coal, iron, etc., all of which are non-replenishable. Water is a vital resource, namely for drinking purposes. It must be guaranteed either by storage of rainwater or by partial desalination, such as reverse osmosis. The source of water used for desalinization processes will be saline water found under, and in the vicinity of, most fossil aquifers containing more fresh water. Saline water will replace fresh water when this is totally pumped out, hundreds of years to come. Until this happens, agriculture and the economy of these regions should develop a system (if wisely planned and executed) which would be able to afford the cost of utilizing partially desalinized water.

Fossil and semi-fossil water should be regarded as any other non-replenishable resource, namely its evaluation should be carried out on the basis of economic considerations. Once its development is found feasible, its exploitation should be implemented by use of a long-term management plan. This should be similar to any adequately planned mining project which is carried out [8,9].

This approach to use fossil water in particular, and to water resources as an economic asset, may confer a more practical approach towards the problems concerning water in the Middle East. This may replace the fateful approach characterizing past and present dealings with this resource. Although utilized for millennia for the purpose of irrigation, water in this region for irrigation of field crops is not regarded as something which should require a price. Crops are still evaluated per area. The amount or cost of water required for growing these crops should not be taken into consideration. This attitude is, and will be, a tremendous obstacle when new resources will have to be developed, taking into consideration that sooner or later new projects have to become cost effective. New investments will be available only when people of the Middle East begin to regard water as an economic asset, having a cost and price similar to oil, fertilizer, etc., which has to be paid for when one wishes to receive or use it.

This line of thought requires a new attitude towards farming which is not the traditional routine one has to adhere to, but a field of innovation and competition. This will call for a drastic change in the education system, giving the farmer better knowledge of modern methods and irrigation systems. As a matter of fact, it calls for the adoption of a new, modern way of life. A modern attitude towards life may even help in mastering the largest menace threatening traditional society, namely the population explosion; accelerating, on a logarithmic scale, the failure of supply relative to demand. If such a change takes place, these prospects are evolutionary and thus frightening to the conservative part of the population and their fundamentalist leaders. They are aware of the possibility that once this water is utilized, with all the innovations it calls for, it can serve as a triggering factor for introducing new methods, ideas, and a way of life for promoting evolutionary processes which would most likely cause a change in the way traditional society lives.

As water becomes more and more scarce due to the perpetual rise in demand, one can predict that the fossil and semi-fossil groundwater resources hidden under the deserts will be utilized in all countries under which they are found. If this occurs while wasteful, conventional methods of irrigation are applied, this treasure of water will be wasted and the soils will be destroyed by salinization. Moreover, in due time this will cause more strife in the region. Pumping on one side of the border of a certain country will deplete this resource on the other side. For example, the regional depression cone in the Kufra basin of Libya may transverse in a few decades between the border of Libya and Egypt. The same will happen along the borders of the Sinai and Negev deserts, Jordan and Syria, Israel and Jordan, and other countries as well. On the other hand, if this water is economically utilized as a result of the application of advanced methods of irrigation and cultivation, the existing and future resources may last many additional years, enabling a gradual shift into a modern economy less dependent on agriculture.

Another positive and economic aspect of groundwater resources in arid and semi-arid zones, in contrast to ephemeral surface water, is that the first contains a storage factor which makes groundwater less dependent on short term fluctuations in precipitation. In other words, it helps to render a more deterministic character to the water supply system otherwise stochastic. When it comes to fossil and semi-fossil water factors, the storage factor is even more prominent. Due to the random nature of precipitation events and the large variance in volume and intensity, the planning of surface water storage projects requires a rather long time range for data collection. As this is not always available, most projects are constructed with a relatively high level of risk. On the other hand, groundwater aquifers, if available, do not possess these limitations. The reason for this is due to the physical principles of flow through porous media. One can regard the minute rock particles as natural retarding dams which reduce velocity by lengthening the flow paths of the water underground. In fossil and semi-fossil aquifers this means the storage of vast quantities of water recharged over many millennia. Another characteristic aspect of groundwater which has an economic impact is that in most cases the aquifers are spread out regionally. Thus a large initial investment for building dams and long canals is not necessary. It is, thus, possible to begin development projects on a rather limited scale, and to up-grade them step by step. Moreover, development can begin with a small quantity of data which is gradually increased as the project progresses.

This does not mean that the development of surface water should not take place. On the contrary, surface water should be developed as a complementary resource, to boost irrigation systems and bring about the situation where all worthwhile water resources are developed from the economical point of view. In general, however, it can be said that when the two resources co-exist in arid and semi-arid regions, namely groundwater and ephemeral surface water, it is advisable to begin with the first and postpone the development of the latter until more observations have become available on the precipitation and hydrological regime of the area. The reason for this is that groundwater is rather cheap to pump in the initial stages of development, when the water-table is high. It may become more expensive as the water table drops as a function of pumping. On the other hand, ephemeral surface water resources are very expensive when considering the risk involved in constructing dams and canals which are built on the basis of scarce data. An additional aspect which should be taken in consideration is that in many cases increasing the supply of surface water brings about an increase in percolation causing a rise in the water table which may cause drainage problems and salinization of soils. The initiation of regional development projects with pumping water from the groundwater, thus lowering of the water table will ensure an empty space in the subsurface for storing the back-flow from irrigation. The rational for this argument is illustrated in Figure 1.

In most cases the cost of fossil groundwater is relatively high, as production involves deep drilling, pumping, transport (the range in Israel is between US 0.05-0.5 \$ / m^3). Utilization for certain purposes demands partial on desalination. It is thus forecasted that unless heavily subsidized, the use of this water will be limited to areas where the real costs of alternative water resources is high enough not to compete with the cost of fossil water. Another possible use is by project that would take advantage of the special water qualities such as the high temperature of fossil water.

In some agricultural projects it is suggested that fossil water should be used as a leverage for promoting modern and efficient water use systems and methods aimed at triggering the general economic progress of rural societies in countries of the Middle East. Such projects should incorporate a strong incentive for development of an extension service and also serve as training sites for farmers from neighboring countries.

In order to minimize the cost of water to its users and broaden the range of demand, it is suggested to plan and develop an optimal line of users. Each user profits from a certain property of the water then releases it with an inferior quality/quantity to the next in line. If the water is primarily allocated for domestic use, the other users sharing its costs should be able to benefit from the reclaimed sewage water. In the case of a project restricted to agricultural users, such a line may consist of greenhouses where the water is circulated in order to benefit from its temperature and partial use of the water for irrigation, followed by aquaculture where the water becomes loaded with natural fertilizers, but is more saline due to evaporation, ending in irrigation of crops tolerant to brackish water, such as cotton or forage crops. It is possible to include other alternatives such as recreation, partial desalination for greenhouses, and/or domestic supply.

On the border with Egypt (where a regional aquifer is located underlying the northern Sinai and Negev deserts which contains water with 8000 ppm TDS), a preliminary feasibility study to be used as a test case has shown that if the cost of water is below the threshold of \$0.10, then it is economical for irrigating fodder crops that can enable the grazing of sheep and cattle. Other alternatives for the use of this aquifer are partial desalination and pumping to the urban-industrial center of Beer Sheva, and/or promoting a line of users as described above.

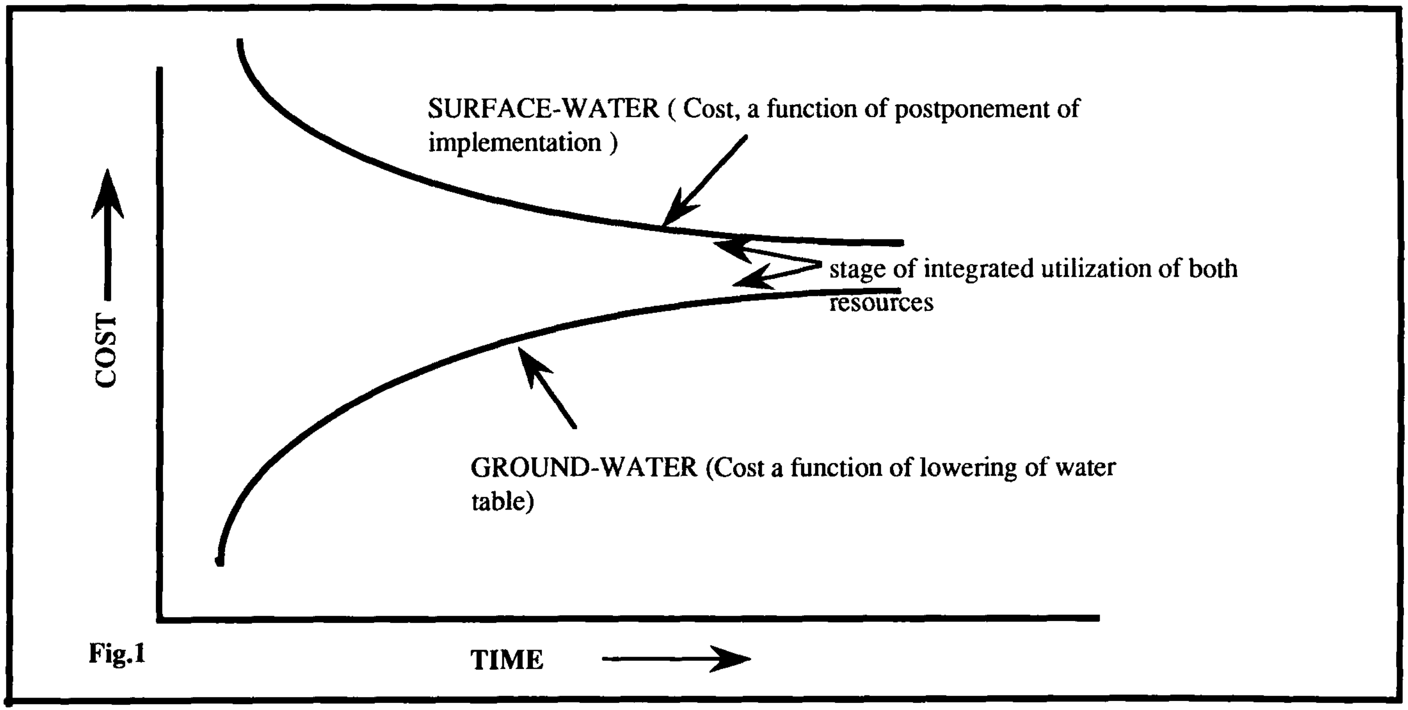

SURFACE-WATER (Cost, a function of postponement of implementation)
stage of integrated utilization of both resources
GROUND-WATER (Cost a function of lowering of water table)
COST
TIME

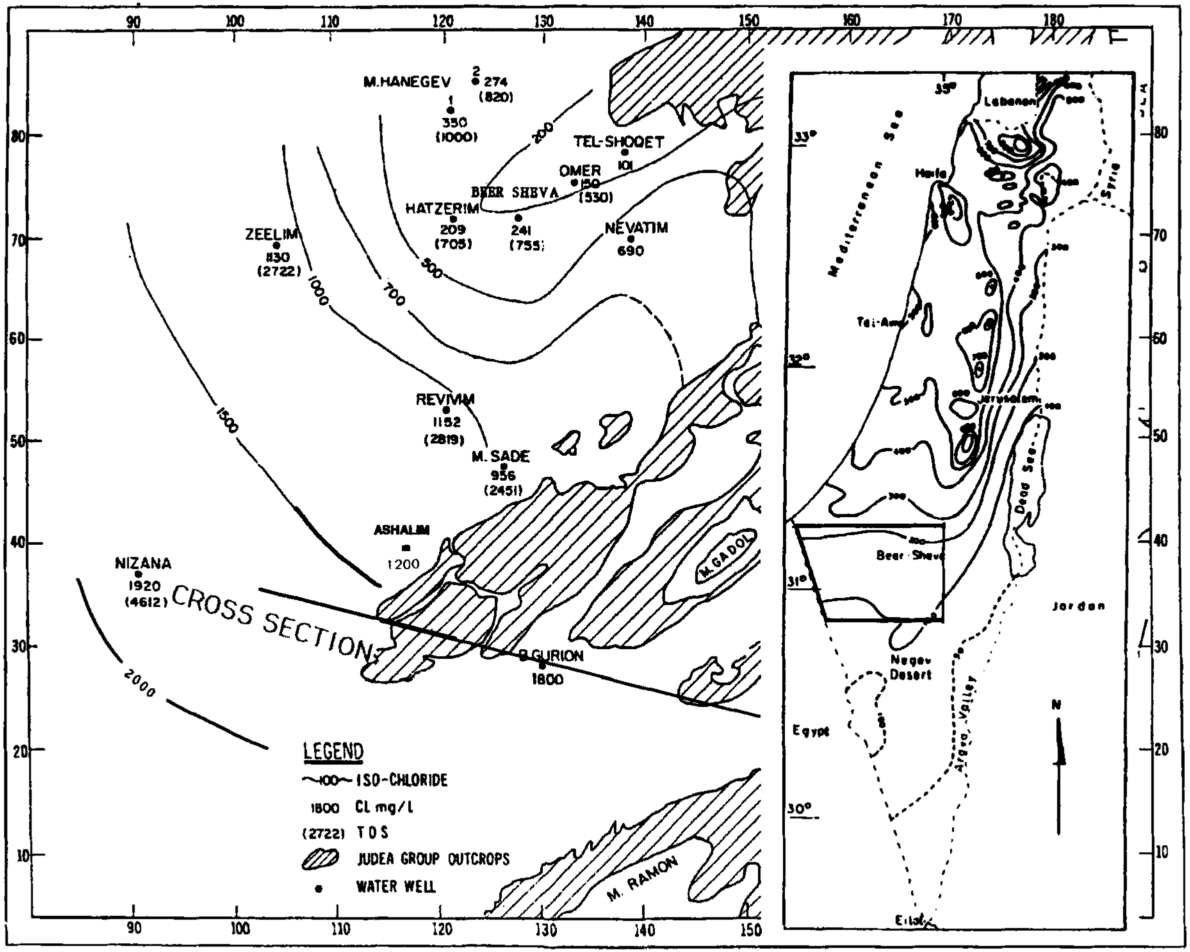
Fig.1

Hydrological constraints limiting the development of fossil and semi fossil aquifers

The main hydrological constraint where such aquifers are concerned is the drawdown of the water table as a function of the gradual mining out of the water. As previously mentioned, and as will be demonstrated later, this constraint can be forecasted and is controllable once the hydraulic coefficients and boundary conditions of the aquifer are known and inserted into the computerized model of the aquifer [10]. The constraint is then pronounced as the output of the model, when different scenarios of pumpage (alternative quantities spread over alternative settings of space and time) are implemented. The computerized models needed for answering these questions are commonly used and knowledge of the basic hydrogeological parameters of the region investigated enables rather good preliminary answers with rather scarce data to be made.

A more complicated constraint for the mining of fossil and semi-fossil aquifers exists in the cases where saline bodies of water lie in the close proximity of fresh bodies of water or even slightly brackish water. In such cases, the saline water is expected to flow into the regional cone of depression created by the mining of the fresher water thus causing the salinization of the well field a long time before the total quantity of fresh water in the aquifer has been mined. In such cases, pumpage of saline water in order to reduce its driving head may be necessary. This research was carried out using the regional limestone aquifer (Judea Group of Middle Cretaceous age) in the northwestern part of the arid Negev for which hydrogeological data was limited. The stages of the study included: construction of a conceptual model in which boundary conditions, the flow regime, and order of magnitudes of different hydrogeological parameters were assumed and tested. A two-dimensional, finite-difference computer code was used to model the groundwater flow. The objective of this research was to understand the quantitative aspects of the hydrodynamic regime of the limestone aquifer for the purpose of forecasting the impact of different pumping policies on the water table and salinity of the aquifer.

This limestone aquifer underlies most of the northwestern Negev, (Fig. 2). It consists of a sequence of limestones and dolomites overlain by chalks, marls and cherts of the Mount Scopus and Avdat groups (Upper Cretaceous to Lower Tertiary age), and is underlain by the marls and sandstones of the Kurnub Group (Lower Cretaceous age). In the area under investigation, the thickness of the aquiferous layers varies from about 650 m in the north to about 500 m in the south. The limestones are exposed in the mountains, which are anticlinorial structures and dip to the plains where they are covered by the impermeable strata (Fig. 3). Elevation of the mountainous part reaches 900 m above MSL. This brings the base of the aquifer above the elevation of the regional water table and, thus, the anticlinorial backbone running south to north also forms the subsurface water divide between the Mediterranean and the Dead Sea Rift Valley. The aquifer in the foothills region and under the plain of Beer Sheva, the average elevation of which is about 200 m above MSL, is under confined conditions. On the whole, this aquifer is the southern extension of the Yarkon Taninim basin, which extends over the western flanks of the Hebron, Judea and Samarea mountain and foothill regions. Thus while the northern part of the aquifer is


M.HANEGEV
2
274
(820)
1
350
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TEL-SHOQET
101
OMER
150
(530)
BEER SHEVA
HATZERIM
209
(705)
241
(755)
NEVATIM
690
ZEELIM
1130
(2722)
REVIVIM
1152
(2819)
M. SADE
956
(2451)
ASHALIM
1200
NIZANA
1920
(4612)
CROSS SECTION
B.GURION
1800
M.GADOL
M. RAMON
200
500
700
1000
1500
2000
LEGEND
100 ISO-CHLORIDE
1800 CL mg/l
(2722) TDS
JUDEA GROUP OUTCROPS
WATER WELL
Lebanon
Mediterranean Sea
Haifa
Syria
Tel-Aviv
Jerusalem
Dead Sea
Beer Sheva
Jordan
Negev Desert
Egypt
Arava Valley
Eilat
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33°
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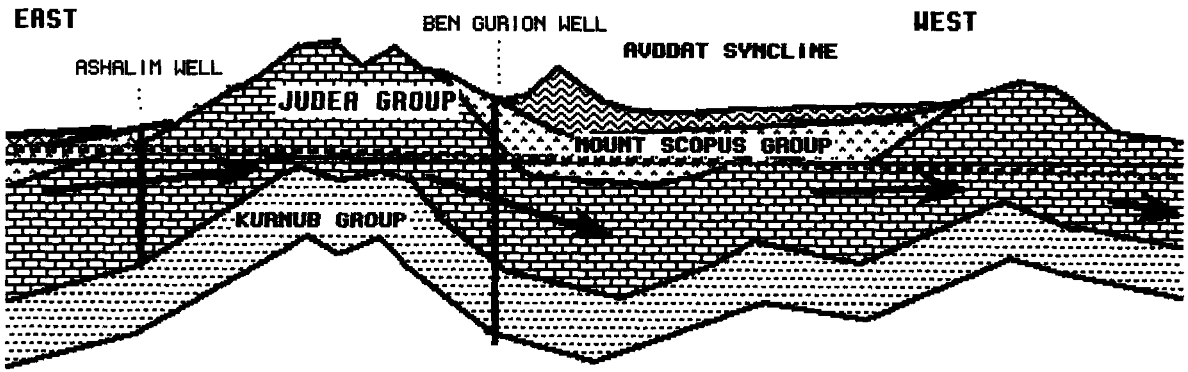
31°
30°
35°

Fig 2



DIRECTION OF GROUNDWATER FLOW

WATER TABLE AND HEAD

FIG. 3

APPROXIMATE SCALE 100 METERS
5 KILOMETERS

replenished annually, the water in the southern part (south to the plain of Beer Sheva) is semi-fossil, and the water along the Sinai border is fossil. This can be seen from the ages of the water, which range between two to three thousand years in the Beer Sheva plain, and reaches the order of magnitude of ten thousand years along the border of Sinai. At present about 20.10^6 m^3 are pumped annually in the vicinity of Beer Sheva. The aim of this research was to learn the optimal balance between the two bodies of fresh and saline water, as explained above.

The recharge area (south of Hebron) is characterized by high water levels (500 m above MSL), with a very strong gradient towards the Beer Sheva well field to the southwest (water level between 10-20 m above MSL). From the Beer Sheva well field the flow direction is north into the Yarkon-Taninim basin. Salinity increases from the Hebron mountains in the northeast to the south and west (Fig. 2). The present model assumes open boundary conditions towards the west and southeast. Based on this model, it is assumed that the limestone aquifer has two main natural inlets and two outlets: One inlet is from the anticlinorial regions of the Hebron mountains and Negev Highlands, the other from Sinai. One outlet is into the Yarkon-Taninim aquifer in the northern part of the region, while the other is in the direction of the Dead Sea and Arava Valley. The groundwater flow was modeled using the Finite Differences Approach [10-12]. A 24 x 31 cell with a non-uniform grid was used. Most of the cells were 25 km^2. In zones where steep gradients are expected, the area of each cell was decreased to 10 km^2. The model was calibrated first according to the water levels, assuming a steady state situation. During this stage recharge in the southern boundary was calculated. Partial optimization was done by varying the values of the transmissivities, by a trial and error process. At the beginning of the research, geostatistic techniques were used for contouring and removing the effects of measurement error from the data sets (hydraulic head, transmissivity). In the second stage, the model was calibrated for the nonsteady state according to the water levels. Due to availability of data, the period of April 1972 to March 1980 was chosen. At this stage of the model calibration of only the values of the storativity were changed. It was necessary to adjust the steady state solution several times before a satisfactory simulation of the nonsteady state could be reached.

At the stage of the steady state calibration, the total recharge on the outcrop areas was calculated to be $35 \cdot 10^6$ m^3/year. The outflow across the northern boundary (into the Yarkon-Taninim basin) was found to be approximately $27 \cdot 10^6$ m^3/year. Across the southeastern boundary towards the Arava Rift Valley it was $4 \cdot 10^6$ m^3/year. For the nonsteady state a one-month time base was used. The initial water levels were assumed to be those of the steady state. During the calibration period, the water levels at the southern open boundary were varied, whereas the level at the southeastern boundary was kept constant. Although the calibration contained a high degree of uncertainty, a general evaluation of the water balance and the flow pattern could be made for the calibration period.

The general conclusions are that if pumping continues to be concentrated mainly in the Beer Sheva field, it will cause a steep cone of depression which will bring the inflow of saline water from the south, which may result in the gradual salinization of the Beer Sheva well field, as well as a decrease in the outflow to the Yarkon-Taninim basin. It may be assumed, however, that if pumping is spread throughout the area, including the Sinai border region, then salinization will be avoided even if pumping will reach the order of magnitude of $50 \cdot 10^6$ m^3/year. This assumption is based on the high transmissivities revealed by the high yield (500 m^3/h) of the well of Nizana (Fig. 1). In order to test this assumption, more wells, longer periods of pumping, salinities and water table data are required in the southwestern part of the region. This will enable the model to be run to determine the influence of well fields in this region and calibrate it according to the data collected from these wells.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

THE PEACE CANAL PROJECT: A MULTIPLE CONFLICT RESOLUTION PERSPECTIVE FOR THE MIDDLE EAST

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Abstract

A new Middle East peace plan based on a water project, designed to deliver 1.1 billion cubic meter of water a year from Ataturk Baraji lake (or from the Ceyhan and Seyhan rivers) in southeast Turkey to be distributed equally (275 MCM/yr each) between Syria, Israel, Jordan and the Palestinians. The paper describes the Peace Canal Project and its possible implications for Middle East water scarcity, competition and conflicts, and to security concerns of the parties to the Arab-Israeli conflict. The paper details the benefits to each participant and the possible contribution of the Peace Canal Project for the peace process.

1. THE PEACE CANAL PROJECT AND MIDDLE EAST WATER PROBLEMS

There have been numerous projects suggested to relieve the extreme water shortage facing the countries of the Middle East. The Peace Canal on the Golan, however, is the only such project that satisfies two of the most important needs of the protagonists in the Arab-Israeli dispute: security through confidence building measures and adequate water. Briefly, the Peace Canal Project proposes to bring 1.1 billion cubic meters of water from the Turkish Ataturk Dam reservoir (or from the Ceyhan and Seyhan rivers) through Syria and the Golan Heights to the Sea of Galilee and the Yarmuk River. On the Golan, the Canal will be combined with an anti-tank barrier that is designed to induce Israel and Syria to reach a territorial compromise.

Educated estimates for Middle East water deficit for the end of the decade and the year 2020 vary widely depending on the criteria and variables water experts use. What they commonly paint though, is a bleak picture of a growing regional water deficit, that if not addressed now, could injure and threaten the viability of the countries involved, and lead to another costly war.

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One conservative estimate, quoted by Israeli officials, suggests that by the end of the decade, Israel would register a 300 million cubic meter annual deficit, the West Bank 100 mcm/yr and Gaza 200 mcm annual deficits.[1] Another estimate predicts that Jordan would need additional 300 mcm/yr for the same period,[2] but that deficit is projected to grow to 430-730 mcm/yr by 2020.[3] While Syria's per capita consumption is estimated at 1300 cm/person/year, Israel's and Jordan's at 300 cm/person/yr, and the Palestinian consumption at only 165 cm/person/yr,[4] it still suffers from water and electricity shortages in the western part of the country, especially in cities like Aleppo and Damascus. This is mainly due to the reduction of the flow of the Euphrates, which reduced the water level and the hydropower generating capacity of Al-Thawrath Dam, Syria's main hydropower generator and water storage site. The most alarming predictions though are for Jordan, which is expected to double its population in the next 18 years and is denied its fair share of the Yarmuk waters by Syrian overutilization of the Upper Yarmuk and by Israel's reluctance to allow for the construction of the much needed Unity Dam.

2. THE FLAWED DESIGN OF THE PEACE PROCESS - POSSIBLE IMPLICATIONS

Peace in the Middle East will continue to be elusive if water problems are not solved through a cooperative, integrative approach. The ongoing negotiations for peace offer perhaps the best opportunity to achieve e breakthrough that will resolve both the security and resource dilemmas of the region. One analyst has offered the following insight:

-"Water is always a terrain security issue, especially when scarce, since all concerned parties feel compelled to control the ground on or under which water flows.

- The relationship between water dependency and security is perceived as absolute, i.e., as zero-sum... and as such carries a constant potential for conflict.

- Because of its complexity, water tends to be dealt with piecemeal both domestically and internationally, thus tending to be fragmented as a strategic and foreign affairs issue."[5]

As it stands, the peace process's format, which was approved by the negotiating parties, prevents the crucial integration of 'water security' with the bilateral agenda and limits the ability to deal with the confluence of water with national security and territory. The flexibility expected from the negotiating parties should also apply to the format.It should allow for potential adjustments relating to an emerging hydrological crisis that hinders progress toward regional peace. Only by addressing 'water security' issues through linkage with questions of national security, territory and peace, (in the bilateral tracks) can there be a chance to bridge the positions of the parties. The 'Peace Canal' project by allocating 275 million cubic meters a year of sweet and affordable Turkish water to Syria, Israel, Jordan and the Palestinians and assuring the equitable allocation of water within their territories can induce the parties to reach agreements on the bi- and multi-lateral levels and move the region to a new era of cooperation and peace.

3. THE 'PEACE CANAL' PLAN: AN INTEGRATIVE, POSITIVE SUM REGIONAL SOLUTION

The 'Peace Canal' plan calls for diverting 1.1 billion cubic meters of water a year from the elevated Ataturk Baraji lake (the heart of the GAP project) in south-east Turkey (or from the Ceyhan and Seyhan rivers) to be equally distributed to Syria, Israel, Jordan the West Bank and Gaza.

The first proposed diversion is via a new tunnel in the southern mountains surrounding the lake. An alternative diversion could be from the Ceyhan and Seyhan rivers, about 240 kilometers west of the lake. From either of these two sources, the pipelines will connect to twin subterranean pipelines crossing through western Syria (parallel to the Aleppo-Damascus road) to a northern point on the Syrian-Israeli border on the Golan Heights. At the point on the border where the Hermon mountain ridge turns to a plateau, the pipelines would terminate and a dual purpose water canal/tank barrier structure, about 60 kilometer long and 750 meter wide, would begin. The proposed route of this dual purpose structure is for the entire length of the common border (UNDOF Zone), terminating at the southern edge of the Golan Heights. There, the canal/tank barrier would diverge and the water diverted for storage through smaller canals (or pipelines) down from the southeastern slope to the Upper Yarmuk river (upstream of the proposed Unity Dam) and on the western slope down to the Sea of Galilee. Hydro-power plants in both sites are proposed to utilize the energy generated by the water falling from the Heights. The hydroelectricity produced could be shared by all four parties, or if needed, for pumping stations in case the gravitational forces of the lake would require assistance in the delivery of the water.

4. TURKISH RIVERS: KEY TO REGIONAL STABILITY

Water for the project could be obtained either from Ataturk Baraji Lake or from the Ceyhan and Seyhan rivers.

Ataturk Baraji lake is known by its Turkish acronym, GAP. According to Turkish officials, the lake behind Ataturk Dam is 817 square kilometers and holds the equivalent of a one and a half year flow of the Euphrates (32 billion cm/yr), or about 49 billion cubic meters of water.[6]

The planned use in Turkey for irrigation and general development through the Ataturk Dam is about 20 billion cm/yr via two 26 kilometer long tunnels which deliver the flow of 325 cm/sec each. The planned release to the Euphrates is a constant 500 cm/sec, or just over 15 billion cm/yr. Turkish goals for the GAP project, which is estimated to be completed in two decades, are to help irrigate 4.2 million acres of land (50% increase over present coverage) and generate 27.3 billion kilowatt hours of electricity, nearly half of Turkey's present output.[7] These goals can still be met despite the proposed annual allocation of 1.1 bcm/yr for the Peace Canal project. Although this amount represents about 5% of Turkish planned domestic use from the lake, it can easily be compensated for by increased irrigation efficiency gained through the investment of revenues obtained from the sale of the water, or via a diversion from the Ceyhan and Seyhan. The GAP project has been a source of

contention between Turkey, on the one hand, and Syria and Iraq on the other. Turkey maintains that through increased irrigation efficiency Syria and Iraq could meet their water needs with the 500 cm/sec released to the Euphrates. Turkey can serve an example by implementing such improvements in the southeast. Improvements in Turkey could be financed by the sale of water and/or an international financial assistance package, a likely source for other countries participating in the project. Simultaneous commitments to and implementation of such improvements could therefore help reduce the conflict.
The *Turkish Daily News'* coverage of the inauguration of the Ataturk Dam included the following quote regarding the GAP project: "Calling it the "peace water project", Turkey has been hoping to pull a diplomatic coup by paving the way for a rapprochement between the Arabs and Israel by exploiting their joint dependence on water".[8]

The other source for the water for the Peace Canal Project may be the Ceyhan and Seyhan rivers. These two rivers have a combined annual discharge of about 15 billion cm/yr and their current utilization is minimal. Most of the water flows to the sea. The rivers have been mentioned before by the Turkish President Ozal as the most likely sources for the Peace Pipeline. Their use for the Peace Canal Project would simplify the political scenario in one hand (since they are used only by Turkey), but they lack the economic viability that gravitational forces from Ataturk Barji lake could provide for the delivery of the water on the other hand.

5. OTHER BENEFITS FOR TURKEY

1. Revenues: By selling water, Turkey will derive valuable foreign exchange revenues. Given the inefficiency of irrigation in the southeast, (36% on average)[9] the opportunity cost of this water is very low. Revenues derived from selling water can be invested to improve the efficiency of water use in the region and overall save more water than the amount allocated to the Peace Canal project. Israeli drip irrigation products and technologies could be used to achieve high crops yield and substantial water savings of current water usage.
2. Construction: Turkish construction companies have extensive experience in the building of large projects. A large segment of the project, estimated to cost $2-3 billion (1992) dollars, could therefore be awarded to Turkish construction companies, generating more revenues and employment for the industry.
3. Such a project would increase Turkey's visibility on the international scene, inducing some wealthy nations and international financial institutions (which share an interest to stabilize the region) to open credit lines and cooperate with Turkey on other projects. is anticipated that similar sources would finance the Peace Canal project and therefore, financial plans can easily be prepared to include specific assistance package for Turkey.
4. The contribution of Turkey to a project that not only supplies water to the Middle East but is conducive to the resolution of the Arab-Israeli conflict will go a long way in improving Turkey's strategic importance vis-a-vis the EC, US and Japan. This is especially important to Turkey in the aftermath of the cold war and the dissolution of the Soviet Union.

5. The Peace Canal project may not need extensive external energy sources to deliver the water (If taken from the lake and not from the Ceyhan and Ceyhan rivers) since it will rely mostly on the gravitational forces of the elevated lake (800-900 meters above sea level) and on the project's ability to self generate hydroelectric power to use and deliver the water. This can reduce Turkey's need to import oil to power pumping stations required by other proposed importation schemes for the Middle East (comparative feasibility studies could determine the exact amounts).

6. Unlike other proposed such schemes, the Peace Canal is not associated with any particular leader in Turkey. This fact coupled with the great interest the project has generated among the participants, US administration and the World Bank increases the likelihood that present Turkish political leaders would be more accepting of the idea.

6. DIVERSION OF WATER FROM THE SEYHAN AND CEYHAN RIVERS TO THE EUPHRATES.

The new proposed diversion project has the potential for defusing Turkey's conflict with Syria and Iraq over the sharing of the Euphrates waters and allows for the utilization of Ataturk Baraji as the source of the Peace Canal Project. A 240 kilometer pipeline could be built from the Seyhan and Ceyhan rivers, parallel to the Adana-Gaziantep road, ending at Hancagiz lake which flows to the Euphrates. This option for development could resolve the conflict between Turkey on one hand and Syria and Iraq on the other, by pumping to the Euphrates an amount of water larger than the amount allocated to the Peace Canal Project. The advantage of this option is that it could reduce possible Syrian and Turkish domestic opposition to allocate the 1.1 billion cm/yr to the Peace Canal Project since that amount would come from the Seyhan and Ceyhan rivers and not on the account of Syrian or Turkish use from the lake. Through an exchange agreement, water for the Peace Canal Project could still come from the elevated lake. This could be achieved by pumping 2-4 billion cm/yr into the Euphrates from the two other rivers and thus allow Turkey to use the original amount of water from the lake, that would now discharge less water to the Euphrates (supplemented in return from the Ceyhan and Seyhan). If the amount of water diverted to the Euphrates would be large enough, it could satisfy Syrian and Iraqi quests for more water from that river. This added amount would come from underutilized rivers and could help resolve the discrepancy between Turkish allocation of 500 cm/sec and Syria's and Iraq's demands for 700 cm/sec. The added amount of water in the Euphrates and via the Peace Canal Project (275 mcm/yr) should add an incentive for Syria to participate in the regional water development plan, and could diminish the water conflict related to the Euphrates.

7. OTHER BENEFITS FOR SYRIA

The estimated 60 kilometer long and 750 meter wide, concrete reinforced canal/tank barrier, could significantly reduce both side's armored ability to rapidly cross the border. This could fulfill the Syrians' interest in thwarting Israel from crossing the border, as was the case at the end of the 1973 war when Israeli forces counterattacked and crossed the border to cover Damascus under artillery range. It could also defuse the mutual strategic question of defense against surprise massive armored attacks by setting a new formula for a territorial compromise based on tactical (offensive and defensive) parity in the Golan Heights.

Syria's current national goals include:

1. Regained control over a demilitarized Golan Heights;
2. Increased hydro-power generating capacity;
3. Increased water allocation from the Euphrates;
4. Gradual peace with Israel in the context of parallel peace with the Palestinians and Jordan.

The Peace Canal Project can have direct positive bearing on each of these goals:

First, the return of the Golan Heights to Syrian hands is contingent by Israel on a Syrian commitment to a peace accord and on a resolution of the Syrian ability to launch surprised massive armored attacks from the Golan. Confidence building measures (CBM), such as the canal/tank barrier, could be the new foundation for territorial compromise through the reduction of Israel's strategic need to maintain control over the Heights and could lead to a Syrian commitment for a gradual peace process. Assuring, through comprehensive regional treaties, a steady supply of water through the Peace Canal project could also alleviate Israeli anxieties with respect to loss of territorial control of the Jordan river's northern tributaries and the return to the pre-1967 lines. Territorial compromise and regained Syrian control over a demilitarized Golan Heights could therefore be tied with adequate assurances of water supply to both countries from within their territories and through the Peace Canal project.

Second, the Peace Canal project can supplement Syria's hydro-power generating capacity through its share of the two (or three) power plants planned for project. The estimated possible contribution of the two proposed hydro-plants combined is 100 megawatts.[10] Water allocated through the eastern extension of the Peace Canal to the Yarmuk could also add to the possible hydroelectric generation of 100 megawatts to be generated by a potential damming the Yarmuk in Maqarin (Unity Dam) and, similarly, 50 megawatts if the Yarmuk were to be dammed at Muheiba.[11] This could compensate some of Syria's loss of hydro-power generating capacity as the result of the GAP project.

Third, Syria will have 275 mcm/yr of water delivered to its western cities at no cost since it is envisioned that it would not have to pay for Euphrates-sourced water and have the project financed by outside sources. This could improve Syria's inadequate distribution of water in the western part of the country. Therefore, Syria should not oppose the construction of the project on the grounds that it deprives it of water from the Euphrates — which, if available, ought to be exclusively released down stream. Such allocation to the Peace Canal project would come on the account of Turkish domestic use (or from the Ceyhan and Seyhan rivers) and should be viewed by Syria in the context of the benefits it can provide, including the return of the Golan Heights.

Finally, Syria linked a peace treaty with Israel to similar progress in peace negotiations with the Palestinians and Jordan. This political liability is another incentive for Syria to approve the Peace Canal project that could have direct positive effect on Israeli positions of security, land and water vis-a-vis its other neighbors. A constructive Syrian attitude could bring the country closer to stated national and hydrological goals and contribute heavily to the reduction of water shortage in the region that hinders progress toward peace.

8. JORDAN'S WATER PROBLEMS

Jordan presently uses over 870 mcm/yr, 170 mcm/yr from unrenewable sources (fossil aquifers) and 700 mcm/yr from renewable sources. 85% is used by the agricultural sector, 10% directed for domestic use and 5% for industrial use[12]. The country has the most negative hydrological balance and prospects among the recipients of water through the proposed Peace Canal project. Eighty percent (400 mcm/yr) of the 500 mcm annual outflow in the Yarmuk was designated for Jordanian use in the Johnston Plan[13] which is considered, with some modifications, the basis for allocating the Jordan basin waters. Israel was allocated in the original plan 25 mcm/yr but today utilizes down stream some 70 mcm/yr, mostly winter flood waters. According to Jordanian officials, Syria utilizes, through its 30 small dams along the Yarmuk's tributaries, well over 200 mcm/yr and plans to increase this amount to 366 mcm/yr by the Year 2010.[14]

In the regional competition for water, Jordan is clearly on the loosing side. It is certain that Jordan's viability and political stability could be endangered to a point of setting off a chain reaction of instability in the region, if the situation is not reversed soon. It is the interest of Syria and Israel, therefore, to reevaluate their over utilization of Jordanian waters and consider new equitable allocations.

The reversal of the growing Jordanian water shortage is possible with a collaborative agreement between Syria, Jordan, Israel and the Palestinians that takes into account the 275 mcm/yr of water delivered through the Peace Canal project and guarantees substantial compensation for the redistribution of some water resources.

9. THE PEACE CANAL PROJECT'S WATER DISTRIBUTION PLAN

The proposed distribution plan of the overall waters associated with this project are as follows: Israel gives up claims for the eastern side of the mountain aquifer, foregoing 125 mcm/yr for Palestinian control. In return, Jordan accedes to Israeli claims on the Yarmuk, estimated currently at under 90 mcm/yr, supplied through a proposed western Gohr canal by gravity to the Jordan valley and some for storage in the Sea of Galilee.[15&16] Israel and Syria allows the building of the Unity and possibly the Mucheiba Dams (630 mcm and 295 mcm storage capacity respectively)[17] where Yarmuk waters would be stored and hydroelectricity produced. In return, Syria commits to the Peace Canal project and to a reduction of its utilization of Yarmuk river headway waters to less than 150 mcm/yr, allowing the remaining waters to flow down stream to the Unity and possibly the Mucheiba Dam for common Jordanian/Syrian utilization (75% of which could be for Jordanian use).

Through the Peace Canal project Turkey could increase Syrian allocation from the Euphrates by 275 mcm/yr, 100 mcm of which could be released down stream to Al-Thawra Dam and 175 mcm for use in Western cities and some agricultural use in the Upper Yarmuk basin. Syria could use most of the hydroelectricity produced from the proposed two dams on the Yarmuk (150 Megawatts combined) , and share with Jordan, Israel and the Palestinians the power produced at the proposed two (or three, if we add a northwestern extension) Peace Canal project's hydro-plants in the Upper Yarmuk and the Sea of Galilee (estimated to produce 100 megawatts combined). The 275 mcm/yr Jordanian share from the Peace Canal project could be split, with the lion's share stored behind the proposed Dams on the Yarmuk although some could be diverted to the west Ghor canal and for storage in the Sea of Galilee. A proposed link via a tunnel or pipelines between the Sea of Galilee and the Yarmuk[18] and a planned increase of the Sea of Galilee's storage capacity from 500 to-700 mcm are recommended to accommodate the growing amounts of water from the Peace Canal project and other sources. These improvements could provide optimal distribution among Israel, Syria, Jordan and the Palestinians designed to minimize the loss of winter floods and allow for the establishment of a regional commercial "Water Exchange Bank."

It is important to remember that the Peace Canal project is designed to deliver a flow of about 3 million cm a day and that Syria would use most of its share before it reaches the Golan Heights. This means that Jordan, Israel and Palestinian would use the water at the rate of arrival or below, resulting in the stabilization of and the gradual increase of their water resources.

10. PALESTINIAN AND ISRAELI REDISTRIBUTION ISSUES

Palestinian and Israeli shares from the Peace Canal project could be distributed the following way: A northwestern extension (in addition to the originally proposed southwestern and southeastern ones) could be built from the Peace Canal, falling from the Heights to the Upper Jordan river near the city of Katzerin. Some of the water could flow for storage in the Sea of Galilee, (for further release to the Jordan river and the National carrier), whereas most could be pumped by a new station to the abandoned Almagor canal (needs restoration and completion) connecting to the Israeli National Carrier. This would require an expansion of the Carrier's capacity, presumably from Beit-Netofa reservoir south. The option could reduce the cost of lifting and delivering the water to the National Carrier from the Upper Jordan river (when compared to lifting water from the Sea of Galilee, at 210 meters below sea level) and could help meet the common goal of recharging aquifers (including the Gaza aquifer) with Israeli and Palestinian shares from the Peace Canal project.

The southwestern extension could assist in the stabilization of the Sea of Galillee's water level and optimize the distribution of water with the Palestinians. This could be achieved through an exchange between Palestinian share from the project, some of which can be utilized by Israel through the National Carrier, in return for increased Palestinian local utilization of the mountain and Gaza aquifers. Some Palestinian waters could be stored in the Sea of Galilee for further use in the Jordan river. The added water would also improve the lake's salinity levels and add an incentive to divert saline springs and treated industrial/agricultural/urban wastes away from the Jordan river to the Dead Sea. This could help restore the ecological balance of the Jordan and would allow water utilization in the lower Jordan especially in summer months. The combined increase of 550 mcm/yr could reduce the intensity of the conflict between Israel and the Palestinians over the utilization levels of the mountain aquifer, facilitating more equitable allocation and progress on the issue of control and water security in the bilateral and multilateral peace talks.

11. PALESTINIAN AND ISRAELI BENEFITS

As mentioned above, the Palestinians can gain substantial benefits by supporting the construction of the Peace Canal project and by reaching a collaborative arrangement with their neighbors. It could help them attain the objectives of equity and control that include:

1) Priority rights and increased utilization of the mountain aquifer;
2) Control over the eastern aquifer;
3) Independent access to quality water from the Jordan;
4) Recharging the mountain and Gaza aquifers and lowering their salinity levels;
5) Sufficient amounts of water for normal population growth and agricultural/industrial/urban development;
6) The facilitation of water agreements to allow territorial compromise.

Israel may also gain substantial benefits by approving the Peace Canal project:

1) Increased amounts of water in the Sea of Galilee, which would stabilize the lake's level and improve its water quality;
2) Reduction of competition over the mountain and Gaza aquifers that could expedite agreements on safe mutual utilization and territorial compromise;
3) Adequate allocation of water from the Yarmuk;
4) More water to restore, stabilize and recharge underground aquifers;
5) New avenue for safer territorial compromise in the Golan, West Bank and Gaza

12. ISRAELI SECURITY ISSUES

Israel's primary national goals include secure and peaceful borders and an adequate supply of water. Israeli fears of an eastern attack has dominated Israeli strategic and political thinking since the birth of the nation. The Peace Canal project could compensate Israel for giving up strategic depth as part of a territorial compromise based on the project. The canal/tank barrier (that was designed by a former commander of the Israeli Combat Engineering Corps) offers an excellent defense against a possible "surprise" Syrian armored invasion of the Golan Heights. Such a barrier would delay Syrian crossing of the border and allow Israel the time necessary to mobilize and recapture positions on a future demilitarized heights.

The Jordan river served as a natural anti-tank barrier despite its summer dryness. Upon the completion of the Peace Canal project, the river would be full and flowing again, enhancing its capacity to delay an eastern armored attack year around. These improvements fits a definition of a defensible border made by a former Foreign Minister Abba Eban, "a border which does not require a pre-emptive strike for its defense." Assuring Israel's national security through physical barriers on the ground, adequate supply of water and peace could all be attained through the Peace Canal plan.

13. THE DEPENDENCY QUESTION

Israeli, Jordanian and Palestinian fears of dependence on a water project which originates in Turkey and runs through Syria should not be the dominant factor when considering the Peace Canal project. First, if Syria interferes, it would deny itself the 275 mcm/yr and its share of hydro-power from the project. Turkey would be able to cut the flow at the source if such infringement takes place. Second, Jordanian and Palestinian share of water from the project (besides that of Israel) will also be cut off, so that Syrian intervention may damage its Arab neighbors, a probable casus-belli with Israel and counter to Syrian interests in the Arab world. Third, the participants in the project could reduce the consequences of a temporary shut down by storing the continuous flow in the Sea of Galilee, underground aquifers and in the proposed storage sites on the Yarmuk, At the same time they could increase the efficiency of usage levels, and develop alternatives, i.e., waste water reuse, conservation etc. Fourth, comprehensive regional agreements relating to the Peace Canal project, water use, management and controls, should specify the international sanctions imposed on any party who attempts to interrupt the flow and the avenues for diffusing such unilateral actions. These issues should increase confidence in the stability of the project and should strengthen the rational which states that such a viable water project, even with a risk attached, is better than other available alternatives.

14. ECONOMIC,ENGINEERING AND ENVIRONMENTAL FEASIBILITY

Economic - The Peace Canal project is estimated by preliminary analysis to cost between $2-3 billion (1992 dollars). Although no estimates are available for operating costs, it would be a mistake to impose the characteristics of other large water transport systems and to judge the Peace Canal's economic viability by them. General costs for such systems, carrying over 500 mcm/yr, have been estimated at about 10 cents per cm per 100 kilometer for pipelines and about 5.5 cents/cm for open canal.[19] Most of these estimates are based on routes which require to move water from around sea level either horizontally or to higher elevations with pumping stations, using polluting, unrenewable energy sources (i.e. Mini Peace-Pipeline, from the Ceyhan and Seyhan rivers in Turkey to Amman in Jordan, situated 900 meters above sea level). The Peace Canal route's design is based on a more favorable topographic layout, taking advantage of Ataturk Lake's elevation (800-900 meters), and using the gravitational force to move water south to the Golan Heights. This could substantially reduce the cost of delivery when compared with other projects, but only a feasibility study could determine the extent of the force and whether or not pumping stations would be required. In case the gravitational force would not be sufficient, hydroelectricity produced by the two stations proposed in the project could be used in pumping stations (through exchange agreement) to supplement the force. No other water delivery project (including the Gur plan, Mini pipeline and Peace pipeline) has the potential for self sufficiency in terms of power requirements, and only the Peace Canal may produce net energy at a competitive cost for the benefit of the users.

Engineering - The technology to implement the Peace Canal project exists. Construction time estimates are not available.[20]

Environmental - Preliminary evaluation takes into account the following issues: First, Ataturk Baraji lake is a large existing body of water holding about 49 billion cm. It releases for Turkish domestic use some 20 bcm/yr and to the Euphrates some 15 bcm/yr. A 1.1 bcm/yr directed to the Peace Canal would have a minute effect on the ecological balance of the lake and its surroundings. Second, the two proposed pipelines for the project will be buried in the ground. This would prevent interference with animal migration patterns in southeast Turkey and in Syria. The canal/tank barrier on the border would replace existing mind fields, fences, anti-tank ditches etc. which prevent now the migration of animals on the ground. The new structure would not change the migrating patterns that were disrupted in 1967. Third, the lake's gravitational forces and the self produced hydroelectricity are environmentally safe means to move water. They are also safer and more economically viable than oil/coal/ nuclear based importation schemes or desalination plants.

CONCLUSION

The growing water crisis hinders progress toward peace in the Middle East. A collaborative, integrated water agreement, based on the Peace Canal project, could answer urgent hydrological and security needs by supplying 1.1 billion cm/yr from Turkey, to be equally divided among Syria, Jordan, the West bank (and Gaza) and Israel (275 mcm/yr each). The artificial water canal/tank barrier on the Golan and the enhancement of the Jordan river as a natural anti-tank ditch would enhance Israel's security, compensate the country for loss of strategic depth resulting from a territorial withdrawal, and increase incentives for a compromise on water issues with its neighbors.

A comprehensive and urgent feasibility study of the Peace Canal project from two sources is proposed. Such a study could be financed by US agencies and international institutions which have indicated interest in conducting such a venture. An indication of interest from each of the participants in the project would not commit them to implementation, but rather show a willingness and openness to study new peace options.

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SECTION V
Approaches to resolving the water conflicts

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Economic and political adjustments to scarce water in the Middle East

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Abstract
The acceptability of a price for water to its users is not related to the real 'value' of the water. Throughout the world there is a very strong traditional tendency to regard water as a free good and where water is plentiful the approach may be reasonable. In regions where water is scarce, however, the belief that unlimited supplies of water 'should' be available is very dangerous as it reinforces already very economically and ecologically unsound allocative and management practices. Markets for water in the Middle East and northern Africa are therefore undeveloped and even more problematical is the general absence of regulatory mechanisms to limit water use.

In a pure market with well developed institutions prices are useful allocative instruments since, if they closely relate to the real value of the resources entering trade, they force consumers, in the case of this discussion, users of water, to examine their utilisation of scarce resources and to cost inputs in relation to returns. It also causes them to consider substitutes for scarce resources, for example for water, in achieving a satisfactory economic and social outcome for water using activities. The paper will examine the possible role of establishing prices for water at the international, the national as well as at the local and farm levels. It will be shown that governments, officials and farmers operate without any awareness of the real cost of delivering water or of its value, yet at the same time massive adjustments, economic and political, have been made which are in accord with the real economy of water allocation and use. The scale of the adjustments augurs well for the region with respect to its inescapably constrained water resource future.

Key words: water allocation, water prices, Middle East, adjustment to water scarcity

> 'Cultivate your world as if you would live forever, and prepare for your hereafter as if you would die tomorrow'
>
> Sharah al-hadith al-nabwi - a saying of the Prophet in the Hadith, as quoted by 'Ali Mubarak (administrator and engineer in Egyptian governments between 1848 and 1892) in *al-Azhar*, Vol. 4, No 10, May 1891, pp 309-315

Introduction

It is not just the shortage of water which makes the utilisation of water in the Middle East difficult. A major problem is the lack of awareness at all levels of the 'value' of water and of the related matter of the costs of delivering it. The starting point as far as all users are concerned is that there is an entitlement to water and that the entitlement is to free water. When a scarce commodity is perceived as a free entitlement, and where measures to regulate use are poorly developed, there will be many difficulties attending its effective use economically and its sound use ecologically.

The countries of the Middle East and northern Africa are unique in the scale of their water deficiency. The aridity of the region is only relieved by the water which arrives from outside via the Nile and the Tigris-Euphrates systems and the fossil water which underlies extensive tracts of the Saharan and Saudi Arabian deserts. The most important indicator of water deficiency is the level of food imports and here the position is disturbing. If Turkey is excluded the region has to import over sixty per cent of its food, and some of the oil economies import about ninety per cent of their food. That the states of the region have addressed very successfully their duty of providing the entitlement of their citizens to food is partly a tribute first to their political and economic skills, secondly to the availability of cheap food on the world market for the past decade or more and thirdly to the preparedness of the United States to support the Egyptian economy particularly with respect to food and that of the Israeli economy more generally. The discussion will proceed on the basis that the water gap is represented by the food gap and the problem faced by Middle Eastern governments and their patrons is the provision of food in sufficient volumes and at affordable prices to meet the inevitable increased food demands of the coming decades. Economic stability, and consequently political stability, in the region depends substantially on the ability of governments to substitute for water and the major means to achieve this will be through gaining access to food raised by producers who have access to cheap water. (Allan, 1992)

The countries of the region can be categorised with respect to the scale of their water resources in relation to needs, and with respect to their ability to substitute for water . The latter capacity can be further classified according to how the substitution can be achieved in that in some cases Middle Eastern and north African countries can substitute for water from their own resources while in others the substitution can only be achieved with significant political adjustment to the terms acceptable to an outside patron. The countries can be classified as follows:

Table 2 A classification of the countries of the Middle East and North Africa with respect to water availability and pattern of trade.

Country	Balance of trade $bn	Food trade $bn	Water deficit* Km3
Countries with strong trading positions, being major food importers and where the <u>water deficit is not significant</u>. For them the international political economy is not affected by water.			
Middle East			
Bahrain	- 0.1	-0.25	-0.15
Iran	+2.0	-2.00	-0.00
Iraq- pre Aug 1990	+5.0	-2.00	-0.00
Kuwait	+3.0	-0.30	-0.15
Qatar	+1.0	-0.15	-0.10
Saudi Arabia	+4.0	-3.50	-1.00
UAE	+7.0	-0.90	-0.20
North Africa			
Algeria	+0.2	-2.00	?
Libya	+4.0	-1.10	0.30
Countries with weak trading positions, being major food importers and where the <u>water deficit is significant or very significant (Jordan)</u>. For them the international political economy could be seriously affected by water.			
Middle East			
Israel	-1.4	-0.30	-0.20
Jordan	-2.0	-0.30	-0.10
Lebanon	-1.5	-0.20	0.0
Syria	-2.0	-0.50	-0.15
Yemens	-1.0	-0.10	potential deficit
North Africa			
Egypt	-6.0	-5.50	-10.00
Morocco	-1.0	0.00	potential deficit
Tunisia	-1.0	-0.20	-0.20
Countries with weak trading positions, but being food exporters and where the <u>water surplus should ensure future food self-sufficiency</u> (provided Sudan can escape internal political disruption). **For them the international political economy is not affected by water.**			
Middle East			

Turkey	-5.0	+1.50	+10.00
North Africa			
The Sudan	-0.5	+0.10	+4.00

(Sudan's position is so affected by the current internal problems that the renewable resource potential of the country cannot be realised. It is therefore difficult to categorise.)

Sources: UN and World Bank data and author's estimates

* The notion of **deficit** is difficult to define, in that it depends on current national policy with respect to water allocation. In Egypt where increased food output is a stated policy it is possible to estimate the amount of water needed to meet the national goals. In countries like Jordan and Israel where adjustments are being made to reduce water use in agriculture the concept of a deficit is more difficult to define. Quantifying the deficit is less important than recognising the relevance of the deficits to the agricultural future of the region.

Table 1 demonstrates that only Turkey and the Sudan have futures which include, for a period at least, self-sufficiency in food. The others all endure significant food deficits and these deficits are rising. The measures taken by the government of Saudi Arabia to develop groundwater to produce food including food staples such as wheat have been remarkable, in that it is estimated that the agricultural sector contributed eight per cent of the Saudi GDP in 1990, an extraordinarily high level in an oil enriched economy. But these policies are neither economically nor ecologically sustainable. Water withdrawals are far beyond natural recharge and the capacity to subsidise the use of irrigation water even for an economy such as that of oil-rich Saudi Arabia has to be questioned in the light of the military events in the Gulf in 1990 and 1991 when it was revealed that not only was Saudi Arabia's economic stability dependent on the will of the Western industrialised community, but territorial security was also dependent on the whim of the military will of the same industrialised countries. Chasing the fantasy of food self-sufficiency (Allan 1983) by Saudi Arabia is as irrelevant as pretending that it can be militarily secure. Misallocating funds to the achievement of either the agricultural or the military fantasy actually weakens the economic position of Saudi Arabia while strengthening the economies of the industrialised countries which supply agricultural equipment and infrastructures on the one hand and military equipment and defence infrastructures on the other.

The most interesting feature of Table 1 is the extent of the estimated water deficits in the national economies of the Middle East and North Africa. All of these deficits are rising with the increased demand for water both from agriculture and the other sectors of the respective economies. Yet no country has renounced food self-sufficiency as a major feature of national policy except very briefly, Israel, in the first half of 1991. But this glimpse of the direction which all governments of the region will ultimately have to embrace was very brief indeed as the posture was uncomfortable for Israel internationally and was overtaken by the unexpected acceleration of the Peace Talks at which it was not possible for Israel to indicate that it could cut water consumption. The heavy rains of the winter of 1991-92 also had their political influence in that they enabled those managing national and local water to relax as they watched water storages, such as Lake Tiberias/Kinneret rise and the coastal aquifers recover. These had been at crisis level during the preceding three years of severe drought.

The historical, psychological and political backgrounds to the development of food policy and related water allocation are very important. Governments of almost all countries find that there is a natural political alliance between apparently responsible leaders and officials on the one hand and the rural community which produces food on the other. The former want to ensure national security including basic food needs. The rural community is the major element in the economy enabling food production and also therefore the major enabling element in the achievement of a country's potential security with respect to food. The natural alliance between those responsible for food security and those capable of providing it dominates policy making in the variously endowed economies of the water scarce Middle East. It also dominates policy making in most economies throughout the world not least in the EC with profound and distorting consequences for world trade in food and for the tormenting discussions in the GATT conferences. But the EC and the Middle East while resembling each other in terms of area and the size of population are very different with respect to water resource endowment and economic competence. In the EC water is rarely a constraint while it is a constraint in all countries except Turkey, the Sudan and the Lebanon in the Middle East. Yet in both the Middle East and the EC countries, despite their differing water resource endowments, water in the agricultural sector is regarded as virtually a free good and in many parts of the Middle East as a real free good. The dangerous fallacy underlying agricultural and especially food production policies of the countries of the Middle East is that water is free. This assumption lethaly distorts the expectations of the farming community and also prevents officials at all levels from making rational judgements concerning the allocation and use of water as the real costs of water are not evaluated in the sectors that use it. If the real costs of water were taken into account, preferably in procedures of environmental accounting (Pearce et al 1990) where the future costs of current policies would also be counted, then water would be allocated to uses more beneficial to the economy as a whole in the long term. At present users of water have no incentive to use water efficiently and governments have no incentive to realise efficient returns to water as there are no institutions or mechanisms which effectively enable its value to be recognised in transactions of distribution and use by either individuals or by the state.

Classification of Middle Eastern countries by population, water resources and the competence to import food.

Population data for 1990

Country	Population '000	% of total regional population	%
Countries self-sufficient in water or able to purchase food			
Water surplus countries			
Turkey	56277	17.1	
Sudan	25191	7.7	
Lebanon	3000	0.9	
Total	**84468**	**25.7**	
Major food importers competent to purchase food			
Iraq	18914	5.8	
Saudi Arabia	14902	4.5	
Libya	4546	1.4	
Kuwait	2141	0.7	
UAE	1592	0.5	
Oman	1554	0.5	
Bahrain	504	0.2	
Qatar	439	0.1	
Total	**44592**	**13.6**	
Oil economies which are major food importers, with serious water constraints and limited purchasing power			
Iran	56925	17.3	
Algeria	25056	7.6	

Total	81981	25.0	
Total of water or economic surplus countries			64.3

Countries with food & water deficits and food purchasing problems

Major economy with water constraints and purchasing constraints			
Egypt	52061	15.9	
Total	52061	15.9	
Other economies with food deficits and water and purchasing constraints			
Morocco	25091	7.6	
Syria	12533	3.8	
Yemen	11612	3.5	
Tunisia	8175	2.5	
Israel	4656	1.4	
Jordan	3154	1.0	
Total	65221	19.9	
Total of water or economic deficit countries			35.7
Overall total	328323	100.0	100.0

Source: World Bank

Countries self-sufficient in water or able to substitute for it by purchasing food on the international market

1 **Turkey** and **the Sudan** may have economic problems but they cannot be attributed to their water resource endowment. **The Lebanon** does not have serious water problems but does of course have serious political problems which make investment and institutional development difficult.

c85 million people, c26 per cent of the region

2 The relatively low population **oil rich countries - Iraq, Saudi Arabia, Libya, Kuwait, UAE, Oman, Bahrain and Qatar** have no real water resource problems; they only arise if they decide to allocate water to agriculture. They will for the foreseeable future be able to acquire food from the world market. They should certainly not be using scarce water to raise food at a period in economic history when food is being traded cheaply. Iraq has temporary problems.

c45 million people, c14 per cent of the region

3 The relatively large population countries with oil, **Iran and Algeria**, have serious agricultural problems and Iran has political and international relations circumstances which means that it does not fall into the same categories as the other oil rich countries or into the protected category of Egypt. Iran will need to address both its

traditional sector farming and its modern sector pursuing policies and practice based on the five guiding principles and goals shown in the table in Annex 1.

Algeria has similar agricultural choices to those of Iran although it does not have a well watered province such as Iran enjoys on the southern shores of the Caspian. Oil revenues have not enabled Algeria to mobilise successfully its scarce agricultural resources and it will require particularly effective policy formulation and implementation if it is to create a viable rural economy on the basis of its scarce water.

c82 million people, c25 per cent of the region

The above countries comprise 64 per cent of the total population of the Middle eastern and North African region.

Countries with food and water deficits and economic problems which make food purchases difficult

4 The large population country with only modest oil resources **Egypt** is such a special case that its problems have for the moment been solved by politically motivated external funding. The US Government has apparently assumed responsibility for the serious and deteriorating water gap of Egypt by providing grants and loans which almost exactly match the food/water deficit reflected in the progressively increasing food import bill of Egypt.

c52 million people, c16 per cent of the region.

5 **Morocco, Syria, Yemen, Tunisia, Israel and Jordan** are countries with significant water resource constraints and with the exception of Israel they have limited ability to mobilise investment to improve water management systems. They will in future have to address their food deficit problems by generating foreign exchange in other sectors with which to purchase food and thereby reduce pressure on their scarce water resources. Israel and Jordan are already, if unwillingly, well down this road.

c65 million people, c20 per cent of the region

These food deficit countries which have food purchasing difficulties comprise only 36 per cent of the population of Middle Eastern countries.

The above analysis suggests that the first three categories of countries do not face serious water resource problems if water could be effectively allocated and managed. They either have sufficient water or they do not need it since they can substitute oil revenues to purchase food which cannot be produced at home because of water shortages. Two oil economies, Iran and Algeria, currently have balance of payments and political difficulties which are impairing their capacity to develop but will still be able to underwrite their food deficits with their limited oil revenues. The fourth category, Egypt, cannot substitute for water on an economic basis but it has been very successfully substituting for water through the acceptance of political support from the United States since the mid-1970s. While this is not a satisfactory long term solution, and is even one which the United States probably cannot afford to sustain, it is also very likely that other sources of funding would be available from other OECD countries if the United States signified that it could not continue to fill Egypt's water gap. There is, however, a much clearer message concerning how Egypt itself will substitute for water in future. It will be through the strengthening of its economy in the industrial and service sectors so that they generate the foreign exchange with which to purchase the food needed to feed the country's rising population. This is the normal pattern of economic activity for economies as they develop. OECD investments will be directed to accelerate this process and thereby gradually ensure that Egypt become a self-sufficient economy despite its inability to be food self-sufficient. The demographic position of Egypt will continue to deteriorate but there will be a reduction in the rate of increase in population as the economy improves.

The 36 per cent of population of the Middle East and North Africa in the remaining categories is currently exposed to difficult water resource circumstances and these will for the foreseeable future continue. These countries will face the greatest challenges in substituting for water in the short term at least. Two of the countries, Jordan and Israel, are close to recognising the impossibility of allocating the 70-80 per cent of water of the national water budget to agriculture, although there will be many years of tormented Peace Talks negotiations before the policies are put in place. Since agriculture contributes less than three per cent to the Israeli economy and about seven per cent of the Jordanian economy the real consequences of reallocating water will not be great, although the internal political reactions may be considerable. Syria, Morocco and Tunisia will have in due course to adopt the same reallocative policies through an evolving ability to substitute industrial sector revenues for the deficient water but the move will only come after their existing water resources have been more effectively reorganised. The problems of Yemen are unique in that the water allocation and management institutions require considerable development.

Available water resources

The sources of water available to governments aiming to provide their citizens with the entitlement to food in arid and semi-arid countries are:

Precipitation falling within the national boundaries
Surface water deriving from within the national boundaries
Groundwater deriving from within the national boundaries
The water content of imports, especially that in food imports

Surface water imported from outside the national boundaries - less that exported
Groundwater deriving from outside the national boundaries - less that exported

Less the water exported in products, especially in agricultural exports.

None of the water listed above enters international trade, and therefore has no price, and even the water integral to the production of the traded agricultural commodities is only indirectly valued. None of the surface water or the groundwater which crosses international boundaries is subject to market processes and it could be argued that international law has been relatively ineffective in moderating the use of water which crosses boundaries in the Middle East and northern Africa in times when riparians actually want to develop water as opposed to when they have no competence to do so. Although in times when there is no pressure on the resource as for example in the 1970s in the case of the signatories to the 1959 Nile Waters Agreement, between Egypt and the Sudan, the legal undertakings appeared to be significant.

International water does not at the moment enter trade and there are few examples of agreements which attribute costs to investment and values to benefits through the development of schemes aimed at realising additional water, such as the aborted Jonglei scheme. The latter type of arrangement was accommodated within the 1959 Nile Waters Agreement when Egypt and the Sudan agreed to invest jointly in, and benefit equally from, the realisation of additional water from the Sudd swamps. Principles of equity were observed vis-à-vis the two national entities, although not with respect to the communities of the southern Sudan who ultimately took action to veto the project. But at no point has there been an attempt to identify the economic cost of the water or its value. That Egypt was prepared to invest in the scheme implies that Egypt valued the envisaged new water but there has been no attempt to analyse the anticipated new water in terms of its value in alternative uses in the two investing countries. We shall see later that effective allocation and management of water is best mobilised if principles of economics as well as those of equity are deployed as a basis for developing shared water resources.

The value of water

In a sustainable commercial market producers and consumers relate to each other through prices which enable both of them to pursue viable livelihoods. There are many examples of vital and apparently successful markets which are by no means straightforwardly commercial and which serve other interests than those of producers, marketing agents and consumers. Many markets have to bear significant intrusions for example by government institutions which extract taxes without impeding the movement of commodities and there are many customs levies which signifcantly affect the prices charged to consumers. The substantial taxes placed on oil and tobacco and oil products at one or more points in the commercial cycle are examples of how governments as well as producers and traders can benefit from the marketing of a commodity. Thus the price which a consumer is prepared to pay is not necessarily related to the cost of producing and marketing a commodity and there are many individuals and institutions which would be prepared to take advantage of circumstances where there is a substantial difference between the cost of production and the price which consumers are prepared to pay.

But oil and tobacco are not good analogies for water. Water does not anywhere in the Middle East and northern Africa command a price which is substantially higher than the costs of making it available to users except in the small but valuable sector of bottled water provision. And because there are very few recognised markets for water in the Middle East at the international or at lower levels in the economies of the region it is not possible to identify price elasticities for water. There is certainly a large and unsatisfied demand for free water but there is no way of testing what the demand would be for water charged at say 25 US cents per cubic metre in the agricultural sectors of Middle Eastern countries. It is meanwhile an economic fact that there are many regions in the world where water is much more abundant than in the Middle East and the comparative advantage of such overseas users of water, at least in mobilising water in the bulk required for agriculture, are very considerable.

One way of gaining an indicator of the **value of water** is to determine the cost of delivering it. Even when it is freely available at the border or below the ground there are costs associated with the delivery of the water to the farm or to an industrial or domestic user. In some cases quantification is easy. For example the delivery of water from the Great Man-Made River scheme in Libya is estimated to be about one US dollar per cubic metre. Delivering water at the rate of at least 10000 cubic meters per hectare to farms in Egypt must be at least 25 US cents per cubic metre if all the costs of engineering, administering the water together with the energy costs of lifting it up to the fields, either by animal power in the past or by fossil fuel energy now, were to be taken into account. In the United Arab Emirates with its remarkable and lavishly landscaped cities of Abu Dhabi and El Ayn and other green amenities, as well as a number of agricultural projects, about half the water budget is provided by desalinised water and the rest from over-pumped groundwater, the cost of water must be multiples of US dollars per cubic metre.

The cost of water in other parts of the world is not politically relevant to Middle East governments but it is relevant in this discussion to point out that in most European countries the price of water is already two US dollars per cubic metre delivered to domestic users and the trend is to adopt such prices.

Another way of trying to gain a notion of the value of water is to determine **what it would cost to gain access to new water.** There are no rules which hold throughout the region in that some countries enjoy significant rainfall, while others have as yet undeveloped water resources which is in sharp contrast to the majority which do not. Also the perceived value of water differs from sector to sector. Domestic users could readily afford and might find it economically reasonable to pay US$25 per year per head for the 100 cubic metres of water per person for annual needs for water priced at 25 US cents per cubic metre, but farmers would not be able to contemplate the use of water costing between US$ 2500 and US$ 4000 per hectare per year which would be the cost of their annual water requirements so priced.

A very crude indicator of the value of water could also be derived from the **cost of substituting for it in imported food.** Egypt imports annually grain valued at over US$ 3 bn per year and rising and there is additional food aid. (World Resources 1992-93) To have grown the volume of grain imported at the level of the early 1990s at home would have required annually about thirty cubic kilometres (30 bn cubic metres) of water. Assuming the real cost of Egyptian water to be about one third of the cost of such imported production if the grain could have been produced in Egypt then it can be further assumed very approximately that the imported water could be valued at about substantially less than 10 cents per cubic metre. In other words a very keen price for water indeed for an arid country facing severe water constraints. There is no way that water could actually be delivered to Egyptian fields at 10 US cents per metre. Egypt is currently gaining access to the equivalent of 30 cubic kilomtres of water annually for about $US one billion. The calculations could change significantly of course if Egypt's grain yields were to improve or world food prices were to change.

We do not yet have the means to determine accurate costs or values for Middle Eastern water and there are no markets to help those interested in throwing light on the capacity of users to pay for priced water, but it would seem that importing water integral to imported commodities is the best way to gain access to new water for the categories (categories 4 and 5 in Table 2 above) of country facing current or imminent water shortages. Egypt, Jordan and Israel, have few, or no, other options to gaining access to new water unless there are radical shifts, in the case of Egypt, to its approach to the international management of Nile waters.

In summary the cost of delivering water other than rainfall in Middle Eastern and north African countries is likely to be between 10 US cents and US$ 2 per cubic metre. Meanwhile the capacity of users to pay is poorly developed and as a consequence poorly understood. The real value of water for the acquisition of those commodities which can be imported would appear to be about 10 US cents per cubic metre. For water delivered to households for which there is no feasible imported source, other than bottled water, the value is probably between 25 and 50 US cents per cubic metre in the non-oil countries and a much higher figure in the oil rich states.

The need for water

The governments of Middle Eastern countries have been successful in ensuring that their citizens have access to a basic entitlement for food. (Sen 1981) The propensity to consume at levels far beyond the basic entitlement have been demonstrated numerous times in the region as the various oil-rich countries brought their oil to the world markets and gained access to unprecedented purchasing power. The value of food imports rise at upwards of 15 per cent per year in the early phase of the expansion of an oil economy and none of the oil rich Middle Eastern and northern African oil producers has had the water resources to underwrite such expansion in food consumption. But it is not just the oil-rich countries which have maintained entitlements to food. Egypt has been particularly successful despite the challenge of its demography and resource endowment.

The issue of food entitlement may seem irrelevant since the governments of the region have apparently successfully addressed this key economic and social challenge. If it had not been addressed the political consequences for the governments of the region and the region's general stability would have been dire. The success of Middle Eastern governments and their patrons in handling the sensitive social and political issue of food entitlement can be contrasted with that of the governments of similarly poorly endowed countries south of the Sahara. Here the inability of governments to address the food entitlement issue and the unwillingness of the international community to assist at an equivalent level to that achieved in key Middle East countries, has had dreadful consequences for the peace, stability and economic development of Africa south of the Sahara.

It is argued above that the food gaps, expressed crudely by food imports, in the individual countries of the Middle East and northern Africa represent their water gaps. The challenge of the food/water gap in the context of the food entitlement imperative has had a determining effect on the approach of governments to the management of natural resources and especially of water. All the countries of the region have versions of food self-sufficiency policies which are quite inconsistent with the capacity of their natural resources. (Allan 1983) As a result these natural resources are not being managed according to sound ecological and economic principles. Water resources have been depleted and misallocated, as in the case of Saudi Arabia, the UAE and Libya, or misallocated in the case of Egypt, Israel and Jordan.

The rhetoric of food self-sufficiency is proclaimed loudly by the political leaderships of the region, and echoed loudly by their farming communities which understandably want to ensure their present and future livelihood by meeting the national needs as well as by the communities of engineers and officials which see a similar coincidence of altruistic and self-interested goals. Despite this rhetoric governments facing real water shortages in the Middle East and northern Africa, namely Egypt, Israel and Jordan, have all solved the major element of their food staple deficiency by importing water in food. The rhetoric of self-sufficiency is socially and politically inspired and is therefore very powerfully driven but is economically and ecologically unsound. That governments are following economically and ecologically sound policies, namely of importing food, while proclaiming an economically and ecologically unsound one is because water is perceived as a free or nearly free good. If economic principles were deployed the allocation of water would be re-examined as well as the capacity to be self-sufficient. If principles of environmental economics (Lutz and Munasinghe, 1991, Pearce et al 1989 & 1990) were to be deployed the ecological impacts of water misuse would be taken into account as well as the interests of future generations of the region's peoples. Donors and descendants don't have political influence on contemporary attitudes.

The need for water in the region is palpable. The sources of new water are limited and while there is scope for the improved management of water which could lead to a doubling of the agricultural productivity it will be circumstances external to the region which will enable its peoples to have access to adequate supplies of food. The major uncertainty is not so much can the countries of the Middle East and northern Africa gain access to more new water. Rather it is can the Middle East as the major food importing region of the world, and with no indigenous solution to its water problem count on the global market to supply food in sufficient quantities and at affordable prices in the decades ahead? In other words is there another constraint on the ability to provide food entitlements than the Middle East's water resource endowment? This is such a large subject that it cannot be discussed here. Suffice it for the moment to say that officials and scientists from the region should be studying with great care the issue of future global food supplies and the likely future prices of food staples.

The costs of gaining access to 'new' water

It has been argued above that there is very little 'new' water feasibly available in the Middle East and northern Africa and the cost of delivering existing water varies greatly. Meanwhile the costs of over one US dollar per cubic metre for delivering new water by means of technologies such as desalination and the development of remote groundwater are prohibitively expensive to more than two thirds of the governments and peoples of the region.

It behoves those responsible for ensuring supplies of water in the countries of the region to examine all possible solutions to the particular water supply predicament which confronts them. Egypt has by far the biggest problem in terms of the volume of water needed. It could absorb productively, and with significant social as well as economic benefits, another ten cubic kilometres of water annually. On some assumptions, namely the use of a volume of water which would enable complete self-sufficiency in food insofar as other climatic, soil and economic circumstances would reasonably permit, it needs an additional thirty cubic kilometres of water to meet even current agricultural water needs.

Taking a radical view, although not an unfamiliar one in terms of the century long debate over Nile management, (Hurst 1952, Hurst and Simaika 1965) the water which evaporates from Lake Nasser/Nubia, could be used more productively if the storage of that water were to be sited elsewhere. Such a change in policy is not on the current agenda, however, since it appears, on the basis of Egypt's interpretations of the predicted behaviour of upstream riparians, to contradict Egypt's economic security as well as reducing the capacity of the existing economy to produce hydropower. It is not yet publicly recognised that the worst assumptions concerning the behaviour of upstream riparians, from Egypt's point of view, could obtain whether the storage capacity at Aswan is available or not . In other words the operation of the storage system at Aswan would become impossible if the flow of the Nile was to be reduced by upstream withdrawals.

Meanwhile the power generation capacity of the hydropower station at Aswan has become a minor element in the national power budget at under ten per cent and falling. Circumstances are very different from those which obtained when the sets were commissioned in 1970 - the dam was officially opened in May 1971. There are, therefore, alternatives to the energy generated by the Aswan power station. These would be less eco-friendly than hydropower and less economic but they would be more conveniently sited.

The as yet unlikely option of storing Ethiopian water in upland Ethiopia where annual evaporation from open water is about a third of that at Aswan is nevertheless worth serious consideration. If water could be obtained at 50 US cents per cubic metre the future economy of Egypt might be able to absorb this cost. At the point at which water was being supplied at such a cost it would be possible to argue that this marginal cost of Egyptian water would make the use of water in agriculture non-economic and it would be more economically effective to use the water currently being used in agriculture in actvities which could support the 50 US cents per cubic metre cost. National, nor even domestic economies, rarely accord with such rational economic principles, however, and the notion of enabling a flow of water takes precedent over the rational economic use of such water.

Without going into the wide range of options which could be available in managing the water at Aswan, from the status quo to storing various proportions of existing average storage - even as far as storing no water in the structure and using the silt deposits of the past two decades at the bottom of Lake Nasser/Nubia for agricultural production, it is possible to identify and evaluate some approximate scenarios which would permit additional water to flow into Egypt. If for example Egypt were to contribute to the construction of storage structures in Ethiopia and pay an annual sum to Ethiopia covering the capital costs and a notional sum per cubic metre of 'new water', it would be possible to realise a volume of water of say five cubic kilometres annually, for a cost of say $US 2.5 billions annually, subject to the agreement of the Sudanese Government and to the capacity of the Sudan's water management institutions to regulate the import and export of water. Smaller, and larger volumes of water could be realised for proportionate rates of investment plus water charges. Similar principles it should be pointed out have already been adopted at least with respect to investment in the 1959 Nile Waters Agreement between Egypt and the Sudan. To date the water losses at Aswan have appeared to be a reasonable price to pay for the security of supply, but the system is entering a new phase with the development of water using activities in Ethiopia and in addition with the Sudan approaching the limit of the allocation agreed with Egypt. The security of existing flow to Lake Nasser/Nubia can no longer be politically assured never mind that of 'new' water. Meanwhile the nature and extent of the economic and social torments of reduced flow have already been demonstrated in the 1980s when the reasons for recurring levels of reduced flow were natural rather than political.

In the case of Egypt for the moment there is no question that is much more economically effective to import water in food than to mobilise new water which would entail the uncertain and very difficult task of sharing the responsibility of constructing new structures in upland Ethiopia. Constructing the High Dam at Aswan was a very difficult financial and logistical task in partnership with a not very economically competent partner the former Soviet Union. A partnership with an entity with the economic problems of Ethiopia is not in any sense attractive.

It has been suggested that Egypt's water, currently treated as a free good in the Egyptian economy, could be valued at under 10 US cents per cubic metre, being the cost of importing water in food, and 50 US cents per cubic metre or more being the cost of mobilising 'new' water in cooperation with upstream riparians. Another option recognised as a real possibility by those who consider that the perceived strategic value of water would move governments to go to war to secure their water supplies is the military option. Little regard is given by such analysts to the cost of military operations with respect to the value of the resource being protected. Modern technological wars can cost one billion US dollars per day and even campaigns of more modest military scope would cost multiples of billions of US dollars over a short period and any protracted and geographically remote campaign would be beyond the economic competence of any Nile riparian or of any other Middle Eastern state. 'New' water gained by military means would be prohibitively costly. Which does not mean to say that military initiatives will not be taken. The recent Gulf War proves very well the matter of the costliness of war both to winners and losers, and for the latter the dangers of disrupting access to the world economy for both imports and exports. That political leaders are unwilling to anticiapte the real costs of military conflict is of much greater significance than any potential conflict over water.

The social value of water: and the political implications

Politicians in the Middle East have to struggle with the dilemma that water is almost everywhere treated as a free good, and especially in the demanding agricultural sectors in individual countries where economic returns to water are poor. It is proper, however, to examine what the social returns to water are and to estimate the political significance of such returns.

Water is job creating and enables livelihoods for families and communities. In economies such as those of Egypt and Jordan it creates many jobs per 1000 cubic metres in industry but possibly only 25 per cent of the livelihood of a single family if the water were to be used in irrigated farming. There are examples of intensive irrigated crop production throughout the region in horticulture where more livelihoods are enabled but such production is not by any means the norm.

Those who have derived their livelihoods from irrigated farming and the professionals who maintain the irrigation structures and systems have argued very powerfully that there should be no change in the system of water provision and with such success that there has been no example of reductions in irrigated farming activity except through the loss of farmland to the construction of dwellings as for example in Egypt or through the salinisation of land in a number of the catchments. The use of water on 'new lands' has brought significant social returns in Egypt and Jordan and of course in Turkey and in the Maghreb countries. But in the oil-enriched countries the social returns are difficult to evaluate in terms of the nationals of the individual countries. There have been significant returns to immigrant labour in all the Gulf countries either in agriculture or in the very significant water using activity of the provision of green amenity. The amenity return is particularly difficult to quantify, however.

There have been no cases in the region, in the Arab countries at least, where political leaderships, considered to be authoritarian and even secure, have challenged the perception that the social returns to water use in agriculture are a sound basis for the allocation of scarce water. Despite the sound principles enunciated by the Prophet calling on Muslims to cultivate their world as if they would live forever, presumably the most succinct statement of 'sustainability' yet coined, this particular injunction is not part of the polices of states, government sectors involved in water use or even by individual farmers. Only Israel has for a few weeks apparently stated that it intended to pursue such a policy during the drought crisis of the spring and early summer of 1991, before the acceleration of Peace Talks meetings made the policy strategically untenable, at least until secure deals on water can be agreed with neighbouring riparians.

Conclusion

The dominant perception in the Middle East and northern Africa of the basic justice of the right of access to free water drives water allocation policies and practice in the region. That it is widely recognised that there are theoretical as well as practical limitations to legal regimes promoting economic efficiency (Sandbach, 1980, p 43) is not yet an idea in currency in the region. It is realistic, therefore, for the moment to assume that Middle Eastern Governments will not confront their farming and professional constituencies with calls to reduce water allocations to agriculture. The rigidity of this feature of the water allocation and management equation is possibly the major source of international tension with respect to water and of potential military conflict. As long as governments in the region have had the option to substitute for water by importing food and especially staples which have been available at historically low prices, as during the past two decades, there has been no necessity to confront domestic agricultural interests. Arguments for pursuing policies guided by principles of economic efficiency and ecological sustainability with respect to indigenous scarce resources have, therefore, been consistently ignored because it has been possible to gain access to relatively cheap water in the form of the water content of imported food. The natural resource endowment of the region dictates that this outside source of water can only become more significant and it is urgent that all the Middle Eastern economies, and not just the oil-rich economies, gain the capacity to trade for food in the global market. In addition it is also essential that such governments, and where appropriate their sponsors, carry out critical evaluations of the capacity of the world to produce sufficient and affordable food for the growing populations of food importers in the decades ahead whether the environment of the Middle East and northern Africa will be affected by global climate change or not.

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A RESEARCH FRAMEWORK FOR INTERDISCIPLINARY AND INTER-PROFESSIONAL EVALUATION OF WATER RESOURCE UTILISATION AND MANAGEMENT FOR THE MAXIMISATION OF THE BENEFICIAL USE OF WATER IN ARID AND SEMI-ARID COUNTRIES

Management goals, ideal guiding principles for management, management policies and instruments

Goals of water using activity	Guiding principles	Policies	Instruments: Institutional	Instruments: Engineering
Facilitation of political circumstances to enable optimum resource use	*Minimisation of conflict; promotion of co-operation in the areas of water use at all levels*	*Conflict resolution; identification of reciprocal arrangements to pro- ote economically and socially beneficial water use and the installation of such arrangements*	*Water sharing arrangements - traditional and new; recognition of water rights & of the ownership of water; consultation between legislators, officials (local, national and international) - ('democratic' institutions); introduction of new economic and legal instruments to shift access to water to the most beneficial users and uses*	*Earth observation (remote sensing); in situ monitoring & information systems*
Productivity *('Development')*	Returns to water, sustainablity of water supplies.	Investment in sectors, activities and crops which bring optimum returns. Economic efficiency and market instruments relevant	Water pricing, agricultural subsidies, crop pricing and other intervention. Advanced pricing systems imply water metering. Agreements both local and international. Subsidies and pricing imply water metering.	Large and small civil works for water abstraction, treatment, delivery and distribution, recycling, water metering. Water efficiency studies and water management programmes.
Equitable use	Social benefits	Identification of the social benefits and disbenefits of water use and the promotion of beneficial uses.	Land reform, water regulation, new legislation, reduction of illegal water use, changes to traditional rights	Water control systems, irrigation management.
Safe use	Provision of adequate volumes & quality of water	Identification of appropriate systems - traditional and new - promoting the safe provision of water use, re-use and disposal	Monitoring, legislation, regulating institutions (traditional and new)	Planning for future demands, water control systems, water treatment, maintenecance for reliability.
Environmentally sound use *('Conservation' Cultivating the world as if you would live forever.)*	Sustainable use of landscape and amenity including intangibles	Identification of appropriate systems - traditional and new - for sustainable water use	Monitoring, legislation, regulating institutions (traditional and new)	Quality monitoring, water treatment, wastewater treatment, waste disposal

ANNEX I

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Isaac/Shuval (Eds), Water and Peace in the Middle East

A novel approach to the allocation of international water resources

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Abstract

This paper is an attempt to present a formula for sharing international water resources. The formula is based on the concept of natural capacities and is compatible with the principles of international law. Unfavorable consequences relating to the expected unconformity between needs and shares is proposed to be resolved through treating water as a trade commodity.

1. INTRODUCTION

The problem of apportioning a limited supply of water between two or more communities is not new. However, the present magnified importance of the problem in many parts of the world is the result of modern conditions. Where the problem is purely domestic, serious difficulties seldom arise. If the peoples involved in a dispute over water were all under a single impartial, benevolent and efficient government, such a government would have little difficulty in reaching and carrying out a fair and reasonable apportionment. No passions were aroused when the British Parliament set up an authority empowered to draw water from the middle of Wales to supply the great urban areas in Birmingham. In such a case, the national legislature takes the responsibility of deciding that the needs of one area are of more weight than those of others.

In Federal States, quasi-international problems may arise, and they may raise serious difficulties if the federal constitution makes no explicit provision for their solution. Such a provision is found in Article 705 of the Swiss Civil Code, which provides that the Federal Council shall have the power to decide conclusively at water disputes which may arise between different cantons. The absence of such a provision in the United States constitution has resulted in a number of inter-state disputes being brought before the Supreme Court, to the evident embarrassment of that tribunal. In practice, the line taken by the court has been to avoid, so far as possible, giving decisions upon purely legal grounds and to do all in its power to induce the litigants to arrive at a solution by mutual agreement. In pursuing this policy, the American Supreme Court has always been able to rely upon the co-operation of the federal government.

Where the involved parties are politically independent, owing no allegiance to any superior or common authority, the solution of any given problem can only be effected either by agreement or by force. This is basically due to the deficiencies inherent in today's international legislative structure and the absence of enforcement tools. Agreement between countries in a dispute over water may take various forms and could be direct or indirect. Indirect agreements involve reference to some third authority, but this is only possible in so far as both parties have confidence in the competence and impartiality of the referee. If the parties are satisfied that the difference between them in purely one of legal right, and this in itself would mean a very large measure of agreement, then it is open to them, as the United Nations Charter provides, to have recourse to the International Court or to some other agreed tribunal. But reference to court is obviously little more than a gamble unless there are clear and accepted rules of law which the court can apply to the facts before it. This is obviously not the case regarding international water rights where the law of nations has so far remarkably failed to keep pace with modern developments. Furthermore, it is clear that any sense of feebleness of stands felt by one party, especially if were the stronger, would be reflected by rejection of that party to resort to arbitration. Under the current international law, there is absolutely no way to force such a party to go to the legal fraternity opposite to its desire.

2. INTERNATIONAL WATER LAW

The law which regulates the rights and obligations of riparian states to international rivers is public international law. This law does not cover groundwater resources and is not binding. Sources of international law include international treaties, international customs, general principals of law, judicial decisions and opinions of writers.

Regarding states rights to international surface water resources, legal literature implies four general doctrines which in many cases are contradictory and/or ambiguous. A brief survey of these doctrines is presented in the following paragraphs to trace the legal viewpoints related to use and distribution of internationally shared water resources.

The first doctrine found in legal literature on international water rights is that of Absolute Territorial Sovereignty (ATS). According to this doctrine, which is usually considered to be extreme, a riparian state has the absolute freedom to utilize the water flowing in its territories regardless of any effects upon other riparian states. Concerning groundwater, the doctrine is explicitly stated in the British legislation organizing water rights. Article 66 of the British Law of Torts on Disturbance of Water Rights states: "*There is, however, no right to the continued flow of water which runs through natural underground channels, which are undefined or unknown, and can only be ascertained by excavation*". In his explanation of the law, the British solicitor Sutton (1946) clarifies that, "*The owner of land containing underground water, which percolates by undefined channels, or defined but unascertained channels, has the right to divert or appropriate the water within his own land so as to deprive his neighbor of it, whether by intercepting and stopping its flow to his neighbor's land, or by causing it to drain away from his neighbor's land instead of remaining there. The same rule applies to common surface water rising out of spongy or* *boggy ground and flowing in no defined channel. If the law were otherwise, no man could safely drain or sink a well in his own land*".

The obvious extremism of the ATS doctrine has led it to be rejected by international customary law. Even the United States, which invoked this doctrine in 1895 during its conflict with Mexico over the Rio Grand River, does not accept this doctrine anymore.

On the other end of the scale is another extreme doctrine, the doctrine of Absolute Territorial Integrity (ATI). According to this doctrine, a riparian state may not use waters flowing within its lands in a way that could have unfavorable consequences on other riparian states. The Absolute Territorial Integrity doctrine was invoked by the Egyptians in 1952 before the Nile Commission which clearly rejected it. Again, this doctrine does not form part of present international law.

The third doctrine is that of Community Co-riparian States (CCS). The CCS doctrine favors ignoring political divisions in order to achieve '*maximum utilization*' of international water courses. This, of course, requires the existence of a high level of integration between the riparian states. This situation exists only in a few parts of the world. Although the doctrine is highly tentative, the doctrine's application difficulties are increased by the absence of a rational measure to determine what the '*maximum utilization*' of a given water resource is. The doctrine is not yet considered as a part of the basis of present international water customary law.

Midway between the above-mentioned two extreme doctrines of ATS and ATI, there exists a temperate doctrine which is the prevailing in today's international law, the doctrine of Limited Territorial Sovereignty (LTS). According to the LTS doctrine, a riparian state is not allowed to utilize the water of an international river in a way which causes '*significant harm*' to the '*reasonable utilization*' by other riparian states. The doctrine has the support of many international arbitration awards, state practices, resolutions of international institutes and many writers.

Despite the unfortunate fact that international law is relatively boneless in judging the legitimacy of claims regarding water rights, particularly groundwater, the principles of international law regarding rights to water resources could still be used to weight contrasting claims and counterclaims of states involved in dispute over water. In addition, the principles of international law should form the basis for the needed appropriate solution.

3. ESSENCES OF ALLOCATION

According to the LTS doctrine, the prevalent doctrine in present water international law, utilization of international water resources should be '*reasonable*' and '*equitable*', meaning that a riparian state is prevented from utilizing water in a way which causes '*significant harm*' to the '*reasonable utilization*' of other riparians. These terms allow a great deal of latitude for interpretation, making it difficult to actually detect progress in a quest for objectionable determinants. It is significant that '*rationality*' and '*equity*' are seen by the law of nations as the appropriate basis for the allocation of water, but the question remains - how can '*rationality*' and '*equity*' be measured? It should be noted that the word "*equitable*" is not synonymous with "*equal*". If the two words were synonymous, the problem of allocartin a water resource would be merely a matter of arithmetics, so that, for example, Israel, Jordan, Lebanon, the Palestinian West Bank and Syria would each have a 20% share of the flow of the Jordan River.

Lately, a number of prestigious international institutions have formulated lists of the factors which should be considered relevant in the process of allocating water shares '*rationally*' and '*equitably*'. These factors, as defined by the International Law Commission of the United Nations, can be grouped into two categories: (1) natural physical factors (geographical, climatological and geological) and, (2) enviro-socio-economic factors (needs of the riparian states and their populations, effects of use on other states, existing and potential use, conservation and protection of the water resource, and availability and cost of other alternatives).

The importance of the natural physical factors in approaching the problem of apportionment of shared resources is self evident. The significance of geographic situation and other criteria is appreciated by all doctrines of international water law which deal exclusively with rights and obligations of riparian states to water resources. This implies that political entities gain rights as well as responsibilities to water resources simply because of a geographic intersection with a given body of water. Thus, the concept of sharing water applies only, and exclusively, to resources which are practically shared and to states which are riparian to that shared resource.

Rates of precipitation and other climatological factors always have been important is shaping maps because of their bearing upon human presence and activity. Of equal importance in drawing natural water resources distribution maps is geology. An excellent example comes from Jordan where a geological structure, the Arja-Uweina Flexure, controls the flow of the country's most important subterranean water resource, the Amman-Wadi Sir aquifer system, tothe east and thus limits the potential for development in the Al-Jafr area. Also of importance are, of course, a number of other natural factors such as topography, geomorphology, hydrogeological setting and characteristics of rocks and soils, etc.

Relative to natural physical factors, dealing with enviro-socio-economic factors is problematic. How can one judge which needs are reasonable and which are not? How can a system of priorities take into account the conflicting demands of states? Is it possible or realistic to speak of allocating the world's resources on a per capita basis, so that China would get 25% of the entire resources of the world? Should the existence of alternatives be considered so that Canada, for instance, where 9% of the world's fresh water resources are found, should give up sovereignty over its resources simply because Canada is a state with plenty of alternatives? How can terms such as '*a significant harm*' be defined and measured? etc.

Often, answers to questions such as these may be as simple as they are not applicable. Answers of this type are best presented by suggesting that existing, or historic, use should have a special weight in formulating allocation rates. But how legal is this under international law? Article 7 of the Helsinki Rules, often considered to reflect international customary law, states that: "*...an existing reasonable use may continue in operation unless the factors justifying its continuation are overweighted by other factors leading to the conclusion that it shall be modified or even terminated*". In 1987, a perhaps more mature and more developed position was taken by the International Law Commission of the United

Nations. The commission reported that "*...neither existing use nor potential use is given priority*".

4. THE NATURAL CAPACITIES ALLOCATION FORMULA

Water is a substance that is naturally available and often abundant on our planet, but not necessary in accordance with human needs. While 9% of the world's fresh water is available only to some 0.5% of the world's population (the Canadians), forty thousand children -mainly in Africa- die daily for reasons related to quantitative and qualitative inadequacy of the water supplies available to them. On a worldwide scale, the fact that the world's natural resources, including water, are mal-distributed had created only little problems until recent times. The world's population has been always distributed according to the distribution patterns of natural resources. Ancient civilizations developed and flourished in the Middle East around water courses and near springs. Desert terrains such as the Empty Quarter and the Negev have always been sparsely inhabited. Nowadays, water resources available to many nations do not satisfy their needs. With the exception of islands, most geopolitical entities share their water resources with neighbors. As a result, many water-related international frictions have developed.

There is presently no regular system of binding international law that can supply clear-cut principles for the situation of conflict between nations sharing water resources. This is particularly true when shared water resources are subterranean. The question of controlling international water resources varies according to the distinct perspectives of different parties concerning their '*legitimate national rights*' in the disputed resource. Usually, involved parties 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 tends to be selective, choosing the legal principles that best buttress its own claims. This raises questions about the aptness of current international law with respect to settling disputes over water resources.

It was made clear in the previous section that allocation of water rights on enviro-socio-economic bases is problematic and could even be unjust. On the other hand, it is not unclear to the authors that allocation of water resources solely on natural physical grounds can result in some undesirable consequences. The most serious may be that some parties may be allocated more than they need, while the needs of others may not be adequately met. However, let us first show how could international water resources be allocated on natural physical criteria to move then to show how can unfavorable consequences be confronted.

In 1966, international legislation first dealt with '*international water resources*'. The Helsinki Rules of that year defined the unit with which international water laws deal to be the '*drainage basin*'. Article 2 of the Rules states: "*An international drainage basin is a geographical area extending over two or more states determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus*". It is believed here that the article's reference to underground waters necessarily relates to flow from springs contributing to the flow of the '*common terminus*' running on the surface. As for states of the basin, the Rules rule that "*A basin state is a state the territory of which includes a portion of an international drainage basin*". Thus, international law views the '*drainage basin*' as the unit of analysis for common surface water resources. But what about how international water deals with groundwater? In 1987, an additional legislative initiative of the International Law Association (ILA), the same body that proposed the Helsinki Rules, clarified that "*...the international drainage basin may be completely underground*". Having established that lawyers define the drainage basin as the critical unit of analysis of surface and subsurface water resources, let us see how hydrologists define their unit of analysis.

Wilson (1990) defines the unit of analysis for surface water as to be "*...the whole of the land and water surface area contributing to the discharge at a particular stream or river cross-section...*". The spatial extent of the catchment area is determined by the water-divide line, also known as the watershed. The water-divide is not purely controlled by topography as usually thought to be. It is perfectly possible for areas beyond the divide to contribute to the catchment due to factors other than topography - geology for instance. As for groundwater, hydrologists deal with subsurface basins. A subsurface basin is defined in space in a similar way to how a surface basin is defined, but in three-dimensions rather than two-dimensions.

Usually, water does not occur in closed or in simple environmental systems, this fact should be taken into consideration when dealing with such systems. Regardless of the degree of complexity, a balance usually can be prepared and used for analysis for any water system. The balance usually takes the form:

Input - Output = Change in Storage

The first term in the above equation represents the overall input to drainage basins. The second term represents combined natural and human-induced output. The balance between the two terms represents the volumetric change in water contained in the system. Positive value for the change means additional storage, and a negative balance means a decrease in the system's water volume.

Obviously there must be a certain range within which the balance between supply and losses/exploitation must be maintained. Since the drainage basin is considered to be the critical unit for hydrological systems from both the engineering and legal points of view, and as liabilities and rights must be apportioned '*equitably*', maintaining the input/output balance in a drainage basin must be the '*equitably*' shared responsibility of all its riparian states. This implies that each basin state should be eligible for responsibilities towards the shared basin corresponding to the size of both its natural input and output capacities. It is recalled here that being a basin state does not only give rights to benefit from the waters of the basin but also confers certain obligations.

In determining the extent of the rights and liabilities of states sharing water resources according to input and output capacities, a special difficulty lies in weighing the relative values of these two parameters. This gains special importance when input and/or output capacities are not evenly matched. However, the fact that the drainage basin is an indivisible unit of analysis prevents either input or output from being divisible. Therefore, equal weight has to be given to the two parameters over the entire basin.

The only way to keep the balance of the above mentioned zero sum formula is through controlling the active variable of the equation, namely consumption. The remaining terms, natural losses and supply, are mostly beyond human control and are thus considered passive or uncontrollable. However, in the long term, these variables also may be modified by human initiatives.

Having concluded that the output capacity and contribution to supply must be given equal weight in determining the size of liability/entitlement of riparian states to the shared resource, the following allocation formula can be used to determine shares of states in a surface or underground drainage basin:

$$S_i = 50 \times [\{B_i / \Sigma B_i\} + \{(I_i - L_i) / (\Sigma I_i - \Sigma L_i)\}]$$

Where:

S_i = Size of rights/obligation of state i [%]

B_i = Basin's area or storage volume within or under the territory of state i [L^2 or L^3]

ΣB_i = Total area/storage volume of basin [L^2 or L^3]

I_i = Natural input to basin originating within the territories of State i [L3]

L_i = Natural loss from basin's waters occurring within the territories of state i [L3]

ΣI_i = Total input to Basin [L3]

ΣL_i = Total natural loss of water occurring throughout the basin's spatial extent [L3]

The equation is presented graphically in Figure 1.

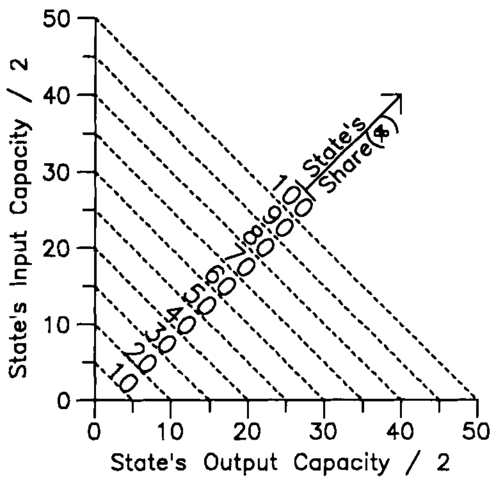

Figure1. Allocation of water resources on the basis of natural capacities.

5. IMPLEMENTATION PROCEDURE

The first step in applying this approach of allocation to a shared resource of water is to determine environmental constraints. Thus, two '*red lines*' are to be drawn demarking the upper and lower limits between which supply and consumption should be maintained. Shares of rights will then apply to the amounts of water above the '*lower red line*'. Conformably, the responsibility to deal with hazards resulting from water levels exceeding the '*upper red line*' will be allocated to riparian states in accord with their respective shares (in the instance of floods for example).

Regarding surface-ground water and interaquifer relationships, it should be remembered that although losses from a given resource within a given territory are considered losses related to that territory's share in that particular resource, such losses are also considered a contribution of flow related to the same territory to the gaining resource. Thus, losses do not actually occur in such cases, but rather become transfers of shares from one resource to another.

Although the proposed allocation formula lacks any reference to '*quality*', the approach itself does not overlook this issue; quality is allocated in accord to flow direction. There is, however, nothing inherently wrong with allocating lower quality water to downstream users. It is well known that water quality degrades with flow. Furthermore, upstream users must have priority to use water. Otherwise it would be impossible for an upstream user to exploit even a single drop of flowing water. Carponera (1978) mentions that Hebraic law organized the order of priority for irrigation from a common well so that "*...the one closest to the well conduit filled his cistern first and other irrigators did so in turn*". Since the approach requires good '*account keeping*' for inputs and outputs, dependence on sophisticated mathematical models is unavoidable for managing the hydrological system as a whole as well as shares of various basin states, the quality issue can be easily resolved since used models' time-steps may be minimized. Presuming enough short time-steps, the quality of water received by a downstream state can be predicted since the quality and the allowed upstream withdrawal are known. If the upstream states fail to draw their shares completely, the result would normally be an improved quality downstream, a thing which would never raise problems. Conversely, if an upstream state used more than its share, the quality of water received downstream will show that violation. The area where violation took place could then be located.

6. OVERCOMING UNFAVORABLE CONSEQUENCES

The principal problem that can result from apportionment of shared waters on purely natural and physical grounds is expected to be the disbursement of surpluses and shortages. This is mainly due to the common mal-distribution of the Earth's resources and to the fact that demand areas may, in many cases, be far from occurrence locations.

Water is not the only resource vital to humans which is not always available at areas and times when most needed. People have always experienced this problem and found ways to live with it. The problem and the answer proposed here are both as old as the human race itself. The solution is simply "*trade*". Trade has always been a capable tool in the satisfying of human need. In addition, this is the most effective promoter of efficiency. This approach corresponds with the global tendency away from centralized economic planning in favor of market-based approaches.

Establishing explicit fair shares and adopting a free market promises an objective and evenhanded solution to disputes over water such as that in the Middle East. The approach is simply to internalize problems of surpluses and shortages among the states sharing the dispute. Something like Napoleon's 'divide and conquer' approach, only with good will.

Open water markets would be good promoters of international cooperation on the long run. Countries with water surpluses would be willing to trade water with short fall countries, in an arrangement fairly valuing water like any other commodity. With time, buyers and sellers would depend on each other, and thus a better cooperative environment will be established as a result of creating a '*community of interest*'.

7. CONCLUSION

Today's international legislative structure is incapable of solving complex water disputes. Present international law provides guidelines for sharing water resources rather than clear-cut basis. A pragmatic, practical and dispassionate formula that is compatible with the principles of international law and legitimacy and capable of figuring explicit shares is urgently needed. The recommended formula is a plausible first step towards this imperative. But for it to work, allocation shares will have to be explicitly determined without consideration for the perceived needs of the various riparians. Subsoil oil and mineral reserves are treated in much the same way without question. Open markets provide a pragmatic solution to questions of needs incompatible with natural distribution.

Clarifying explicit water rights must be teamed with establishing international free markets for water. In such markets, transfer of entitlements must be permitted through various means such as rental, exchange, selling, etc. Explicit water shares and open markets would result in transferring water to higher-value uses, since purchasing states would stop subsidizing water and waste will be reduced. One of the most important benefits is likely to be the reduction of environmental degradation as waste and improper management are curbed.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Water Sharing Through Trade In Markets For Water Rights: An Illustrative Application To The Middle East

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abstract

The growing demand by countries in the eastern Mediterranean over the waters of the Jordan and Yarmuch Rivers, and the highly depleted coastal and mountain groundwater reservoirs, raise the need to explore ways and means to ameliorate existing and expected water scarcity. Economists have for some time proposed ways towards more efficient exploitation of existing water supplies, specifically by employing market incentive mechanisms in order to encourage voluntary water sharing among countries and regions. Such trading schemes may involve two or more countries. It can be shown that such schemes, given any initial assignment of property rights to water resources, can often lead to increases in the welfare of the countries concerned.

The paper proposes two specific mechanisms for international markets in water rights in the eastern Mediterranean region, in which parties voluntarily engage in such trades, as they would expect to gain real benefits from these transactions. Simulation exercises with real data show that - as is true for any opening of markets to international trade - that all parties in the region might benefit to a greater or lesser degree from trade in water rights, either from actually using imported water or from the monetary gain from water exports.

1 Introduction

Water scarcity and water pollution are today viewed by many as the most urgent environmental problems facing the region, and could result in famine, economic crises and even regional wars. Scarcity of fresh water has thus been judged to be the number one environmental problem facing the countries of the region (The World Bank and The European Investment Bank, 1990). Some have termed the situation as the era of "the geopolitics

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of water", with water taking over the role of oil. One can cite many examples. Some of the most dramatic involve the conflict between Egypt and Sudan over the waters of Nile; the concern of Iraq and Syria over the Turkish Anatolian project; the growing demands by Israel, Jordan, the West-Bank, and the Gaza Strip over the waters of the Jordan River and the highly depleted groundwater coastal and mountain reservoirs.

It has often been proposed that political tensions arising out of resource conflicts may be partially resolved by market mechanisms where economic incentives constitute positive inducements for resource sharing through trade in water rights. Such trade could lead to better utilization of the resource and yielding net benefits to all trading parties, thus promoting cooperation and lessening conflicts.

This paper focuses on the issue of allocative efficiency through water resources sharing. It is well known that optimal regional welfare that would be achieved under an omniscient, supra-national "Social Planner" institution. In reality, it is questionable whether such an institution is politically feasible. Individual nation states - and Middle Eastern countries, to put it mildly, are no exception - would be reluctant, better yet - outright against yielding sovereignty over resources to any supranational entity. It is also well known from economic theory, however, that under certain conditions a decentralized market mechanism can replicate the efficient outcome of the Social Planner institution, while refraining from encroaching on national property rights. In contrast to a Social Planner, a decentralized incentive system also has the advantage of not requiring detailed information on individual country supply and demand, which would be difficult to obtain even if the concerned countries were ready to divulge reliable data.

Specifically, in this paper we examine two economic incentive mechanisms, which operate in the framework of an auction market in water rights. These mechanisms could serve in our opinion as realistic surrogates, albeit imperfect, for the ideal Social Planner. In devising these mechanisms, we have tried to take into account the uncertain nature of water supplies and demands. In this case it may be noted that, with uncertainty, prospects for a Social Planner solution are further diminished because shadow prices would fail to properly perform their allocative function. The two proposed economic incentive mechanisms are: (a) market for percentage rights, where potential water consumers bid for a share of an uncertain quantity of water, and (b) market for priority rights in which potential consumers bid for a slot in a queue, and once assured a position, are in a position to use as much water as they need and is left by bidders further up the queue.

The paper analyzes the efficiency of these two decentralized, auction-type allocation mechanisms, and compares their outcome with that of the Social Planner, in terms of the welfare losses resulting from each mechanism when it fails to fully replicate the Social Planner. We use water supply and demand data from Middle Eastern countries, which would be potential candidates for such trades. In section 2 a brief description of the best allocation of water that results from a social planner decision is followed by a rational and characteristics of the markets allocations. Section 3 presents the illustrative case study, which deals with water re allocation between Israel, The West Bank and Gaza. A number of concluding remarks are offered in Section 5.

2 Allocation Mechanisms

Water Allocation By Social Planner

A social planner is an institution that would allocate the entire available water quantity in the most efficient manner. The social planner seeks to maximize the sum of benefits of all the countries in the region from selling and consuming water, subject to the water availability constraint. In order to do so, the best allocation the social planner would issue will equate the expected marginal net benefits each country has from water consumption to the cost of providing the water in each source.[2] This cost include the cost of extracting the water plus the cost of transporting it to the consumers. Therefore, since countries differ in their distance from sources, maximizing the sum of benefits, dictates allocating larger quantities of water to consumers that are located closer to the source. In this way the spending on transportation is minimized. However, if a country is in grate need for water, its marginal benefit from water consumption would be very high and it would be granted a larger portion of the water available, even if it were located further away from the source.

The Rationale For Markets in Water Rights

Theoretically, a social planner could achieve an optimal allocation. However, a social planner institution is not very likely in a scenario involving voluntary international trade in water or in water rights, and even if it were to be imposed on potential participants in a water re allocation scheme, it could be costly. The reason is that the principles guiding the social planner's decisions might not reflect the characteristics of the individual countries participating in a water allocation program. An individual country may achieve higher benefits without central intervention, and therefore would be reluctant to participate in a program developed by a central planning authority, which aims to maximize *aggregate* benefits. A country may be risk averse with respect to its water supply, whereas the planner is assumed to be risk neutral. These differences in attitude between planner and participants could render the central planning institution a fragile entity, resulting in partial compliance, and creating an incentive to cheat in order to achieve a higher level of individual benefits.

It is widely accepted, however, that a creation of a market for water rights would achieve the efficiency and flexibility of a competitive water allocation (Eheart and Lyon 1983 , Howe et al. 1986 , Saliba 1987 , Burness and Quirk 1979). However, markets in water rights present users with a degree of uncertainty because of the stochastic nature of water supply (Eheart and Lyon 1983 , Benedict et al. 1983). A construction of storage facilities may smooth much

[2]A comprehensive analysis, and mathematical derivation of the allocation mechanisms that are described in this section, is found in Zeitouni, Becker, and Shechter (1993).

of the uncertainty in the water market and enable a market in water quantities to operate. However, the presence of transportation costs that differ among potential consumers is a source of inefficiency in the market operation that yields market solutions that are different than the optimal social planner allocation. To investigate whether or not a trade in water rights would result in an optimal or near optimal allocation, the nature of trading such rights ought to be carefully analyzed.

In the following analysis, we assume that countries may engage in selling (say, on an annual basis or through longer term contracts) rights to their water (although this assumption may be somewhat naive; see, for example, Dinar and Wolf 1993, and Wolf 1993). Surplus countries auction off these rights to shortage countries. The consumer countries submit a sealed bid in which they state their offer price for the rights. Since it is assumed that they do not know the other bidders' offers, they may tend to bid their maximum valuation for any given quantity of rights. A seller can therefore receive different prices from different buyers.

Bidding For Percentage Rights

A percentage right is a contract that gives its owner the right (and the obligation) to purchase a certain percentage of the commodity. The countries interested in purchasing the water buy these rights from the countries with water surpluses. A country may submit a bid to purchase a right for a certain percentage of an (unknown) quantity of water from each of the sources. The size of the bid is derived from each bidder's optimization optimization of its expected net social welfare from water, i.e., the benefits from water consumption minus the amount paid for the water rights. Equilibrium in the market for percentage rights requires that each consuming country gets an amount of water proportional to its bids for the rights from the respective suppliers. The result is that the bid for the marginal percentage of water is equal to the expected marginal benefits from water each demanding country derives from each source, respectively.

Bidding For Priority Rights

When potential consumers bid for priority rights, instead of percentage rights, the party that is granted a given priority right can exercise the option of purchasing all available supplies left by parties with a higher priority rights, before parties with lower priority rights can exercise theirs. A form of priority rights in water allocation is rather common in western U.S.A. There, water allocation is often determined on the basis of seniority claims. However, in that case the claims are a function of institutional factors, rather than market forces as is the case studied here. In other words, in this work the seniority claims are determined *endogeneously*, through an auction market for priority rights to water usage, reflecting economic demand and supply forces, rather than political negotiations.

Purchasing a priority right with the k-th seniority gives a country the k-th place in a queue of water consumers. There are $k-1$ countries that can purchase their respective desired water quantities before it may exercise its right. The expected water quantity to the holder of the k-th right therefore depends on the availability of water to the more senior right holders; it does not get anything if the quantity is less or equal the sum of quantities demanded by the $k - 1$ preceding right holders. Otherwise, it may get part or all it bid for depend on the amount of water available in the source. The priorities are distributed according to the size of the submitted bids. The highest offer is granted priority of all others with smaller offers. The second highest offer is given second priority and so on. The amount country i will pay for the k-th place in the queue will then be proportional to the stock of water available for the k-th consumer from country j.

The amount every potential consumer would be willing to pay for the right to be the k'th in a given source's queue, is such that its expected marginal benefits from being in that place in the said queue is equal to the scarcity value of water in the respective source. Therefore, countries would be willing to offer more for the right given by a source with a higher expected quantity of water. Each source when receives the bids from all demanding countries, then orders the queue in such in such a way that its benefits from selling the water are maximized, and proceeds to collect the bid payments.

3 An Illustrative Example

3.1 The Setting

In this section we describe an application of the three allocation schemes (Social Planner, bidding for water rights and bidding for a position in a queue for rights) to data from several Middle Eastern countries.

In general, the eastern Mediterranean region can be divided into countries which are relatively rich in water and those who are not. The major sources of potential water surpluses are found in Egypt, Turkey and Iraq. Shortages are most common in Israel, Jordan, the West Bank and Gaza, and somewhat less severely in Syria and Lebanon.[3]

The Jordan river, for example, flows through Israel, the West Bank, Jordan and Syria, with its various tributaries under Syrian and Israeli control. Potentially beneficial projects, however, are not confined to the transfer of water from regions where it is found in relatively plentiful supplies to water-poor ones. Conceivably, Israel could help in replenishing the West Bank aquifers in exchange for getting Nile water for its arid Negev region. Another sharing project would involve storing water from the Yarmuk river[4] in the sea of Galilee for use by Jordan, Israel, and the West Bank in the dry period, or damming the lower part of the Jordan river. Yet another project might involve a joint de salination project for several countries, the joint exploitation the Litany river by Israel and Lebanon to generate hydroelectric power, and so on.

[3]However, part of the shortage of water is due to non efficient water pricing mechanisms.

[4]one of the tributaries of the Jordan flowing through Syria, Jordan and Israel.

As an illustrative example, a proposal for water diversion that was suggested in (Kally, 1986) is considered here. In this proposal the regional water supply is augmented by a certain quantity of water from the Nile river basin. The augmented supply of water is used in the southern part of Israel (Negev) and Gaza, while part of the water that is currently diverted from the Sea of Galilee to the Negev would be re directed to the West Bank. This scheme has two advantages. First, the water supply to the whole region is enlarged (based on certain assumptions regarding the Nile basin). Second, there is a re allocation of water to achieve greater efficiency. The sharing schemes are dealt with within the framework of the two market mechanisms proposed here. They are compared to each other and to the (optimal) social planner allocation.

Four major sources for water supply are considered. Excess water from the Nile river (NI), [5] Israel's water potential(IW).[6] Considerably smaller are the present water supplies in the West Bank(WB) [7] and Gaza(GS). The available water supply in the four sources is given below:

Israel	-	1500 $10^6 m^3$
Nile River	-	1300 $10^6 m^3$
West Bank	-	110 $10^6 m^3$
Gaza	-	70 $10^6 m^3$

The four demand (use) regions considered here, are: Israel (without the Negev)(IS), the Negev(NE), the West Bank(WB) and Gaza(GS).[8] Assuming the domestic markets for water are free of taxes and subsidies, the price a water is supposed to capture all the variability in the quantity purchased.[9]

The quantity demanded in each region is composed of two components:

1. A fixed quantity of water per capita for domestic and industrial use multiplied by the population size (see World Resources, 1990).

2. Demand for agricultural use. This was determined on the basis of estimates of the marginal value of water.[10]

Demands were estimated using log-linear functions, whose estimated coefficients are given in table 3.1. Water transportation costs are given in Table 3.1. These are based partly on

[5]Based on current potential and consumption (see Krishna, 1988, Shanin 1989, and Withington 1985).

[6]Includes all the fresh water in Israel including the two major aquifers (Naff and Matson, 1984).

[7]Estimated quantities for the West Bank and Gaza are based on Kahan (1987).

[8]The analysis does not include Egypt as a demand entity. Rather, it is assumed that Egypt uses a fixed quantity of Nile water according to its needs which determines the surplus available for diversion.

[9]For lack of satisfactory studies about overall water demand for the regions under consideration, aggregations of crop patterns were used to calculate the value of marginal productivity of water.

[10]Crop patterns and water consumption data for Israel and the Negev were taken from Kislev (1990), and from Kahn (1987) for Gaza and the West Bank.

Table 1: Estimated coefficient of the water demand functions

REGION	A	α
IS	5.82	-1.20
	(110.78)	(-3.19)
NE	6.25	-1.47
	(39.57)	(-1.75)
WB	5.18	-1.23
	(12.86)	(-6.8)
GS	5.25	-1.20
	(12.31)	(-6.8)

* Numbers in brackets are t-values

Table 2: Cost coefficients for water transfer (in $\$/10^6m^3$)

From/To	IS	NE	WB	GS
IW	0.11	0.19	0.09	0.19
NI	0.14	0.13	0.14	0.13
WB	0.11	0.11	0.01	0.11
GS	0.19	0.11	0.11	0.01

Kally (1986), and partly on the real costs of diverting water from The Sea of Galilee to the central and southern parts of Israel (Tahal, 1985). They include maintenance and operation cost, as well as capital costs for the delivery system. Following Mosenzon (1986), we have specified cost for delivering water from source j to destination i in the form of the following function:

$$C_{ij} = c_{ij}q_{ij}^3 \tag{1}$$

were c_{ij} is a parameter

3.2 An Optimal Water Allocation

The incorporation of the Nile water provides opportunities for trade and also increases the total quantity of water available to the region. In order to get a better perspective of the role of the water from the Nile river basin we have explored two scenarios, one without, and one with Nile water.

Tables 3.2 and 3.2 summarize the social planner allocation in these two scenarios. It can be seen from Table 3.2 that, even *without* the Nile, regional re allocation of water would result in an increased regional net benefit. In such a re allocation scheme, Israel (including the Negev) uses 1183 10^6m^3. Some of the water that goes to the Negev is diverted from the West Bank (14 10^6m^3). The West Bank itself gets 228 10^6m^3, which means that it more than doubles its present water supply. Gaza uses 270 10^6m^3. Part of it, 200 10^6m^3, is diverted

Table 3: A Social Planner's allocation without Nile water

Demand Region	Use level in mil.cu.m				Economic Benefit in mil.
	Israel total	West Bank	Gaza	Total Use	
Israel	742	0	0	742	1145
Negev	427	14	0	441	371
West Bank	132	96	0	228	225
Gaza	200	0	70	270	329
Total Supply	1500	110	70		
Shadow Price in cu.m.	0.29	0.46	0.46		

Table 4: A Social Planner's allocation with Nile water

Demand Region	Use level in mil.cu.m					Economic Benefit in mil.
	Israel total	West Bank	Gaza	Nile	Total Use	
Israel	738	0	0	457	1195	1239
Negev	398	0	0	445	843	457
West Bank	177	110	0	147	434	253
Gaza	257	0	70	251	508	367
Total Supply	1500	110	70	1300		
Shadow Price in cu.m.	0.15	0.3	0.3	0.17		

Table 5: Percentage rights allocation without Nile water

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	%	Trade mil. $	mil.cu.m	%	Trade mil. $
Israel	679	45	90	0	0	0
Negev	403	30	54	0	0	0
West Bank	188	13	25	110	110	19
Gaza	230	15	31	0	0	0
Total	1500	100	200	110	110	19

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	%	Trade mil. $	mil.cu.m	%	Trade mil. $
Israel	679	45	90	0	0	0
Negev	403	30	54	0	0	0
West Bank	188	13	25	110	110	19
Gaza	230	15	31	0	0	0
Total	1500	100	200	110	110	19

from Israel, and the rest comes from local sources. Water is transferred from Israel to the West Bank and to Gaza, because the latter have higher shadow prices for water scarcity. The solution indicates that an upper limit for the price for water from new projects is 45 cent per m^3. More expensive projects would not be justified.

When water from the Nile is incorporated into the analysis (Table 3.2), we notice that the shadow price of water scarcity is reduced significantly in all four regions. As expected, the benefits to the entire region increase by about 12%.

3.3 Allocations Under The Two Market Mechanisms

Percentage rights

As in the previous section, allocations with and without water from the Nile are considered in this section, and the performance of each proposed market mechanism is examined. The allocation resulting from trading in percentage rights without the Nile water is summarized in Table 3.3. Local water in the West Bank and Gaza is used only for domestic consumption. Water from Israel is re allocated in such a way that more goes to the West Bank and Gaza and less to Israel and the Negev, than in the social planner allocation. Israel gets only 1082 $10^6 m^3$ which is 91% of its optimal (i.e., social planner) allocation and its net benefit is reduced by 6%. The West Bank use is increased by 43% and Gaza by 15%. Nevertheless,

Table 6: Percentage rights allocation with Nile water

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	%	Trade mil. $	mil.cu.m	%	Trade mil. $
Israel	688	46	48	0	0	0
Negev	391	26	27	0	0	0
West Bank	207	14	14	110	110	12
Gaza	214	14	15	0	0	0
Total	1500	100	104	110	110	12

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	%	Trade mil. $	mil.cu.m	%	Trade mil. $
Israel	688	46	48	0	0	0
Negev	391	26	27	0	0	0
West Bank	207	14	14	110	110	12
Gaza	214	14	15	0	0	0
Total	1500	100	104	110	110	12

net benefits for the West Bank decreases by 15%, and for Gaza by 11%, due to the wealth transfer associated with the purchase of rights. The total regional net benefits decrease by 9% compared with the optimal allocation.[11]

When water from the Nile is incorporated (Table 3.3), benefits increase, as expected. However, payment to Egypt for providing this water should be deducted from the benefits of the use regions.This transfer of wealth reduces the total welfare of the region to 89% it level under the social planner. The percentage market allocation provides the southern part of Israel a grater quantity of water from the Nile than is socially optimal, and in turn results in the sale of a portion of Israel's water to The West Bank. Thus, the West Bank gets more from Israel and less from the Nile, and Gaza gets less from each source, compared with the social planner solution.

Priority Right

When allocation is determined in a market for priority rights without importing water from the Nile (Table 3.3), the West Bank and Gaza consume their own domestic water without any transfer of water between them. Israel and the Negev are first and second in the queue, Gaza is third and the West Bank is last. Therefore, Israel and the Negev get more water than in the optimum. They also buy more water than they would in a market for percentage

[11]Note that even though payments to Israel are included, they net out in the overall regional welfare figure.

Table 7: Priority rights allocation without Nile water

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	Place	Trade mil. $	mil.cu.m	Place	Trade mil. $
Israel	885	1	206	0	2	0
Negev	483	2	84	0	4	0
West Bank	2	4	0.2	110	1	15
Gaza	131	3	18	0	3	0
Total	1500		308	110		15

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	Place	Trade mil. $	mil.cu.m	Place	Trade mil. $
Israel	885	1	206	0	2	0
Negev	483	2	84	0	4	0
West Bank	2	4	0.2	110	1	15
Gaza	131	3	18	0	3	0
Total	1500		308	110		15

Table 8: Priority rights allocation with Nile water

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	Place	Trade mil. $	mil.cu.m	Place	Trade mil. $
Israel	896	1	114	0	2	0
Negev	284	3	22	0	3	0
West Bank	321	2	46	110	1	8
Gaza	0	4	0	0	4	0
Total	1500		104	110		8

Demand Region	Use and trade level in mil.cu.m and mil. $					
	Israel(total)			West Bank		
	mil.cu.m	Place	Trade mil. $	mil.cu.m	Place	Trade mil. $
Israel	896	1	114	0	2	0
Negev	284	3	22	0	3	0
West Bank	321	2	46	110	1	8
Gaza	0	4	0	0	4	0
Total	1500		104	110		8

rights. As a result Gaza and the West Bank, are each left with a smaller allocation, and the regional net benefits reach only 82% of the optimal net benefits.

Incorporating water from the Nile river in the trade in priority rights changes the picture somewhat (Table 3.3). Now Israel (without the Negev) is still first in queue because of the lower transportation cost, followed by the West Bank in second position.

The Negev and Gaza step down one place in the queue because once Nile water is available, the importance of the Israeli source diminishes since it is cheaper to haul Nile water to these regions. This is also the reason that Gaza is first, and the Negev is second in the queue for Nile water, while Israel is third and the West Bank is last. This market mechanisms reduces overall regional net benefits to 81% of the optimum, because the first two demand regions in each queue get more water than the optimal allocation, while the last two regions get less.

Note that even though overall efficiency is larger under percentage rights mechanism (Table 3.3, Table 3.3), the supply regions benefit more from the selling of priority rights. This is especially important with respect to Egypt, since it does not play a double role (as does Israel) of seller and buyer. When selling priority rights, Egypt collects 25% more revenues than when selling percentage rights. Israel also collects 29% more revenues when the Nile is included, but it has to pay 58% more to Egypt. Overall Israel's net benefit when it "sells" percentage rights, is 16% higher than when it "sells" priority rights.

4 Concluding Remarks

A Social Planner institution solves for the economically efficient allocation arrangement. It is doubtful, however, that such an institution could be implemented. Instead, this paper examined the efficiency of two forms of markets in water right for allocative efficiency in the Middle East, where the region's water supplies are efficiently shared, under conditions of uncertainty.

The results of the analysis indicate that trade in water rights can improve the welfare of each participating party, and increase the efficiency of regional water use. For the cases studied in this paper the results show that a percentage rights mechanism is relatively more efficient than priority rights. However, the priority rights scheme would probably be favored by the parties with a surplus of water, since this mechanism transfers more wealth to the selling parties. Two options were considered: trading only local water, and trading local water augmented by water from the Nile. Although transporting water from the Nile may not be politically feasible at the moment, it was interesting to note that all parties involved in the trade (including Egypt!) might benefit

It should be emphasized that the models and application largely disregard important institutional and political aspects of the problem, at least explicitly. These aspects concern issues such as who should decide what, if any, mechanism will be adopted? What will be the bargaining framework for arriving at such and similar decisions, and what kind of supranational agency will be empowered to enforce them? How, and who will be entrusted with the resolution of equity and re distribution issues if and when they arise? It is of course imperative that these issues be dealt with, but they would have carried us beyond the special aspects we chose to address here.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

Water Policy in the Context of Palestinian Self-Government

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Abstract

An Israeli-Palestinian agreement on an interim period would alter the relationship between the two parties concerning the control and utilization of water. The principles of equity and mutuality would form the basis of water use in Israel, the West Bank and Gaza Strip. The Interim Self-Governing Authority (ISGA) would establish a water department to plan and monitor water use and would participate with Israel in joint bodies to regulate the aquifers. Regional water projects might supplement the water projects implemented by Israel and the ISGA.

Introduction

Israeli-Palestinian negotiations introduce the possibility of mutually-agreed and substantive changes in their relations. An accord on self-rule could alter ingrained behavioral patterns and launch the relationship on a different trajectory, away from the current zero-sum situation. The study undertaken by the American Academy of Arts and Sciences seeks to demystify the issue by linking the principles of Palestinian self-rule to precise measures on the ground that would underpin a meaningful interim period.[1] It provides evidence that a transitional period is feasible and beneficial to both Palestinians and Israelis. The report specifies three critical arenas: civil-political, security, and the economy and resources.

The study assumes that, following the interim period, the West Bank and Gaza Strip will form the basis for either an independent Palestinian state or a confederation with Jordan; the study does not advocate Israeli sovereignty over the West Bank and Gaza Strip. Nonetheless, the transitional process would not be automatic or irreversible. Implementation of the various facets of self-government would be essential before the transition could be completed. The process might be delayed or halted if severe difficulties arose along the way. In line with those uncertainties, the report does not delineate the exact nature of the long term status. The feasibility of alternative outcomes would be affected by the real-life dynamics of the interim period. Arrangements that appear impossible today might be realistic in an altered political environment.

<u>Political Institutions and Security Structures</u>

Consideration of key aspects of the institutional and security structures are needed before the issues of water use and water rights can be delineated. The political and strategic accords will establish the context within which a water regime will be created. The principles underlying the Interim Self-Governing Authority (ISGA) need to be established at the outset, even though their operationalization might take time:

* **The source of authority:** The ISGA's authority would derive from the negotiated agreement, on whose basis the ISGA would be established. Israeli officials prefer retaining the Israeli military government and its military orders as the source of authority; Palestinians want the ISGA itself to be the source of authority. If the bilateral accord is the legal basis, ISGA powers would be specified in the accord and Israel's government would not automatically retain any residual authority.

* **The ISGA's powers:** An effective ISGA would formulate public policy, levy taxes and regulate finances, control police and local security operations (in coordination with Israel at certain levels) and operate educational, health and other services. Administrative structures would include a water department to regulate water use and to issue permits for drilling wells. That department would provide technical assistance, in conjunction with the planning department and municipalities, in the construction of reservoirs, dams and water systems.

* **Personal and territorial self-rule:** The territorial and personal aspects of self-rule are inextricably intertwined since the people cannot be separated from the land. Policy-making, planning, and economic stability necessitate the ISGA's having at least shared authority over public land, guaranteed continuity of private land holdings, and joint monitoring of water resources.

In the security realm, Israelis and Palestinians both emphasize the safety and survival of their communities in the face of external threats and internal violence. Each believes that its security is undermined by the other's aspirations and actions. The mutuality of their needs must be recognized. Israelis focus especially on regional security: to consider withdrawing militarily from the occupied territories, their security at the regional level needs to be assured through bilateral accords with Syria, Lebanon and Jordan, complemented by multilateral agreements on arms control. Palestinians are preoccupied by communal insecurity caused by Israel's military occupation and by their vulnerable status in Arab countries. At present, Palestinians lack security of property and person. With self-rule, they could protect property from confiscation and secure their communities using their own police forces.

Economic and Resource Issues

The Palestinian economy operates under severe constraints caused by the military occupation. The Israeli government controls the basic resources and infrastructure: land, water, electricity, roads and communication systems. All policy-making and long-term planning are in the hands of Israeli officials and the economy has been molded to serve Israel's interests. The disparity in Gross National Product (GNP) and income levels is pronounced: an estimated $1000 per capita in the occupied territories as against $2000 in Jordan and $7000 in Israel.[2] Key economic issues that impact on water are highlighted here:

Policy making: All policy-making and long-term planning are controlled by Israel.[3] Israel's Higher Planning Council controls all spatial development, which is oriented toward expanding Israeli settlements while constricting the growth of Palestinian towns and villages. An all-Israeli board reviews Palestinian appeals against planning decisions. The military government also restricts the authority of municipal and village councils to regulate infrastructure development and frequently denies requests for building permits.

Land: The military government has barred land registration by Palestinians since 1967 and forbids Palestinians not currently residing in the territories from inheriting land. The military government controls the land registers and must approve all land transactions. Notification of expropriation can be oral and appeal to local (Palestinian) courts is prohibited; the only recourse is to the Israeli high court or to an advisory military objections committee. The Israeli government has taken control over six categories of land which comprise at least half of the West Bank and a third of the Gaza Strip:[4]

1) land that Jordan and Egypt designated state land;
2) land owned by persons who were outside the territories in June 1967, designated absentee or "abandoned" land;
3) private land requisitioned for military use;
4) private land whose access is denied, e.g. "closed areas" used for military firing ranges, training grounds and general "security" zones;
5) private land requisitioned for public use, such as roads, utilities and parks;
6) land where registration was incomplete in 1967, which the military government designated "public" even if the occupant possessed tax records or sale documents; one third of the West Bank and 20% of the Gaza Strip are affected.[5]

Agriculture: Agriculture provides a quarter of the Gross Domestic Product (GDP) and employs a third of the Palestinian labor-force on the West Bank; for Gaza, 18% of GDP and 19% of the work force. Limitations are placed on the amounts and kinds of agriculture, livestock and fishing and access to technology:

* The military government requires farmers to obtain permits to plant fruit or citrus trees and vegetables. No permits for

citrus in Gaza have been issued since 1967, causing a severe drop in quantity and quality.[6] Access to 80% of the fishing area in the Mediterranean Sea is blocked on security grounds.

* Crops are restricted that might compete with Israeli produce, whereas Israeli farmers can sell freely in the West Bank and Gaza Strip. Until mid-1991, all produce sold to Israel required a special permit; most produce could only be sold through the Israeli marketing monopoly.
* Government agricultural research stations and extension programs have been reduced markedly since the mid-1970s.[7] Farmers have few opportunities to study planting methods, seeds, and the proper use of fertilizers and pesticides.
* Farmers cannot upgrade their production by controlling the entire process, e.g. the government forbids Israeli companies from selling tissue culture for dates to Palestinian farmers and selling dairy cows and chicks for breeding.[8]
* Collective punishments damage agriculture: the army may uproot trees,[9] confiscate land, cut water allocations, forbid the transport of produce, and destroy farm machinery. During curfews, crops rot in the fields and chickens die unfed.

Industry: Industry comprises only 7.7% of the West Bank GDP and 13.7% of the Gaza Strip GDP, whereas construction contributes 16.8% and 21.2%, respectively, and services account for 51.1% and 46.5%.[10] Israel does not permit the establishment of industries that might compete with Israeli factories, whereas Israeli manufactured goods sell without restriction in the West Bank and Gaza Strip. Extensive sub-contracting by Israeli firms enhances dependence on the Israeli economy: Palestinian workers earn piece-work wages and the profits accrue to the Israeli firms. Fruit and vegetable packing houses rely on Israeli containers and lack adequate refrigeration for storage.

Trade and Labor: Eighty percent of West Bank and Gaza exports is sold to or through Israel, half the agricultural produce is exported to or through Jordan, and 91% of imports enters from or through Israel.[11] An Israeli marketing officer issues the permits to export produce to Israel. A third of the labor force works in Israel.

Research limitations: Palestinians try to upgrade their research into the feasibility of economic projects and to expand outreach to farmers, businessmen and industrialists. They lack baseline data, feasibility studies, management and marketing plans, all of which are vital in order to establish new product lines and to expand or modify existing ones. The Israeli government restricts Palestinians from collecting data and conducting surveys. Palestinian agronomists emphasize that analyses are needed of soil content and water salinity in order to assess the suitability of particular plots of land for certain crops. Farmers need to be educated in the treatment of crop diseases. Poultry hatcheries, breeding cows, and tissue culture for dates are vital for self-sustained agricultural development. Private research institutions, universities, agricultural committees and cooperatives try to fill the gaps in knowledge and production, but lack adequate funds, expertise and enforcement power. Palestinian organizations also promote environmental research and outreach projects. The Environmental Protection Agency and Gaza Environmental Program monitor the water crisis in the Gaza Strip.[12] Bir Zeit University's Center for Environmental and Occupational Health Sciences monitors water in Ramallah district on contract for the local water authority and conducts campaigns to train farmers in the use of pesticides. The Palestine Hydrology Group assists farmers to improve yield from their springs, build rain-fed cisterns, and purify water supplies.

Water:[13] Water use is constricted by the explicit limits that Israel places on Palestinians' access to water as well as by its use competitively by Israeli settlements and within Israel:

* The military government controls all water resources in the West Bank and Gaza, prohibits drilling new wells or deepening old wells without permission (sometimes granted for domestic use, but not in industry or agriculture), fixes pumping quotas, and forbids Palestinian use of wells in closed areas.
* The Palestinian population on the West Bank grew 84% since 1967 but domestic water allotments only increased 20%; no increase was allowed for agriculture and industry. Only 6-7% of the 1.7 million dunums cultivated by Palestinians on the West Bank is irrigated; the same amount as 1967. A third of West Bank villages have piped water and half the cities have sewage networks. Waste water flows untreated from the towns, causing illness and contaminating the soil.
* The approximately 100,000 settlers on the West Bank use 160 million cubic meters (mcm) yearly, irrigate 69% of the 563,000 dunums that they cultivate, and pay a third to a sixth as much as Palestinians per cubic meter of water. 137 mcm water was allocated to the 1 million Palestinians in 1989.[14] In 1990, 17% of the West Bank's water was used by Palestinians; 83% was used within Israel or by Israeli settlements in the West Bank. Each settler received 1,600 cm that year and each Palestinian received 127 cm. Deep bore wells drilled by settlements dry up nearby Arab springs, notably in the Jordan valley.
* Two-thirds of West Bank water resources are used inside Israel (1990), providing a third of Israel's total water needs.[15] Despite reduced levels in the aquifers, pumping on the coastal plain remains high.
* The Gaza Strip relies on fresh water from an aquifer that originates in Israel.[16] The Palestinian residents irrigate 45% of their agricultural land, using 90% of their water for irrigation. Yearly replenishment of the aquifer stands at merely 60% due to overpumping by Palestinian farmers, pumping from new wells for settlements in the Gaza Strip, pumping from wells inside Israel that serve the Israeli National Water Carrier, and dams on Wadi Gaza inside Israel that prevent its water from flowing into the Strip. The resulting intrusion of seawater into the aquifer has raised salinity to levels that damage agriculture and contaminate drinking water, causing

serious health problems. Restrictions have been placed on pumping by Palestinians but not on pumping by Israelis inside the Strip or along the border. Palestinians have access to 200 cm per capita water yearly, a tenth of the settlers' share.[17]

The Interim Period

The economic relationship between Israel and the occupied territories would be recast during the interim period to promote mutual benefits. There will be simultaneous processes of disengagement by Israel, restructuring of the economy, and institution building by the Palestinians, which will cause stress for both parties. Asymmetries will arise: Palestinians will gain control over their resources and livelihood, but Israel will lose its guaranteed markets and easy access to a large, low-cost labor pool. Israel will, however, realize gains through trade and tourism with the Arab world as well as potentially increased access to water and electricity from regional sources. Moreover, the transition from occupation to self-government will be smoother for the Palestinians and less threatening to the Israelis if the West Bank and Gaza are encouraged to have viable and productive economies.

In the interim period, Israel would remove barriers that limit Palestinian trade, credit, and population movement. The ISGA's financial and monetary authority would include the right to levy taxes, negotiate external grants and loans, and regulate and set standards for the economic sectors. Fiscal and monetary policy would be coordinated with Israel as long as the movement of currencies remains unrestricted.

The ISGA would conduct long-term planning, particularly to enhance the basic infrastructure and expand housing. Municipal and village authorities would initiate improvements immediately: the rehabilitation of long-neglected schools, clinics, roads, electricity systems, and water supplies. A system to raise funds through bonds, taxes and fees would be instituted.

Private investors would expand light industries in a wide variety of fields, notably pharmaceuticals, clothing, textiles, shoemaking, quarrying, agricultural processing, fishing industries, and agricultural technology. Infusions of capital and skills, mandatory quality controls, improved marketing techniques, and intensive research will be essential.

The expansion of agriculture will be limited, in part, by the scarcity of water resources. Nonetheless, in the context (discussed below) of a fair share of water being allocated to the West Bank, land in the Jordan Valley being restored to Palestinian farmers, and the recycling of waste water, a marginal increase in irrigated agriculture is possible in the West Bank. Fishing can be expanded in the Gaza Strip and aquaculture introduced. Agricultural productivity can be enhanced by expanding drip irrigation and plastic greenhouses, by using crops and fruits that require limited or brackish water, and by investing in waste water for irrigation.

The ISGA would tackle the serious desertification on the West Bank highlands, partly caused overgrazing as the area available for pasture has been restricted. Former pasture land would be restored and afforestation resumed. The ISGA would need access to satellite and remote sensing data and information from weather stations in order to assess rates of evaporation and precipitation, study soils and plants, and monitor weather patterns. Comprehensive studies of environmental pollution caused by pesticides, herbicides, human waste, and industrial refuse would be vital. Those studies would form the basis for systematic efforts to educate farmers concerning the proper use of chemicals, repair the networks for piped water and sewage, and regulate industries' waste disposal.

Utilization of Land Resources

The issue of control over land resources would be particularly important. Palestinians who criticize the negotiating process emphasize their fear that self-rule will exclude land and water resources.[18] For meaningful self-rule, either the ISGA will control land during the interim period or a joint Israeli-Palestinian body will determine land use. The purchase and seizure of land by Israel would cease and construction of settlements would halt. A Palestinian land registry department would be established and land registration would resume. Municipal and regional zoning boards would develop new plans for the coordinated use of land for residential, industrial and agricultural purposes.

Residents would need access to what Israel terms public and absentee land and much of the land closed for military purposes. Miri and mawat land could revert to Palestinian control. Since only 8-9% of West Bank land is currently used by settlements, Palestinians could gain sizeable tracts without affecting the settlements directly. The Jordan valley and the grazing land on the eastern slopes of the highlands would benefit, particularly.

Since the Israeli government cannot be expected to accord full authority over land to the ISGA, a joint commission is the most realistic option. That body would assess current land use, demarcate settlements, evaluate the settlements' assets, and compensate Palestinians whose land was seized by Israel.

Local Water Use

Principles of equity and mutuality would form the bases for water use in Israel, the West Bank and Gaza Strip. An Israeli-Palestinian water-use regime would end the disproportionate allocation to settlements and establish comparable levels of access to water for Israelis and Palestinians. Israeli and Palestinian experts tend to agree that Israelis and Palestinians should receive an equal allocation of fresh water per person for domestic use. Hillel Shuval proposes that 100 cm per person per year would provide a hygienic standard for urban life. Water use for industry and agriculture might be based on a fair market price, rather than subsidized. Substantial water conservation, waste water recycling, and restructuring of agriculture would be required. Even so, Shuval argues, water resources would be insufficient and water would have to be imported by Israel and the ISGA within a decade.[19]

Most experts argue that an accord would permit a slight increase in water use by Palestinians, particularly for domestic and industrial purposes. They disagree, however, as to whether that would require Israel to reduce its relative share of West Bank ground water: some maintain that is neither necessary nor desirable, since Israel has an established right to use that water. Others disagree, arguing that Israel has used a disproportionate share and has artificially restricted the amount available to the West Bank. They maintain that reduced usage inside Israel is essential, which would require enforcing a strict water-use regime within Israel.

Comprehensive planning concerning water and sewage would be a top priority for the ISGA. Since water plants and masterplans require a decade or more to develop and construct, systematic attention must be given them early in the interim period. In the short run, agreements could be signed with the Israeli water authorities for the guaranteed supply of water through existing pipelines at negotiated and reasonable rates. Standards for environmental pollution will be required, including analyses of the polluting of ground water by fertilizers, pesticides, and garbage disposal. Remote sensing devices could monitor water use and ensure compliance with the limitations. Particular water management issues include:

* **Ground water from the West Bank and Gaza aquifers:** joint Israeli-Palestinian monitoring of the use, level and quality of the aquifers will be needed as the basis for restructuring water use in Israel and the territories and ensuring that neither party deprives the other of water. Regulations concerning Palestinian wells would balance the need for more water against the danger from overpumping; Israel would institute water-saving measures and prevent its wells from drying up Palestinian wells or depleting aquifers; joint planning would begin for the long-term rehabilitation of aquifers.
* **The eastern aquifer:** Palestinians could gain immediate access to and control over the eastern aquifer that drains into the Jordan River, since that aquifer flows entirely within the West Bank and does not affect the Israeli hydrologic cycle.[20]
* **Waste water for irrigation:** some Israeli hydrologists argue that half the fresh water used in households in the West Bank could be recycled through waste water plants and sedimentation ponds. While those estimates appear high and such recycling is costly, recycled water would help meet agricultural needs in the central West Bank and would ease the shortage in Gaza, when accompanied by shifts in crops, fruits and methods of cultivation. Construction costs might be covered by external funding, but farmers would pay the market price for water.
* **Water storage projects:** Replenishing the Gaza and West Bank aquifers could be enhanced slightly by constructing small dams on <u>wadis</u> (seasonal rivers), at relatively low cost, and by constructing storm water recycling systems in cities.[21]
* **Desalination in Gaza:** Palestinian experts propose to build a plant inside the Gaza Strip that would either convert brackish

water into drinkable water by reverse osmosis or, at much higher cost, distill sea water and generate electricity.[22] They give higher priority, however, to rehabilitating the pipe networks, enhancing storage, and recycling waste water. Some Israeli experts propose a joint plant on the border between Gaza and Israel that would also supply parts of the Negev and the southern West Bank. Despite the high capital investment (which would have to be covered by foreign donors) and on-going fuel costs, some experts believe that consumers, hothouse-agriculture and certain industries could afford the water.

Restructuring the use of ground water on an equitable basis, supplemented by waste water and possibly desalination projects, will be vital to meet local needs during the interim period and in the long run. Some analysts argue that such restructuring alone will not be sufficient and that regional water projects will be needed in order to share water on a more comprehensive basis. Although the regional projects outlined below could provide increased access to water and, through enhanced storage, increase the availability of water, they will not be a panacea. Tough decisions on water allocations within Israel and the territories will remain essential.

Regional Water Projects

Regional water plans could be important components of the bilateral and multilateral accords. The opportunity to increase access to water could serve as an inducement for Israel to negotiate security accords with its neighbors. Numerous projects have been planned or proposed; most may prove infeasible for technical, economic or political reasons. Nonetheless, multilateral negotiations and feasibility studies serve as confidence-building measures, which start to reduce Israeli concerns about implacable Arab hostility. They foster changes in the perceptions and preferences of the Israeli public, since many Israelis see water scarcity as a key obstacle to peace. Moreover, Israel would view the establishment of regional resource projects as a positive incentive to reduce its own control over water in the West Bank and Gaza. And such plans would improve the prospects for the negotiated resolution of contested water sources, such as the Hazbani headwaters of the Jordan river, located on the Golan Heights. Planning would indicate that cooperative approaches are conceivable and that the conflict need not remain zero-sum.

At present, there are severe imbalances in the availability of water among Middle Eastern countries. Israel and Jordan, for example, each use 108% of their safe-use stocks, thus degrading their water stocks and depleting their aquifers and rivers. The declining water stock in the Jordan river basin raises the level of tension among the riparians, Thomas Naff argues.[23] Experts maintain that longterm solutions will come from restructuring regional economies in order to economize on water as well as from comprehensive regional water-supply plans, including new storage facilities, desalination, and recycled waste water.

The five options sketched here are not all feasible, but they have all been proposed as possible means to increase the water available to Israel and the territories:

* **Jordan River:** Completing Jordan's Unity (Wihda) Dam would store the flood waters of the Yarmouk River, which flow into the Jordan River, and would provide essential domestic, industrial and agricultural water for Jordan. Syria has already been promised most of the hydroelectric power to be generated and uses water from the Yarmouk. Israel would gain hydroelectric power and regularize its access to Yarmouk water. In the long run, if sufficient water were available, the West Ghor canal could be constructed in the West Bank, as anticipated prior to 1967. The Unity Dam would thereby reduce pressure on Israel to release fresh water stored in Lake Tiberias for use by downstream Jordanian and Palestinian agriculture.[24]

* **Desalination:** A joint Israeli-Jordanian plant for Eilat and Aqaba could meet both country's needs for increased water for domestic consumption, tourism and industry in those growing port cities. Sharing in the operation of the plant would make it economical for both governments.

• **Litani River:** A multilateral study of the utilization of water from the Litani River in Lebanon and its potential for meeting regional demand for domestic water and hydroelectric power could pave the way to long-term accords among Lebanon, Syria, Jordan, the Palestinians and Israel for its shared use. Lebanon would sell the water on a commercial basis. In the past, Israeli experts have proposed that such water be piped to and stored in Lake Tiberias. Some Israelis now recognize the political sensitivity of that proposal and suggest that part of the water be stored behind the Unity Dam, with joint inspection and management. That alternative storage system may remain unacceptable to Lebanon and Syria. Moreover, Litani water would be available for at most forty years: anticipated economic development in south Lebanon, which is essential in order to stabilize the internal situation in that war-torn country, would soon absorb the excess flow. Thus, the Litani cannot provide a long-term solution to the regional water problem.[25]

* **Turkish pipeline:** The transport of water for 600 kilometers from rivers in south-west Turkey through Syria and Jordan to the West Bank would entail high initial capital costs. Its operating costs could be higher than piped water from the Litani but are potentially less expensive than desalination. Nonetheless, such a massive multi-country pipeline poses serious political and logistical problems and requires complex forms of multilateral management. The current Turkish government appears to have withdrawn the proposal. Palestinian experts argue that investing in efficient energy, waste water systems and desalination are preferable at this time, rather than relying on a problematic long distance pipeline from Turkey.

• **Nile pipeline:** Israeli experts propose that the pipeline from the Nile River to el-Arish be extended to Rafah in order to convey emergency supplies of water to the Gaza Strip. The water would be purchased at commercial rates on the basis of a forty year contract. Subsequently, they argue, Egypt would not have any excess water and lowered desalination costs might make desalination a feasible alternative for Gaza. The Egyptian government, however, rejects the idea of exporting Nile water, for political as well as economic reasons. And Palestinians prefer alternatives based on local water sources and desalination. Although water from a pipeline from the Nile would absorb a third of the current cost of desalinated water, this project is not likely to be realized.

Thus, of the five options, completion of the Unity Dam and construction of a joint desalination plant in Aqaba/Eilat are most likely and have the highest priority. Those projects would enable Syria, Jordan and Israel to increase their water and electricity supplies. Some water might be purchased in the short run from the Litani River, but not from the Nile. Water storage and hydroelectric plants on the Litani would, however, primarily benefit Lebanon itself. The availability of water from Turkish rivers remains highly problematic, even in the long run.

Jordan and Israel would also embark on major reforms in their water-use programs, in order to economize on that scarce resource. Given the centrality of water to the lives of all the riparians in the Jordan basin, ongoing multilateral systems for consultation, research and coordination would be essential in cooperation with international development agencies.

Conclusion

Resolution of the water-sharing problem is deeply political and is intertwined with the security dilemmas faced by Israel, the Palestinians and the neighboring Arab states. In the context of political and security accords, mutually beneficial agreements on water allocation are possible. In the absence of such accords, even the most elegant technical plan will fail. Nonetheless, efforts to construct such plans and to demonstrate the feasibility of mutually beneficial water projects are essential and can reinforce negotiations at the political level.

Palestinian self-rule will begin to alter Israeli-Palestinian relations and to create the possibility of restructuring the reality on the ground. Within that political framework, substantial changes are possible in the patterns of water use among Palestinians and Israelis and in the institutional arrangements that govern water use. Equity and mutuality should serve as the principles underpinning a restructured water regime, reinforcing the transformed political relationship.

ENDNOTES:

1. This paper was prepared for the First Israeli-Palestinian International Academic Conference on Water, Zurich, December 10-13, 1992, and based on the author's Transition to Palestinian Self-Government: Practical Steps toward Israeli-Palestinian Peace, report of a Study Group of the American Academy of Arts and Sciences.

2. Patrick Clawson and Howard Rosen, "The Economic Consequences of Peace for Israel, the Palestinians and Jordan," Policy Paper No. 25, The Washington Institute for Near East Policy, p.17.

3. For charts on the planning process and requirements for obtaining building permits, see Rami S. Abdulhadi, "Land Use Planning in the Occupied Palestinian Territories," Journal of Palestine Studies, XIX: 4 (summer 1990), pp. 46-63.

4. Raja Shehadeh, "The Changing Juridical Status of Palestinian Areas under Occupation," pp. 177-188 and Ibrahim Matar, "Israeli Settlements and Palestinian Rights," pp. 204-206 in Naseer H. Aruri, ed. Occupation (Belmont, MA: AAUG Press, 1989); and Aryeh Shalev, The Autonomy (Tel Aviv University, 1980), pp. 99, 105-6. Meir Shamgar, ed., Military Government in the Territories Administered by Israel, 1967-1980 (Jerusalem: Hebrew University Press, 1982), Appendix C: the text for military order no. 58 concerning "abandoned" (i.e. absentee) property.

5. The land is mostly miri (originally held in the Ottoman sultan's name but gradually privatized by Jordan) and mawat ("dead"), which villages held for pasture and future growth but did not register as private property.

6. Jeffrey Dillman, "Water Rights in the Occupied Territories," Journal of Palestine Studies, XIX:1 (autumn 1989), p. 55.

7. Dr. Jad Isaac cites figures from David Kahan (1987): in 1975, 464 Palestinians worked in the military government's agricultural extension department, but only 219 in 1987; funds were cut from $59,000 for agricultural research in 1972 to $14,600 in 1981.

8. In 1991 the UN Development Programme was permitted to open a chicken hatchery in the West Bank, after three years' wait.

9. From December 1987 through September 1991, more than 123,000 olive trees were uprooted and 379,000 dunums of land confiscated. (One dunum equals a quarter acre.) Gulf War Aftermath, the Human Rights Research Foundation, December 1991, p. 13.

10. Statistical Abstract of Israel (1988), cited in PASSIA, The West Bank and Gaza Strip (Jerusalem, 1990), p. 39; Lesch in Ann M. Lesch and Mark Tessler, Israel, Egypt and the Palestinians (Indiana University Press, 1989), pp. 246-8; Abd al-Rahman Abu

Arafa, "Development of the Palestinian Agricultural Marketing Sector" (Arabic, mimeographed essay).

11. Clawson and Rosen, p. 13.

12. Information on environmental organizations from Tanmiya, no. 25, pp. 1-3, and on agricultural efforts from Glenn Robinson, "The Role of the Professional Middle Class in the Mobilization of Palestinian Society: The Medical and Agricultural Committees," forthcoming in The International Journal of Middle East Studies.

13. Gershon Baskin, "Israel Puts the Squeeze on West Bank Water Resources," Challenge, 2:1 (January-March 1991), pp. 16-17; Middle East International, 26 May 1989, p. 16; Dillman, pp. 46-71. Although many municipalities control the supply of water within their borders, the military government must approve all municipal plans, budgets and rates. (Moshe Drori, "Local Government in Judea and Samaria," in Shamgar, pp. 245, 253.) Once the Israeli military took over most municipalities in 1982, the value to Palestinians of municipal control over water diminished.

14. Miriam R. Lowi argues that Palestinians have never received more than 125 mcm water; West Bank Water Resources and the Resolution of Conflict in the Middle East, Occasional Paper #1 of the Project on Environmental Change and Acute Conflict, American Academy of Arts and Sciences, September 1992, pp. 35-36, 41. 14.

15. An Israeli expert stated at a meeting in 1991 of the water committee of the Israel-Palestine Center for Research and Information (IPCRI) that 85-90% of the water from the mountain aquifer (300-350 mcm yearly) is used by Israeli wells.

16. Issam R. Shawwa, "The Water Situation in the Gaza Strip," in Water: Conflict or Cooperation, ed. Gershon Baskin (IPCRI, I:2, May 1992), pp. 16-20; Lesch, "Gaza: Life under Occupation," in Lesch and Tessler, p. 248. Jerusalem Post (international edition) 18 January 1992 reported that, in response to the emergency conditions, Mekorot Water Company completed a 30-km water line to supply 20 mcm daily from the National Water Carrier to the Gaza Strip. It was unclear whether this pipeline would serve settlements or Palestinian residents.

17. Settlements receive water from both the Israeli National Water Carrier and the Strip's aquifer: data is not available since statistics on water use are classified. Dillman, p. 53, contrasts two credible researchers' figures: David Kahan estimated that settlers have 2,667 cm yearly per capita or 5 mcm yearly; whereas Sarah Roy estimated that settlers use 14,200 cm per capita and 30-60 mcm yearly. I have used the lower figure.

18. Abd al-Latif Gheith said he could consider supporting self-rule "If there were a plan for autonomy that included control over lands and water, where the source of authority would be Palestinian, and which would be defined as an interim stage on

the way to statehood -- even if this stage would take five or ten years," News from Within, VII:12, 5 December 1991, p. 4.

19. Hillel Shuval, "Approaches to Finding an Equitable Solution to the Water Resources Problems Shared by Israel and the Palestinians Over the Use of the Mountain Aquifer," in Baskin, pp. 40-42.

20. Nader al-Khatib, "Palestinian Water Rights," Baskin, p. 13. Dillman says 125 mcm water could come from east of the watershed, of which settlements in the Jordan Valley use 30 mcm; pp. 47, 57.

21. Shawwa in Baskin, p. 21, describes a project in Gaza city to channel rain water through underground pipes into an artificial lake that will inject 1.5 mcm yearly into the aquifer, irrigate nearby groves, and end urban traffic and health hazards.

22. A UNDP study (1990) concluded that a seawater desalination plant could generate 50 megawatts electric power and produce 18 mcm fresh water yearly with $180 million capital investment; each cm water would cost $1.00. Israel Desalination Engineers (1990) argued that that amount of electricity and water can be produced for only 48 cents per cm. Shuval maintains that $1.00 is more realistic and desalinating brackish water would cost half as much. See Shawwa (pp. 21-24) and Shuval (pp. 47-48) in Baskin.

23. Comments, 16 April 1992 and Thomas Naff, "The Jordan Basin: Political, Economic and Institutional Issues," proceedings of the World Bank Conference on World Water Problems, June 1991.

24. Naff; Shuval in Baskin. The Jordan government stresses that regional water sharing will avert future conflicts over the control of water supplies. With Arab-Israeli peace, the Unity dam will be completed and international donors will underwrite regional efforts to build small dams in the Jordan basin, construct water treatment plants, and utilize brackish water for agriculture. Jordan: Issues and Perspectives, October/November 1991, p. 3. In a meeting at the Ministry of Water and Irrigation in Amman on 5 October 1992, Jordan's Munther Haddadein argued emphatically to the author that Jordan would need every drop of water from the Unity Dam; none would be available for the West Bank and the West Ghor Canal project would never be revived.

25. Shuval in Baskin, pp. 46-48, discusses the Litani, Turkish pipeline and Nile pipeline projects; Thomas Naff, "Israel and the Waters of South Lebanon," unpublished paper for the Center for Lebanese Studies, Oxford, October 1991.

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THE ALLOCATION AND MARGINAL VALUE PRODUCT OF WATER IN ISRAELI AGRICULTURE

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Abstract

Given the economic structure of the countries of the Middle East it is no wonder that at least two-thirds of the utilized water is for agricultural activities, while domestic consumption, industrial and other activities together take less than a third. This division is already under pressure but economically is very sticky. On the other hand, the domestic consumption would increase continuously due to both population growth, economic growth and the continuous migration towards the urban centers.

In this study we provide an analysis of the demand for water of the agricultural sector in Israel. We start with the agricultural sector since even at present, 1992, it consumes about 60 percent of the total water consumed in Israel.

The conclusion regarding Israel is that at the cost of a continuous shrinkage of the agricultural sector, sufficient quantities of water could be saved to provide for the growing population. Eventually, however, although in the long run, an external source will be required, this means that its planning has to begin today.

INTRODUCTION

The balance of water usage and water supply in the Middle East in general and in the area west of the Jordan River in particular indicates that for the last two decades the area west of the Jordan is running a continuous deficit. The area cashes in on its water reserves and their depletion has already taken its toll on the remaining reserves, both in terms of quantity and quality. More and more wells every year become salty and it becomes necessary to stop using them until recovery. Part of the water deficits were due to poor rainfall, the frequency of which was relatively high in the last decade. Thus, in spite of the fact that total water usage in Israel has not changed over the last decade its water balance has worsened considerably and every other year of poor rainfall pushes it closer to a crisis. A similar prediction applies to the West Bank and in particular to the Gaza region. Hence, if in the short run active steps of either increasing the supply of water from external sources or lowering the demand for water are not taken, we might witness a year in which the agricultural sector would be at the risk of being extinct.

In this study we provide an analysis of the demand for water by the agricultural sector in Israel. We start with the agricultural sector since even at present, 1992, it consumes about 60 percent of the total water consumed in Israel. In order to complete the analysis and obtain a detailed view of the problems, potentials and implications of the water shortage in the area west of the Jordan, one has to supplement this study with similar ones for the West Bank and Gaza. We plan to do this in the near future, once the relevant data becomes available.

The study follows with a general discussion on the Israeli agricultural sector from the point of view of water utilization and water productivity. We then continue with a residual evaluation of the returns to water in field crops and then with a linear programming analysis that aids in obtaining the shadow prices of the water constraint at declining quantities of available water. The following step is the introduction of water saving technologies, where applicable, to Israeli agriculture, and the revaluation of water productivity. The results are that, given the technological specifications, water savings weaken the water constraints without having a major impact upon the level of activity of the sector. Yet water saving might be costly especially given the market constraints of products of several agricultural branches.

THE AGRICULTURAL SECTOR IN ISRAEL

This section is by no means a substitute for a detailed study on Israeli agriculture (e.g. Kislev (1990)). We present it as a background against which the water problem is to be studied. Thus, all the data, trends and analyses are related to water consumption. Table 1 contains data on the development of crops production and their water consumption. As one can see, water, c.m, per unit output has been continuously trended downward. The calculated values for the output and value added per unit of water are averages. For efficiency analysis the meaningful information is that related to the marginal output and value added. The term "marginal of the sector" is a combination of two marginals. One is of the marginal unit of water used for a specific crop or activity. The second is related to the marginal crop. Thus for the sector it is the marginal water for the marginal crop. In order to identify the first marginal the crops production functions have to be estimated from experiments or from various field data. In order to identify the second marginal an inter branches analysis has to be done. In this study we turn to the latter, leaving the first to the agronomists. Concentrating on the inter branches analysis makes the decision regarding the unit of measurement of the marginal product of water almost trivial. The only meaningful measure is that of value-added measured in monetary units per unit of water.

Table 1
Agricultural crops output, water usage and water per unit output
Israel 1971/72-1990

Year	Agricultural Production	Crops	Water Consumption	Water
	Index (1967/8=100)	Dollars (10^6)*	$(10^6$ c.m.$^{***})$	c.m.per $ Crops**
1971/2	136	760.0	1210	1.60
1972/3	131	732.1	1297	1.77
1973/4	140	782.3	1180	1.51
1974/5	150	838.2	1208	1.44
1975/6	155	866.1	1328	1.53
1976/7	164	916.4	1271	1.39
1977/8	176	983.5	1231	1.25
1978/9	179	1000.3	1327	1.32
1979/80	187	1045.0	1235	1.18
1980/81	201	1123.2	1212	1.08

Table 1 (cont'd)
Agricultural crops output, water usage and water per unit output, Israel 1971/72-1990

Year	Agricultural Production Index (1967/8=100)	Crops Dollars (10^6)*	Water Consumption (10^6 c.m.***)	Water c.m. per $ Crops**
1981/82	215	1201.4	1282	1.07
1982/83	231	1290.8	1255	0.97
1983/84	209	1167.9	1356	1.16
1984/85	223	1246.1	1389	1.11
1985/86	222	1240.5	1434	1.16
1986/87	238	1329.9	1025	0.77
1987	252	1450.0	1179	0.81
1988	242	1410.0	1230	0.87
1989	236	1400.0	1236	0.88
1990	268	1550.0	1162	0.75

* The exchange rate used for 1971/2 was 4.0. IL/$.
** The fluctuations are mainly due to the fluctuations in rainfall. In a rainy year the production is higher while water consumption is lower.
***Agricultural total.

THE VALUE OF MARGINAL PRODUCT OF WATER - THE ACCOUNTING APPROACH

For each field crop, vegetable and fruit growing activity, data on variable costs of production details by input per unit land are available. For all the inputs the data are for quantity and price. Given the yield per unit land and the product price, relevant to the producer, various profitability indices can be calculated. In this study we are interested in the net returns per unit of water (cm). The returns per cm water is defined to equal: (Revenue - variable cost (excluding on water))/Q water. Hence, these returns are sensitive to quantities and prices of *all* variable inputs and the corresponding ones for the output. Regarding the quantities of the inputs, they are country (or regional) averages and would not change unless a technological change takes place. The variables to be questioned are usually those related to prices. Here we have two cases. The first raltes to prices that are market prices. Those are given to the producer. The second relates to prices that are imputed prices, depending upon either alternative income or costs of living. A specific and crucial one in this category is the costs of labor. The share of labor in total costs varies over the various activities. It ranges from a low of about 15 percent of total variable costs to a high of 40 percent. Hence changing its price might considerably affect the returns to water. Another input, land, is not priced when calculating the variable costs. The argument is either that it is a fixed input or that it does not have alternative usages. This might be the case in certain locations or in the short run for some agricultural producers. It is not the general case. Thus, what we define below as "the returns per cm. of water" are, in a sense gross returns; they embody the returns to land. Table 2 below contains the following information for each field crop: yield (quantities) Q, value of outputs PR, variable costs not including labor and water, VCN, quantity of labor, LB, and quantity of water, WW. Below some more issues are discussed.

The Price of Output: The activities can be divided into two groups, the first for which the price of output is determined by the international market. The price in NIS is that in the international market times the exchange rate (in our calculations NIS 2.40/$1). Hence, the demand for the output is perfectly elastic. The price of products that are in the second group is determined in the local market depending on quantity supplied and on all the parameters and the corresponding magnitudes of the variables that determine demand.

Table 2
The Rents from Water, Israel, Field Crops 1991 Prices

Crop	Unit of Measurement	Groundnuts Light Soil	Groundnuts Heavy Soil	Groundnuts Bet Shean	Groundnuts West Negev	Sweet Corn Early	Sweet Corn Season a	Sweet Corn Season b	Corn Season c	Corn Season d
Main Product	Kg.	500	500	400	580	1800	1800	1800	1800	1800
Total Revenue	NIS	1,346	1,346	1077	1554	626	622	673	723	739
Variable Cost (excluding Labor and Water)	NIS	488	485	541	587	273	253	249	291	329
Water	NIS/cm.	500	400	900	650	500	350	350	500	600
Labor	hours	6	6	6	6	4	3.2	3.2	4.0	4.0
Returns to Water (A)	NIS/cm	1.43	1.80	0.44	1.27	0.52	0.84	1.00	0.68	0.53
	$/cm	.60	.75	.18	.53	.22	.35	.42	.28	.22
Returns to Water (B)	NIS/cm	1.72	2.15	0.60	1.49	0.71	1.05	1.21	0.86	0.68
	$/cm	.72	.90	.25	.62	.29	.44	.50	.36	.28
Returns to Water (C)	NIS/cm	1.51	1.90	0.48	1.32	0.57	0.90	1.06	0.73	0.57
	$/cm	.63	.79	.20	.55	.24	.37	.44	.30	.24

Return A - value of labor as charged - 23.37IS/H, 10$/H.
Return B - value of labor zero.
Return C - value of labor, average labor costs - 16.8 IS/H, 7$/H.
Exchange Rate: 2.40 IS/$.
The land is not assigned a value.

Table 2 (Cont'd)
The Rents from Water, Israel, Field Crops 1991
Prices

Tomatoes for Industry Seeding	Sunflower Supplementary Irrigation	Chickpeas North	Chickpeas South	Bulgarian Chickpeas North
9000	220	220	200	220
1530	446	371	338	328
914	123	226	238	190
350	150	160	220	120
8	3.15	1.9	1.8	1.85
1.23	1.66	0.66	0.26	0.79
.35	.69	.28	.11	.33
1.76	2.15	0.90	0.45	1.07
.73	.90	.38	.19	.44
1.38	1.80	0.71	0.32	0.81
.57	.75	.29	.13	.34

Bulgarian Chickpeas South	Wheat Irrig.	Wheat Supp.Irr.	Sorgham Supp.Irr.	Corn Grain	Chickpeas Spanish	Sunflower Supp.Irr. Seeds
200	650	400	500	1000	150	120
298	322	214	227	475	307	325
190	216	195	127	325	213	126
200	220	120	100	350	200	100
1.85	2.50	1.70	2.10	2.3	1.85	3.15
0.32	0.22	-0.17	0.50	0.27	0.25	1.27
.35	.09	-0.07	.21	0.11	.10	.53
0.54	0.48	0.16	1.00	0.43	0.47	1.98
.23	.20	.06	.42	.18	.20	.82
0.35	0.29	-0.07	0.65	.32	0.35	1.45
.15	.12	-0.04	.27	.13	.14	.60

Cotton Akalla Sprinklers	Cotton Akalla Drip	Cotton Pima Drip	Tomatoes Industrial Planting
450	500	420	9000
806	895	948	1530
487	539	552	1124
400	480	520	350
7.0	8.0	8.0	8.0
0.39	0.36	0.40	0.63
.16	.15	.17	.26
0.80	0.53	0.76	1.16
.33	.22	.32	.48
0.50	0.46	0.50	0.78
.21	.19	.21	.32

Changes in output would change the price of the product and correspondingly the returns to water. Hence, these activities require a sensitivity analysis. One proper model to be used is that of quadratic programming.

Yields: We view the yield as a constant. Yet in most cases it is a function of the quantity of water (as well as of other inputs). The relevant question is: what is the partial elasticity of output w.r.t. water. This relation is not dealt with here.

The residual analysis was done for sampled vegetables and fruits and for all relevant field crops. The reason is that preliminary calculations showed that the marginal value product of water in all the examined vegetables and fruits is above $0.5/cm also when self-employed labor is charged $10/hour. This is not the case for field crops. The other reason is that the prices for most field crops are exogenous, i.e. independent upon the quantity produced while the prices of the other products are expected to be inversely related to the quantity produced, thus requiring a more delicate analysis.

The above residual analysis regarding the water, using specific activities in the agricultural sector, can be summarized in the form of a demand function of agriculture for water (Figure 1). The implied conclusions regarding production and supply of the water using agricultural products are presented below.

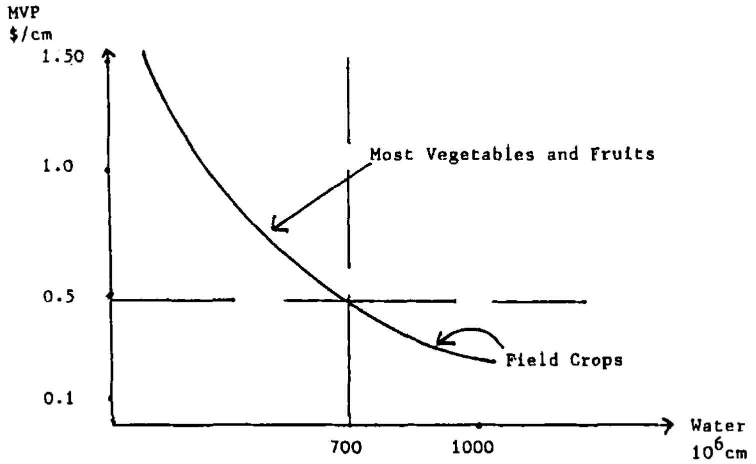

Figure 1: Marginal Value Product of Water in Israeli Agriculture,1990/91

Vegetables: Most of them nontradeable, or tradeable over short distances by truck, long distances by plane. Costs of transportation $3/10 km. per ton and $500/ton respectively.

Most of the vegetables will continue to be grown locally. Supplements to local production will be imports from neighboring areas, such as Gaza Strip, the West Bank, Egypt, Syria and Lebanon. One necessary constraint on imports is sanitary requirements. A market constraint: the imported varieties have to be similar, if not identical to the locally grown ones (taste).

Fruits: Eliminate marginal plantations. Selectivity in planning for new plantations, only where the yield is high, e.g. 25% above average. Consider the importation of fruits from the West Bank, Lebanon, Turkey.

Field Crops: Take advantage of the rain-fed ones where possible. Consider supplementary irrigation where it is agronomically and economically feasible. Start to phase out crops with low returns to water. Try to substitute recycled water where feasible, e.g., brackish water in cotton.

Agricultural Sector: The sector will have to shrink in terms of water consumption, but not necessarily in output and employment. Also its internal structure will change over time from field crops and plantations to vegetables and imports. The sector will continue to be affected by technological progress, mainly those that are reflected in water saving per unit of output and per unit of land. The water saved and substituted for in the agricultural sector will be consumed by the residential sector. A relatively small quantity of this water will be used by the commercial and industrial sectors.

Furthermore, if one expects that domestic population growth and immigration to Israel would seem to be 180 thousand persons per annum, this means that approximately 20 million cm. of water will have to be transferred annually out from the agricultural sector, while keeping the total quantity of fresh water used by the Israeli economy at the current level. There is sufficient water in the field crops branch to supply this process for more than 15 years. If, on the other hand, the domestic sectors, households and commercial sector, will increase their transfer of brackish water to agriculture (and landscaping), e.g. towards 30 percent on the national level, the net change of total water used in agriculture will not be negative. On the contrary it will even increase.

One can take alternative ways for the investigation of the demand for water of the agricultural sector. The Linear Programming approach is presented below while the Quadratic Programming approach is in the process of investigation.

WATER EFFICIENCY ANALYSES

The average efficiency of water in each economic, agriculture, branch is by definition the ratio of the branch's value added and the quantity of water it consumes. Unfortunately these variables are not available on a continuous annual basis. If one looks for a reasonable breakdown of the agricultural sector into branches the only source of useful data are the input-output tables. For recent years, they are for 1972/3, 1975/6 and 1982/3. Over this period of time global prices and relative prices of inputs, including water, and outputs have changed considerably.

From various data one sees that the quantity of water per unit output and per unit value added has declined over time indicating a continuous process of water saving. From these data one can also identify the marginal branches in the Israeli agricultural sector. They are various livestock, various field crops and cotton. Hence, if water is to be allocated among the agricultural branches given that one wants to maximize the value added of the sector, the order of water allocation is: poultry, dairy, various small agricultural branches, roughage, melons, vegetables and potatoes, various fruits, field crops and citrus. As a matter of fact one might ask why not allocate the water to only the most productive, in terms of water, branch, poultry in 1982/3? To answer this question the market constraints for the various agricultural products have to be introduced. In order to bypass detailed and very time consuming studies on market demands we assume that regarding the domestic market the observed outputs were equal to the quantities demanded at the targeted (policy wise) prices which equalled market prices. This assumption also takes care of imported products for which the domestic production is only a supplement (grains, some beans). The only products are the exported products and various grains, production of which should not be limited. In Israel one should consider only two significant exportable products (from the water consumption point of view), citrus and cotton. With regard to citrus there are already marketing difficulties as well as planting. Thus, its output at least in the short run (2-3 years) is limited at the current level of production. This leaves only cotton to be unconstrained. Thus, if cotton ranks high on the value added-water list of ratios it deserves to get as much water as is available from the pure economic point of view. This, however, is not the actual case. One has also to recall that some agricultural products are used as inputs in the production of other agricultural and non agricultural products.

The above discussion implies that in order to solve the water allocation problem, given the market constraints, a mathematical optimization mechanism has to be used. Since the relevant data at our disposal are from an input-output table we decided on the Linear Programming method to be the optimization technique. As will become clear below there are other advantages to the L.P. method in addition to the readily available computer package.

THE LINEAR PROGRAMMING ANALYSES

The optimization problem is a classical one, maximization of the value added of the agricultural sector in Israel subject to an annual water constraint and various market constraints. Given the scale of each branch on the one hand and the fact that we are interested only in the totals (not internal distributions over regions or producers) the assumption of fixed input-output coefficients, i.e., of constant returns-to-scale is not an extreme one. Thus, the problem became

$$\text{Max. } \sum_{j=1}^{j} C_j X_j$$

subject to:

$$\sum a_{ij} X_j \le B_i \qquad i = 1,\ldots,K.$$

where C_j is the value added per unit of output of activity j.

a_{ij} is the input output coefficient of constraint i. One constraint is the total water available to the agricultural sector. In this case i is water and the a_{ij} is the quantity of water needed per unit output of activity j. The L.P. problem using the 1982/3 input-output table is shown in Appendix A followed by explanations for the specific coefficients and constraints.

In addition to the optimal values of the activities, the L.P. package also provides information on the value of the objective function, on the shadow prices of the constraints and enables a sensitivity analysis on the values of the C_j's and B_i's. In Table 3 we present the results of the basic problem in which the water constraint is 1.255 billion cubic meters, the 1982/2 agricultural water consumption, and of another seven maximization problems in which this quantity was reduced gradually, by 0.1 billion cubic meters at a time, down to a level of about 50% of the initial constraint.

Table 3
The Optimal Solutions for the 1982/3 Technology, Values of the Objective Function and the Shadow Prices of Water

Problem	Water Constraint 10^6 c.m.	Value of Objective Function (10^6NIS 1982/3 prices)	Net Shadow Price of Water NIS/1000 c.m. 1982/3 prices	$/c.m. 1982/3 prices
1	1,255	33.36	14.67	.49
2	1,155	31.89	14.67	.49
3	1,055	30.42	14.83	.50
4	955	28.94	14.83	.50
5	855	27.31	16.33	.54
6	755	25.67	16.33	.54
7	655	24.04	16.33	.54
8	555	21.75	26.06	.87

From Table 3 one sees that the value added in agriculture declines by about one third which in macro terms is not impressive. In 1982/83 the agriculture in Israel constituted only 6% of GDP. This implies a decline of 2% of GDP due to a reduction of water usage in agriculture by more than 50% of the total annual water consumption. The decline of water by this amount will eliminate four agricultural branches, irrigated grains and beans, cotton, various livestock and fruits excluding citrus. One has, however, to consider the social-cultural effects of this outcome which might have a very high social cost.

One also sees that at the base level of the water constraint the net value of the marginal water is 14.67 IS/1000 c.m. which is about .49 $/c.m. This value increases very slowly and becomes about .87 $/c.m. when the constraint slips below .625 billion c.m. i.e., at about 50% of the base level. The net shadow price of 49 cents per c.m., everything in 1982/83 prices, is considerably above the price already paid for water, 9 cents per c.m. Hence, the gross marginal product of water is about .60 $/c.m. This implies that when considering the development of new water resources the marginal costs of their supply should not exceed 60 cents per c.m.. We pointed to such a source in the Egyptian-Israeli, capital-water exchange study (Fishelson, (1991)). Furthermore, the rapid depletion of the local sources (pictured in our study by the decline of available water to .555 billion c.m.) implies that within a few years alternative sources with marginal costs of supply of about 80 cents per c.m. should also be considered. However, before searching for these sources let us see what can be done in terms of water saving that might become technically feasible due to R&D that is related to irrigation, genetics and advanced production technologies.

WATER SAVING AND WATER VALUES EMERGING FROM R&D

This section might be regarded as wishful thinking, although in various aspects it is already not far from reality. We do not detail the possible outcomes of R&D. We only show their impact on the agricultural sector in Israel in terms of water usage. Given that a resource is an effective constraint, a resource saving technology would make its constraint less binding and would thus lower its shadow price. This result seems to contradict the common economic wisdom that associates the input's saving with the increase of its marginal product. The reconciling of the two truths is presented in Figure 2. The explanation is that the saving generates a new effective constraint at which the marginal product is smaller than at the "old" effective constraint because the level of the "new" constraint is larger. An indication of the higher productivity of water is the higher value of the objective function, the integral of the MPV curve up to the effective constraint. On the other hand, if the market constraints, discussed previously, are not relaxed, the increase of the value of the objective function might not be realized.

The analysis below contains the following modifications relative to the one presented in the above section:

(a) Water needs per unit output, a_{ij}, in the activities in which water saving can be applied are lowered.

(b) In these activities the value added per unit product, C_j is changed. The assumed relations between the rate of water saving and the change in the value added are given below:

Case:		1	2	3	4
Change water,	-%:	15	25	35	45
Change value added,	-%:	5	10	20	30

(c) Market constraints of activities for which exports or import substitution are feasible are relaxed.

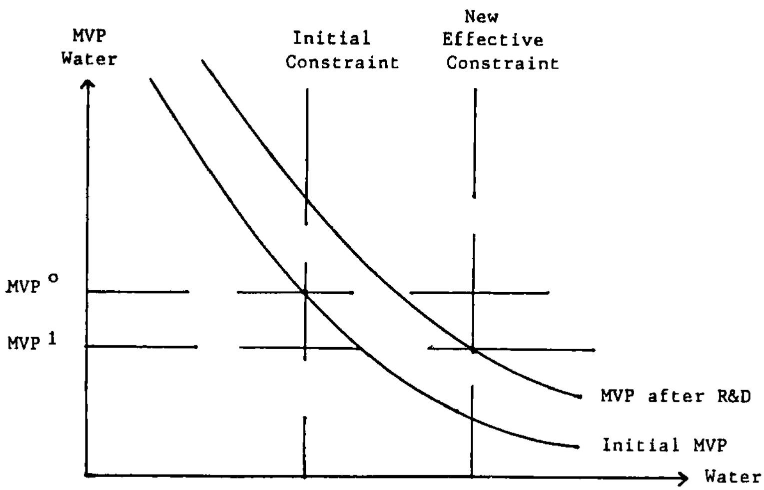

Figure 2. The Effect of R&D on the MVP of Water.

Table 4 presents the solutions for cases 1 to 4. Each column follows Table 3 that was presented previously and contains solutions for water quantities ranging from the base level, 1,255 billion c.m., down to .555 billion c.m.[1] The water saving technological progresses are hypothetical ones. They were assumed for illustrative purposes. In order to appreciate their implications, it is necessary to compare their results with the base case.

The immediate result from the introduction of water saving technologies, everything else constant, is that water ceases to be an effective constraint. The markets' capacities for the products become the effective constraints and they limit the production. In cases 1 and 2, the water constraint becomes effective after a small decline of water, by about 5%. In case 3, it becomes effective only after a cut of available water of about 10%, and in case 4 after a cut of about 20%. In all cases the value of the marginal product jumps up very steeply from zero to about $.5/c.m. The reason is that even at the marginal activity, the marginal value product of water is about $.5/cm. For example, in case 1 the marginal activity is cotton. The MVP of water in cotton in 1982/3 was $.54/c.m. (one unit of output, 1000 NIS, generated 549 NIS of value added and required 33.5 thousand cubic meters of water. The exchange rate then was .03 NIS/$). After the initial jump of the MVP it increased gradually and might have another jump (in case 1 when the water constraint fell below 588 million c.m.). A second jump is also noticed in case 2, while in cases 3 and 4 there is only one steep increase of the MVP.

Table 4

Value of the Objective Function (10^6\$), V, and of the Marginal Product of Water (\$/c.m.), MVP, The Four Cases

Water Constraint (10^6c.m.)		Case 1	Case 2	Case 3	Case 4
1255	(V)	1,179.0	1,215.8	1,184.7	1,081.2
	(MVP)	.000	.000	.000	.000
1115		1,141.1	1,199.2	1,184.7	1,081.2
		.54	.58	.000	.000
1055		1,086.5	1,140.5	1,152.2	1,081.2
		.54	.58	.60	.000
955		1,031.7	1,081.5	1,092.0	1,0768.3
		.55	.58	.60	.51
855		975.5	1,022.6	1,031.6	1,0149.0
		.61	.59	.61	.60
755		914.6	954.5	968.8	956.0
		.61	.65	.67	.62
655		853.8	892.5	901.4	892.1
		.61	.65	.67	.69
555		782.9	816.0	834.4	815.6
		.91	.98	.67	.69

The values of the objective functions decline gradually. Here it is interesting to compare the four cases. One sees that case 2 is preferable to case 1 at all the levels of the water constraints. The same holds for case 3 vs. case 4. Comparing, however, cases 2 and 3 shows that case 2 is preferable to case 3 when the water constraint is above about 1.08 billion c.m. Below this level case 3 is preferable. Hence, the choice of technology to be adopted depends upon the severity of the constraints of the limiting input and on the constraints imposed by the markets (one reason for the inferiority of case 4 to case 3 is the non-expansion of the markets capacities).

CONCLUSIONS

The value added of the agricultural sector in Israel in 1982/3 was 33.4 million NIS (1.13 billion $). With no water saving technology it would have declined by about 33% (to 0.725 billion $) if the water constraint would have declined from 1.255 billion c.m. to .555 billion c.m. Given the water saving technologies (which are paid for - the value added per unit output is lower) the value added of the agricultural sector increases by 8% (case 1) to 16% (case 3) when the water constraint is very effective, available water is only .555 billion cm. The MVP of water was already relatively high (this was specific to 1982/3 and resulted from local prices, international prices and the exchange rate). It is thus doubtful whether it is at this level also at present. But one cannot answer this question without repeating what we did for 1982/3 for the current technology and prices. The estimated MVP's, in spite of the possibility of being overvalued, are still encouraging. They do imply that nonconventional technological solutions for water supply might be close to being economically justified. The gap that remains could be closed by other benefits, the most important of which is removing one of the major obstacles to a peace process.

The above results require, however, some reservations:

(1) Since 1982/3 there were major changes in absolute and relative prices of agricultural products. For example, cotton lost most of its superiority, its world prices dropped by about 50%.

(2) Regardless of the optimal plan, the nontraded products will have to be produced locally, at least to some extent (melons, vegetables, various fruits). A decline in their supply would result in a major increase in their prices which would eventually make the product worthwhile for production. The price increases would also take their toll in terms of inflation, required change in daily diet and social behavior.

(3) Mathematical planning does neither consider the social impacts nor those upon the landscape. With less than 50% of field crops and plantations, the State of Israel would not be the same. The country would look different. It would return to being a desert. The dream of making the desert bloom would partly fade away. This has its costs which might be quite high.

The implications are that water saving is either to come through technological progress of water saving technologies, or that the solution should be on the supply side, i.e., technologies and means of increasing the available quantities of water. Cutting the quantities of water is feasible and seems to be economically of relatively low cost, but this cost is only a fraction of the true total national cost.

APPENDIX A

The Base L.P. Problem*

```
Max          .49 X1 + .754 X2 + .578 X3 + .518 X4 + .594 X5 + .193 X6
     +       .17 X7 + .359 X8 + .59 X9 + .735 X10 + .618 X11
Subject to
         2)  20 X1 + 22.56 X2 + 39.47 X3 + 43.62 X4 + 22.05 X5 + .56 X6
     +       .1 X7 + 31.32 X8 + 36.24 X9 + 28.24 X10 + 6.9 X11 <= 1255000

         3)  .897 X1 <= 2940

         4)  X2 - .28 X6 - .081 X8 <= 1

         5)  .993 X3 <= 600

         6)  .999 X4 >= 600

         7)  .985 X5 - .021 X6 - .24 X8 <= 7200

         8)  -.003 X3 - .004 X4 - .014 X5 + .99 X6 - .003 X9 - .003 X10
              - .003X11 <= 8885

         9)  -.005 X5 + .885 X7 - .002 X9 - .001 X10 - .001 X11 <= 13300

        10)  -.001 X5 - .001 X7 + .925 X8 - .001 X9 - .001 X10 - .001 X11
             <= 2680
        11)  X9 <= 8838

        12)  X10 <= 9400

        13)  -.019 X5 - .004 X6 - .005 X8 - .001 X9 + .946 X11 <= 6170
End
```

* See explanations below.

<u>Explanations</u>

(1) All the coefficients and levels of constraints are for 1982/83 and were extracted from the Input-Output tables for that year.

(2) The C_j, the coefficients in the objective function, are the sum of the input-output coefficients of returns to labor and value added except labor. The C_j's are 1000 NIS of value added per unit of activity j (1000 NIS).

(3) The a_{2j}, the coefficients in the second row, are the water inputs (1000 c.m.) per unit of activity j (1000 NIS).

(4) The coefficients in rows (3)-(13) are the input-output coefficients taken from the I-O tables. The a_{jj} coefficient is 1 - the a_{jj} in the I-O tables.

(4) All the signs of the constraints in rows (2)-(13) are $\leq$ except for row (6).

Except for row (2) the levels of the constraints, B_i, are the market constraints on domestic production in 000 NIS. The $B_{i's}$ were calculated from the I-O tables as follows: Grand Total less Purchases by Other not Agricultural branches. The Grand Total is the sum of Intermediate Uses Total + Final Uses Total - Competitive Imports. The B_2 is the water constraint, 1.255 billion c.m. The B_6, 600, was imposed to assure the production of at least 600 units of activity 4 (other field crops) since in the initial run the optimal value of X_4 was zero.

NOTATIONS OF ACTIVIES

X1 - Cereals and Pulses
X2 - Roughages
X3 - Cotton
X4 - Other Field Crops
X5 - Vegetables, Potatoes and Melons
X6 - Dairy and Meat Cattle
X7 - Poulty Farming
X8 - Other Livestock
X9 - Citrus
X10- Fruit Growing
X11- Agricultural not mentioned elsewhere

FOOTNOTE

1 The agricultural branches for which water saving is considered to be feasible are: field crops excluding roughage and cotton (1), roughage (2), cotton (3), other field crops (4), vegetables, potatoes and melons (5), citrus (9), other fruits (10). The numbers in parentheses correspond to the activities in the L.P. model and to the branches in the Input-Output table of the 92 branches aggregation.

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ECONOMICS, ECOLOGY AND EQUITY: LESSONS FROM THE ENERGY CRISIS IN MANAGING WATER SHARED BY ISRAELIS AND PALESTINIANS

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ABSTRACT

Whereas almost all nations in the Middle East faces a chronic problem of water shortage, the riparians of the Jordan River (mainly Israel, Jordan and Palestine) are close to crisis. To deal with this situation, the author suggests that we shift emphasis in water management from supply to demand and from quantity to quality. This approach emulates alternative energy analysis, dubbed the "soft path," which has demonstrated that it is typically economically cheaper and ecologically less damaging to approach problems from the demand than from the supply side. Major opportunities exist to increase efficiency ofuse in the Jordan River basin, particularly for irrigation, which is by far the main consumer. Other opportunities lie in avoiding the degradation arising from excessive use of pesticides and fertilizers, inadequate treatment of sewage, and industrial dumping. Continuing the analogy to energy, we should recast policy analysis in terms of normative scenarios so as to determine the feasibility and impacts of alternative policies and reactions. All sides see close linkage between water and security. Therefore, only through exploration of alternative futures, not simply projection of the present into the future, can we find ways to minimize the potential for conflict.

1. INTRODUCTION

For most of recorded history, conflict in the Middle East has had more to do with water than with land, much less oil. Few of the main rivers in the region belong exclusively to a single state, and the need to share water has challenged each people, each civilization, each government. Genesis, perhaps the oldest "history" of the region, contains incident after incident where water was at issue, and more than 50 direct references to water can be found in the Koran (Water Authority of Jordan, no date).

Recent history is no less contentious, and has of course been particularly so in the land shared by Israelis and Palestinians. Again, one of the key areas of contention is water, which is exactly why we are here together at this very special, indeed historic, conference. For this audience, there is little need to review the history of conflict over water, and I can assume a general knowledge of regional geography and hydrology.

Shuval (1992) has provided a convenient summary of claims and concerns about water of each Israelis and Palestinians.

2. CHRONIC PROBLEM OR CRISIS SITUATION?

The most common word used in popular articles on water in this part of the world is "crisis." Academic articles, however, tend to suggest that we face not so much a crisis but a chronic condition. Both popular and academic literatures on water in the region are already vast, which, if nothing else, indicates that everyone recognizes that there is a problem!

What I will try to do in this keynote address is to suggest directions from which amelioration of that problem may come. I will distinguish three inter-related and interacting issues:

- The first issue is the classic one of water quantity. In much of the Middle East, and notably in Israel, the Occupied Palestinian Territories and Jordan, the quantity of water demanded exceeds that which can be supplied on a renewable basis. This is mainly an economic issue, and my first point is that amelioration of the situation is more likely to come from conservation in demand than expansion of supply.

- The second issue is the newer one of water quality. Much of the region's water is polluted by industrial and agricultural wastes, and in some cases by human sewage. This is bad enough for surface water, but for the groundwater on which the region depends so critically, it is disastrous (Goldenberg and Melloul, 1992). My second point is that continued neglect of water quality will ultimately compromise attempts to resolve water quantity problems.

- The third issue, geopolitics, is both new and old. Almost all nations in the region depend on water supplies in which at least one other nation has a significant interest. However, in no other case are national interests so interlocked as with the aquifers and rivers shared by Israelis and Palestinians. Here I will suggest a different approach to incorporating equity into economic and environmental discussions.

From the foregoing, it would seem that water problems in the Middle East are indeed chronic. But is this really the case? By emphasizing their chronic nature are we understating the extent of the problem? In using the word "crisis," popular writers may be closer to the mark than academics. For one thing, the problem today is not simply to find ways of ameliorating a supply problem but to do so in ways that are simultaneously economically efficient, ecologically responsible, and politically equitable. Attention to one dimension alone is unlikely to be helpful.

Moreover, to emphasize the chronic nature of the water problem is a bit naive. Never have so many people been dependent on piped water and sewage systems that dare not fail, nor have we have we ever had such volumes and varieties of pollutants released into water courses, nor have we ever experienced such rapid rates of population growth, urbanization and economic change.

And, while conflict over water may be endemic to the Middle East, nowhere is the conflict sharper than in the Jordan River basin shared largely by Israel, the West Bank and Jordan (with Syria and Lebanon also having some rights). Not only is demand and supply most seriously out of balance in these areas, but a good part of the water consumed in Israel originates in aquifers that rise on the West Bank -- on land that, in the context of a peace settlement, is likely ultimately to come under the control of Palestinians. If this does not cumulate to make a crisis, I can not think of what does.

3. THREE ISSUES

3.1. Moderating Water Demand: The Economic Challenge

From the moment that the first human being placed some stones to direct water toward crops, supply augmentation has dominated water policy. Only in emergencies does conservation take priority. Supply orientation is not absent from this Conference. With but few exceptions, much more attention is devoted to options for increasing or adjusting supply than for reducing or redirecting demand.

In my view, it is time to shift emphasis to the demand side of water management. There are lessons for us in the experience gained following the energy crisis. Just as with energy, we are likely to find that gaps between water demand and water supply are more easily, more cheaply and more safely resolved by reducing use than by increasing delivery.

True, countries in the Middle East are already relatively efficient in their use of water; per capita withdrawals in Israel are only about 25% as great, and in Jordan only about 10% as great, as in the United States or Canada. The problem, to quote Thomas Naff (1990), is not that these nations are inefficient but "that they are not as efficient as the crisis and the scarcity requires them to be." Here too there may be an analogy from the energy crisis where it was the already energy-efficient countries, such as Sweden and Germany, that led the way toward even greater energy efficiency.

Consider further water use in Israel, which is the nation I have most closely studied (Brooks and Shadur, 1991; Lonergan and Brooks, 1992). Management of Israel's water system rest with the Water Commission, which is under the authority of the Minister of

Agriculture. Clearly, water policy is subordinate to agricultural policy. Farming accounts for about 70% of all water use in Israel, including saline and recycled water. The point is not that this is high; the share of water taken by irrigation is even higher for most other countries in the region. Nor is the point that this water is inefficiently used; Israel is a world leader in the development and operation of irrigation systems that optimize the flow of water to root systems where it does the most good. Rather, the point is that the same water could be used even more effectively and with greater economic gains in other sectors of the economy. The issue is not one of micro-economics but of macro.

Only recently has the domination of the Israeli water economy by agriculture been challenged. In late 1990, the Israeli State Comptroller charged the Water Commission with "25 Years of Mismanagement" -- courageous in itself but even more so as an implicit attack on the Minister of Agriculture, who is near the top of the bureaucratic hierarchy in Israel (State Comptroller, 1990).

The State Comptroller later identified the low price of water to farmers as a major cause of the decline in water availability in Israel. This too is a common problem. In no country can farmers afford to pay a very high price for irrigation water if they are to make a profit. In Israel proper, water is sold to farmers at highly subsidized rates; typical prices are $0.16 per cubic metre for agricultural use, compared with $0.40 for domestic use. Zarour and Isaac (1991) estimate that the actual cost to supply water in Israel is $0.36 per cubic metre. Marginal cost is presumably even higher. Even if the level of subsidy to farmers is modest by regional standards (Khouri, 1992), the low marginal productivity of water used in agriculture suggests strongly that, despite economic history and despite Zionist tradition, a considerable volume of water should be reallocated from irrigating crops to industrial and household uses, or simply left unpumped so as to protect the aquifers. Perhaps flowers and some fruits and vegetables exported fresh to Europe can pay the full cost of water, but not most field crops and certainly not cotton.

Water is expensive because even conventional water supply systems are capital intensive, especially per dollar of revenue. According to a World Bank study mentioned by Joyce Starr (1992), the Middle East/North Africa has the highest capital costs in the world. Operating costs are also high. Israel and Jordan each use about one-fifth of their electricity just to pump water.

Alternative water supply systems are still more capital intensive, none more so than desalination. The appeal of desalination is easy to understand. One might say that desalination is to water as nuclear power is to electricity -- the promise of unlimited supplies coupled with the curse of high costs, environmental problems, and megaproject fragility. Desalination takes enormous quantities of energy, and even with low oil prices, the cost would have to be three to ten times even what urban dwellers pay for drinking water. Thus, it is not surprising to find that three-fifths of the world's desalination capacity is located in just two countries, Saudi Arabia and Kuwait. Still, the idea continues to draw attention, and of late has been linked to the Med-Dead or Red-Dead canals, which, by dropping water from sea level to the rift valley, would generate about 70 percent of the electricity required for a reverse osmosis plant (Office of the Prime Minister, 1985). Such plans are questionable on both economic and environmental grounds, at least prior to full consideration and implementation of demand side measures. If there is a near-term future for desalination, the plants are more likely to start with brackish water than sea water.

There are many analogies between the post-1973 experience with energy and what is now occurring with water. Both water and energy have been priced below true costs; in both cases, environmental damages occur at the production and end-use stages; both are governed by institutions geared to augment supply rather than to manage demand; and both are so widely used that many people doubt that conservation can be an effective force.

The alternative approach to analysis of energy -- dubbed the "soft energy path" -- challenges conventional wisdom at each of these points (Lovins, 1977). Space does not permit even a cursory review of soft energy analysis, but its first principle is a focus on the services provided by energy, not delivery of the commodity itself. This principle is based on recognition that energy (water) use is only a means to an end, not the end in itself, and that the purpose of energy (water) consumption is to satisfy particular end-uses or services, such as growing a certain amount of protein or cooling a certain amount of material. The question then becomes how each end-use or service can be most efficiently satisfied, and, as Lovins (1981) trenchantly remarks, "in the soft path how much energy we use to accomplish our social goals is considered a measure not of our success but of our failure."

The conventional conception of the problem is very different. It focuses on the question of ensuring that adequate supplies exist to meet present and future energy (water) demands. This perspective (with its roots in the doctrine of the purported insatiability of human wants) leads to a supply orientation in which demand is treated as virtually exogenous to the policy process, a "given" which must be satisfied by ever-greater sources of supply. Conservation may be considered, but generally as a way to buy the time necessary to bring new supplies on line.

The soft path stands the conventional approach on its head. Analysis starts with end-uses, not sources of supply, and this reversal forces a bottom-up rather than top-down view. From this perspective, conservation and end-use efficiency are not merely unfortunate necessities, but instead the primary components of rational resource planning, the first place on which to focus attention.

Of course, the analogy between energy and water is not perfect. Among other things, water lacks the direct linkage to thermodynamic constraints; except for hydropower, supply does not vary from year to year; and direct use is more important than indirect. Nevertheless, the analyses already done suggest enormous opportunities to maintain standards of living with lower consumption of water (Brooks and Peters, 1988; Rocky Mountain Institute, 1991). For both water and energy, the amounts actually needed to support life, indeed to support a high quality of life, represent but a small fraction of total consumption. The lesson for both Israel and the Occupied Palestinian Territories is that the largest, safest and cheapest "source of supply" for water is likely to be found through conservation in and reallocation of existing uses, mainly irrigation water.

3.2. Water Quality: The Ecological Challenge

A second principle of the soft energy approach is to devote as much attention to conserving quality as quantity. If in discussions of the Middle East water, demand is neglected in favour of supply, so too is quality neglected in favour of quantity. Too many analysts ignore the simple equation: Water In = Water Out (where water out includes evaporation and transpiration, both of which emit greenhouse gases).

All Middle Eastern countries have a wastewater problem, and one that links directly to water supply. Dumping of wastewater is common, sometimes directly into water courses and sometimes into wadis which, at the next rainfall, seep into aquifers. Among the major problems affecting Israel and the Occupied Palestinian Territories are the following:

- Per hectare use of pesticides and of fertilizers are among the highest in the world, and run-off is equally high (and unregulated). As one result, nitrate concentrations in the Coastal Aquifer in Israel (partly from sewage effluent) are rising toward levels at which the water will no longer be acceptable even for irrigation (Gabbay, 1992).

- Olive oil mills, an otherwise excellent way to increase the value added from farming and provide employment in rural areas, release a black liquor that carries a very high BOD level yet that is typically merely dumped into wadis.

- Israel is among the world leaders in recycling sewage for agricultural use, and other countries in the region are now following suit (Shuval, 1987; Gabbay, 1992; Khouri, 1992). However, re-use has its own problems; even in Israel, two-thirds of the re-used water receives minimal or no treatment, and much of it contains excessive quantities of chemicals.

- Industrial contamination of surface and groundwater can also be assumed to be serious, even in the absence of regular testing. Spot checks in Israel, especially near the coastal aquifer, regularly show concentrations of solvents, petro-chemicals, gasoline products and other contaminants at levels that are above those specified as acceptable in international standards (Gabbay, 1992).

- Coastal rivers are the most seriously degraded ecosystems in Israel. Most are only a few ten's of kilometres long and exist today with greatly reduced flow because the springs which fed them have been diverted to the National Water Carrier. According to one source, the Kishon River in Haifa receives 10 thousand cubic metres daily of industrial waste water, bad enough in itself but made worse by the absence of regular flushing (Hirschberg, 1991).

Neglect of water quality also has the effect of limiting recreation opportunities. Flow in the Jordan River has been reduced to a fraction of its former volume, and now an Israeli kibbutz plans plan to dam (albeit for electricity rather than, directly, for water) the last free-flowing stretch of the River. Flyways for tens of millions of migrating birds, which pass through this area every spring and fall, and which attract thousands of bird watchers, are threatened by pesticides, habitat loss and water development projects.

There are exceptions to the generally dismal picture of water quality in Israel. Lake Kinneret (the Sea of Galilee) has been under a unified management plan that prohibits dumping and restricts uses of water from the lake. As a result, Kinneret retains its quality, its beauty -- and, not incidentally, its tourist income. The Yarkon River in Tel Aviv is serving as the test case in a study of the physical and economic feasibility of rehabilitation to a level that would permit recreational use.

In summary, the availability of water in Israel and in the Occupied Palestinian Territories is threatened as much by declining water quality as by declining water tables. However, quality and quantity are linked in a positive sense as well. Conflicts between economics and environment that arise so commonly when approached from the supply side are typically attenuated if not eliminated when approached from the demand side. For example, efficient irrigation systems reduce run-off and soil salinization, and low-flow toilets and showers cut wastewater flows into sewers. With only scattered exceptions, the same policies that promote economically more efficient use also support environmental protection.

3.3. Water Equity: The Geopolitical Challenge

How many times have we seen projections for water that show deficits between water use and water availability that grow greater year by year! Such projections are all but meaningless. In point of fact, water deficits cannot continue growing. Economic and ecological barriers will prevent the gap from growing ever wider, and in some cases they may even force corrective measures. As a way to identify short-term problems and to manage operations in water utilities, forecasts have their place. As a way to determine policy options, they are inadequate if not misleading.

One last time, I turn to the soft energy path for an alternative approach. The third main principle of soft path analysis, after its foci on demand and on quality, is to substitute "backcasting" for forecasting. Forecasting begins from the present and tries to determine the future. Backcasting begins from the future and tries to work back to the present. For example, in a water backcast, one would define a future water economy in as much detail as possible (including not just technical coefficients but also social and security considerations), and then analyze whether there exist feasible and acceptable paths from the present to that future. If so, and this is the real objective of the exercise, what must be done if the economy is to follow one or another of those alternative paths.

Backcasting is much more useful than forecasting in showing where the system can give and in identifying alternative policy and program options (Robinson, 1988). In the case of energy, traditional forecasting always showed the need for greater supplies whereas backcasting indicated the option to maintain or cut consumption. Actual energy use has turned out to be much closer to the patterns suggested by the soft path than by the traditional analysis, and countries that adopted policies recommended by soft path analysis are today economically stronger than those that stuck with traditional policies.

What does this have to do with equity, and particularly equity in water between Israelis and Palestinians? I believe that approaching water problems through a soft water path could work to reduce conflicts. Because it is concerned not with what futures are likely to happen but with how desirable futures can be obtained, backcasting is an explicitly normative exercise. It has none of the pretensions to objectivity sometimes alleged by forecasting. This makes it an ideal partner for political science in a search for regional cooperation and accommodation. All sides see close linkages between water availability and national political and economic security. Water problems in Israel and the Occupied Palestinian Territories are real and pressing; they cannot be solved simply by eliminating wasteful consumption patterns. Therefore, only through the exploration of alternative futures, not merely a projection of the present into the future, can we find ways to minimize the potential for continuing conflict.

4. CONCLUSION

In areas of water stress, which is clearly the case for the three main riparians of the Jordan River, we should regard seriously only those approaches that treat quantity and quality issues together, and that recognize that neither can be maintained in the absence of explicit recognition of mutually shared rights and responsibilities for management. Indeed, that was the principal message of the Brundtland Commission (World Commission, 1987). Sustainable development is not just a matter of economics and ecology; if it fails to incorporate equity, it will fail.

The current water economy and existing water policies in Israel and the Occupied Palestinian Territories are coming under sharp questioning because of the ways in which they have been used to the severe and evident disadvantage of Palestinians, and to the less severe and less evident disadvantage of Israelis themselves. With the parallel bilateral and multilateral tracks of the current peace process, we may at last be witnessing the "iterative process by which progress beginning at the political process -- that is, the Arab-Israeli peace process --requires concrete progress at the 'practical' level -- for example, sharing water resources -- for both consolidation and fruition" (Rothman and Lowi, 1992).

There are grounds for cautious optimism. If the three dimensions of the water problem -- economy, ecology and equity -- are treated together in the current negotiations, water could become a route to peace instead of a source of conflict.

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TOWARDS AN EQUITABLE DISTRIBUTION OF THE COMMON PALESTINIAN-ISRAELI WATERS: An International Water Law Framework*

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Abstract

The present article is primarily concerned with the redistribution of the common Palestinian-Israeli water sources, a core issue of the water conflict between the two sides. More specifically, I wish to explore how redistribution can be worked out on the basis of factors stipulated in the doctrine of "equitable apportionment" of international water law. I argue that those factors favor Palestinians and certainly entitle them to a much larger share than Israel permits them to tap at present. Exact shares cannot be determined except on the basis of agreed data as well as more rigorous calculations than attempted here. I also argue that redistribution is possible without causing "appreciable harm" to Israel, and that, within the context of a peaceful political settlement, it is not a zero-sum game. The assumption here is that the endogenous water resources of the West Bank and Gaza would be repossessed by Palestinians as part of an eventual peaceful settlement.

1. Why Redistribution?

The need for redistributing the common water resources[1] is predicated on: (1) the unilateral, lopsided appropriation by Israel of the common waters; (2) the substandard level of water consumption and for Palestinians; and (3) the wide water gap between Palestinians and Israelis. These are commonly acknowledged realities and need only a brief summation. Relevant data are summarized in Tables 1, 2 and 3. Before proceeding, it must be cautioned that, for technical as well as political reasons, those and other data cited below are in dispute among Israeli, Palestinian and outside specialists. Palestinian researchers often cite, albeit mistrustfully, Israeli statistics, for the simple reason that Israel exercises a virtual monopoly on water-related research, severely restricting their access. Until mutual agreement is reached, the data in the paper ought to be considered tentative.

Water in the West Bank and Gaza is available in aquifers and surface sources, with underground water being the chief source. Insofar as the water conflict is concerned, those water sources can be divided into "endogenous" sources, that is sources commence and terminate within the boundaries of the OPTs and "international," sources that flow into or out of them.

In the West Bank, the surface sources consist of two groups of wadis, the Jordan River[2] and numerous springs.[3] The two groups of wadis issue from the central hills region, which is the topographic backbone of the West Bank and the predominant hydrological region. One group flows untapped east of the watershed toward the Jordan, and is endogenous. The second group flows west through the West Bank and Israel toward the Mediterranean and is international; its waters are "harvested" inside Israel.

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Table 1
Common Hydrology and Lopsided Appropriation by Israel

	Recharge (mcmy)	Israel's appropriation (including Settlers') (%)
West Bank		
Common:		
a. Western aquifer	340-390	94
b. Northern aquifer	120-145	85
c. Western wadis	20	≈ 100
d. The Jordan	(See text)	
Endogenous:		
a. Eastern aquifer	100-175	30-50 (?)
b. Eastern wadis	30-40	0
Gaza		
Common:		
a. Wadi Gaza	20-30 (?)	(?)
"Disputably" common:[a]		
a. Flow from Israel to Gaza's aquifer	50-60	90
Endogenous:		
a. Gaza aquifer	50-70	10-25 (?)

Sources: Abu Mayli (1992); Boneh and Baida (1977); Bruins and Tuinhof (1991); Friends of the Middle East (1969); Kahan (1987); Khudari (1992); Kolars (1992); (Naff, 1991a,b); Orni and Efrat (1973); Rofe and Raffety (1965a,b); Save the Children, (1990a); Schwarz (1982); Shuval (1992); Tahal (1990).

Notes:
[a]So designated because Palestinian and Israeli specialists disagree on whether it is common.

Underground water in the West Bank is comprised of three main aquifer systems: eastern, western and northern. The eastern aquifer, falls essentially within the West Bank (endogenous), while the western and northern are common to the West Bank and Israel. Perhaps as much as 95 per cent of the area of the western and northern aquifers is located in the West Bank, from which they also receive 70-85 per cent of their annual replenishement.[4] In other words, those aquifers are, physically speaking, primarily West Bank aquifers. They are at the center of the water dispute, because Israel appropriates, from hundreds of wells on its side of the border, more than 90 per cent of their annual recharge.

In Gaza, too, the chief source of water is underground water. There are no rivers, and the only surface water sources are wadis. The most important is Wadi Gaza (Hebrew: Nahal Bessor) with catchment areas in the West Bank, Gaza and Israel; its water is impounded by Israel before it enters Gaza. Underground water is available in the highly absorbent sand-sandstone, coastal aquifer. This is an endogenous aquifer. Part of its water, however, flows from the east, from Israel. Palestinian hydrologists contend that Israel intercepts this flow, leaving meager quantities for Gaza. Israel denies the claim. Until there are mutually-agreed data, this flow should tentatively be designated "disputably" common.

In all, and apart from the Jordan River, the aggregate volume of common Israeli-Palestinian water resources may amount to 565-655 mcmy, replenished primarily from the West Bank.

Israel unilaterally and through the imposition of severe restrictions on Palestinian access appropriates as much as 90 per cent of the common waters. It also has been overpumping, that is pumping more than the rate of replinishment or safe yield, from the common aquifers and those within its borders.[5] Such overextraction has been criticized by Israelis themselves, because it endangers the long-term viability of the aquifers. (e.g. State Comptroller, 1990) In addition, Israel significantly encroaches, through the Settlers, on the endogenous waters of the OPTs, particularly the West Bank's eastern aquifer. Finally, Israel has been extracting 150-200 mcmy more water from the Jordan basin than the 375-400 mcmy allotted to it under the Johnston Plan, not to mention 5-10 mcmy from the Golan Heights.[6]

The net result of Israel's unilateral action is a substandard level of consumption for Palestinians in the OPTs as well as a wide water gap between them and Israelis. A few statistics starkly illustrate the situation. Palestinian consumption level in the West Bank rose by a mere 20 mcmy during the period of the occupation, compared to Israel's 400 mcmy. Palestinian domestic consumption is meager, 20-30 cubic meters (cm) per person per year, or about 15-20 gallons a day. In villages and camps, consumption can a third of this. In relative terms, the per capita aggregate water consumption in Israel is 3-4 times as much as in the OPTs, and the same is true of domestic consumption. Furthermore, Palestinians in the West Bank are charged 3 times as much per unit of domestic water as in Israel, or a minimum of 15 times as much if the comparison is based on the relative GNP per capita income.[7] (See also fn. 22, below.)

Beside the low quantities and higher prices, Palestinians obtain water of inferior quality. In central Gaza, the water's salinity can be as much as three times the standards of the World Health Organization (WHO).[8] Water is also polluted with nitrates from the return water of human consumption and agriculture.[9] The result is a deleterious impact on health conditions and quality of life. (e.g., Bruins and Tuinhof, 1991; Hulaili, 1987; Save the Children, 1990b) Even in the West Bank, salinity of irrigation water in the Jordan Valley and Jinin areas has been a growing problem, primarily as a result of overpumping by Settlers and the refusal of Israeli authorities to let Palestinian farmers extract water from the deeper aquifer. (e.g., Awartani, 1991a:31-9)

Still, the water gap between Palestinians and Israel is most apparent in agriculture. The overall irrigated area in Israel is 10 times greater than in the OPTs, or nearly 4 times greater per person. Israel has been able to irrigate 95 per cent of irrigable land, while the irrigated Palestinian land on the West Bank, where considerable expansion is possible, is less than one-

Table 2
Water Consumption and Irrigated Land for Palestinians, Israel and Settlers

	Consumption (cmy)		Irrigation	
	Aggregate	Domestic[a]	Area (1000 dunums)	Irrigated/ irrigable (%)
Palestinians:				
West Bank	125-130	25-35	100	20-30[b]
Gaza	100-183[c]	23-38[c]	120	55
Israel	450-500	≥ 100	2,150	95
Settlers:				
West Bank	580-650	90-120	40[d]	--
Gaza	≥ 1,400[e]	?	7[d]	--

-- = not applicable
1 dunum = 1,000 square meters = 0.10 hectare

Sources: based on Abu Maylih (1991); Awartani (199a,b); Awartani and Juda (1991); Benvenisti and Khayat (1988); Haddad and Abu Ghusha (1992); Hyatt, et al, (1992); Kahan (1987); Khudari (1992); State Comptroller (1990); Tahal (1990).

Notes:
[a]For the West Bank and Gaza domestic consumption includes small amounts of industrial consumption also.
[b]Tahal estimates the irrigable area at 310,000 dunums, excluding 320,000 dunums which it says have low soil classification. Awartani and Juda put the irrigable area at 535,000 dunums, of which 172,000 could be readily irrigated. Of these, about 150,000 dunums in the Jordan Valley, which have been confiscated, enclosed or deprived of water by the Israeli authorities, or the owners of which do not have access to investment capital.
[c]The high figure is from Tahal (1990:3-5), and the low from Abu Maylih (1992); the difference derives from Tahal's greater estimate of consumption and lower population count. Abu Maylih's are also for 1991 and Tahal's are for 1989. Awartani's estimate (Awartani, 1991b) falls between the two.
[d]These are summations of various areas, data for first half of the 1980s.
[e]Much higher figures are cited in Palestinian sources. The per capita consumption of the Settlers is sensitive to the increment in the overall estimate, owing to their small number, 3,000 or more.

Table 3
Summary of Indices of the Israeli-Palestinian Water Gap

	Palestinian	Israeli
Consumption per capita:		
Aggregate	100	300-400
Domestic	100	300-400
Price per cubic meter:		
Absolute:		
Domestic	300	100
Agriculture	120	100
Relative to GNP/capita:		
Domestic	≥ 1500	100
Irrigated agriculture		
Land area per capita	100	400
Irrigated/cultivated	100	800-900
Irrigated/irrigable	100	400-500

fourth of the irrigable. For reasons of state, Israeli farmers receive heavy water subsidies that encourage profligate water consumption and the growing of export crops with huge water appetite, thereby increasing the pressure on the common water sources.[10] As if this is not enough, Israel has allowed its Settlers in the West Bank and Gaza to irrigate 47,000 dunums of confiscated land, with water allocations per unit area nearly double that on Palestinian land. (Kahan, 1987:113) Meanwhile, Palestinian irrigated area has stagnated, and water salinity in many places has lowered crop yields and quality.

Israeli and other analysts often point out that their country suffers a water stress that affects its social and economic development. (e.g., Falkenmark, 1989; Shuval, 1992)[11] Certainly, no one would suggest that geographic Palestine is a water cornucopia. But it is not so obvious that the social and economic development of Israel has been hampered by the lack of water, not when it has been able to irrigate nearly all of its irrigable land.[12] More important, water stress is relative, and Palestinians are far more water-stressed than Israelis. And, as Jerome Lipper (1969:44) observes: "it is precisely because the water is often inadequate to satisfy the needs of all that rules [of equitable distrbution] are required."

2. International Water Law and Equitable Distribution

A mutual agreement on dividing the common waters between Israel and the Palestinians can be achieved through direct negotiations, mediation or arbitration. Because joint water management, by definition, requires cooperation, direct negotiations are preferrable.

Unfortunately, however, Israel's current position does not give much hope for the success of direct negotiations, as will be pointed out shortly. On the other hand, mediation could subject Palestinians to undue pressure based on considerations of power, rather than fairness. In the end, and unless Israel exhibits more flexibility, arbitration, to which Egypt and Israel resorted to resolve the dispute over Taba, may be the most viable Palestinian option.

Whichever procedure the two sides opt for would need a guide for devising a new sharing regime. One such guide is international law; another relies on analytical methods based on optimization and cost-benefit analysis, such as Paretian environmental analysis and cooperative game theory (Rogers, 1991). I am concerned in this paper with the division of waters according to international water law. International water law serves as a better framework for clarifying many issues in the conflict, such as Israeli insistence on maintaining prior or existing use and telling Palestinians to import water instead of redistribution, or Palestinian advocacy of nature-based redistribution. Also, international water law incorporates all the "variables" of the other approach.

The pertinent aspect of international water law is the "factors" spelled out in the doctrine of "equitable apportionment." I will consider five factors common to the 1966 Helsinki Rules,[13] the 1988 Report of the International Law Commission (ILC) and the 1989 Bellagio Draft Treaty[14] (which Palestinians and Israelis may wish to consider as a model). Those factors are: (1) the natural attributes of the water source; (2) prior or existing use; (3) social and economic needs; (4) alternative resources and their comparative costs; and (5) avoidance of appreciable harm. (Garretson, et al, 1967:782-91; Goldberg, 1992:72; Hayton and Utton, 1989:695-7)

It has been often pointed out that international water law is nonbinding and lacks enforcement mechanisms. This is true, but it may also be the "best we've got" as a guide for negotiations. The factors it stipulates are based on treaties and conventions ratified by governments, custom, generally accepted principles, decisions in the judiciary, and the opinions of qualified persons (publicists). They contain certain "checks and balances" that, if approached in good faith, would protect the interests of both sides. One assumes that both Palestinians and Israelis would wish to abide by international water law.

2.1 Prior Use versus Natural Attributes

Israelis usually insist on one factor: prior or existing use. Prior use means maintaining the status quo, or extracting 80-90 per cent of the common waters. Many Israelis have in fact convinced themselves that the common waters are theirs, as, for example, when they speak of how Israel is using 95 per cent or more of "its" water resources. Unfortunately, this statement has been repeated, wittingly or unwittingly, by international commentators and water specialists. There is no doubt that Israel's dominant military power and present control of the headwaters represent the backdrop of this stance. The following statement by Elisha Kally (1991/92:32) exemplifies the Israeli stance:

> Palestinian claims to water presently under Israeli control--particularly the Yarkon Taninim aquifer [the Israeli term for the western aquifer]--will not be practical because of Israel's own water shortages and because they will not have any standing in international law (due to the legal pereference for existing and historical consumption

over new claims).

Insistence on prior use is but an instance of Israel's long-standing strategy of fait accomplis. Authorities on international water law stress that all factors must be weighed and prior use is not paramount. For instance, Hayto and Utton (1989:669), two prominent members of the group that drafted the Bellagio Draft Treaty, state: "This language [weighing all the different factors] has become accepted virtually universally." Not so universally, it would seem.

Other arguments could be marshaled against prior use. It may be said that it was lucky for Israel that prevailing social and economic conditions before 1967 did not permit Palestinians to extract larger amounts from the common aquifers. Now that Israel has exploited that very water successfully to spur its own economic development, it is time that Palestinians be given the chance to develop their own economy, a process hamstrung by, among other things, lack of water. In fact, in some of the rules of equitable distribution the "stage of economic development" is deemed as one of the factors to be weighed. (Third Report to the ILC, 1982, cited in Hayton and Utton, 1989:700) In any case, prior use remains a de facto condition and does not acquire legitimacy or become de jure, unless the co-riparian agrees to it. Israel appears not to have given "prior notification," as international water law requires, to Jordan, then the co-riparian, when it began in the first half of the 1960s to extract substantial quantities of water from the common aquifers and to modify the hydrology of the basin by extracting water from wells and letting the spring discharge diminish. (PHG and PAG, 1992:23) Be that as it may, Palestinians today cannot be expected to accept a grossly unfair status quo.

And if it is a matter of selective interpretation of international water law, Palestinians could insist that the only factor to weigh is the natural attributes of the water sources. Some Palestinian authors and specialists have indeed called the western and northern aquifers "Palestinian waters." (IPCRI, 1991/92; Al-Jirbawi and 'Abd al-Hadi, 1990) More concretely, Jad Isaac and Hisham Zarour (1992) have proposed that "nature's apportionment" be the sole criterion for dividing common waters. The formula they develop on this basis is certainly attractive for its neatness and simplification of the web of "factors." Also, nature-based apportionment is the way shared mineral resources are divided. (Barberis, 1991:177-78) If their formula were applied to the common Palestinian-Israeli waters, the Palestinian share would perhaps be 80 per cent or more, the exact opposite of the present distribution. Obviously, Israel would reject such an outcome. Even more, one fears it would use such a proposition as an extra excuse to retain the headwaters.

Briefly, it would seem then that selectively invoking factors based on prior use and hydrology leads to irreconcilable claims. A realistic redistribution would give each party less than the 80 per cent they now demand. How much each party should be allotted would be calculated by weighing the rest of the factors as well.

2.2 Social and Economic Needs

Assessing how water division can be based on the social and economic needs of both sides helps us to view water as a means rather than an end. This has a precedent in the Johnston Plan, where the divsision of water was based on irrigation water requirements. The region has changed since the plan, and the substantial population growth in the interim and that expected in the coming years have led many analysts to argue that securing fresh water for drinking ought to top the hierarchy of needs.

In order to estimate the needs, I use the "baseline," or basic- needs, approach employed by Shuval (1992)[15] Shuval posits that baseline fresh water requirements per person would be: 100 cmy for municipal (domestic, commercial and industrial), and 25 cmy for agriculture. He assumes 65 per cent of municipal waste water would be treated and reused in industry and agriculture,[16] which means the gross per capita agricultural water requirements would be nearly 90 cmy.[17] Based on these assumptions, and a "hypothetical" population in the year 2022 of 5 million Palestinians and 10 million Israelis, the baseline requirements would total 625 mcmy and 1,250 mcmy for the two sides, respectively.

Shuval does not examine the implications of his estimate of needs for the redistribution of the common waters. Estimating the needs requires the inclusion of population as a variable.[18] Furthermore, after determining the water needs it is necessary to check them against the water each side possesses, apart from the common waters, and then divide the common water accordingly. In effect, splitting the common waters according to the needs factor amounts to splitting the water sources within the boundaries of Mandate Palestine according to population ratios. If we take Shuval's estimates at face value and keep in mind the data difficulties, the shares would be 74 per cent for Palestinians and 26 per cent for Israel.[19]

2.3 Comparative Costs of Alternative Reources

Alternative water resources refer specifically to potential sources--such as desalination of brackish underground water, seawater, imported water--not sources presently exploited or those comparable to them. Those sources, by increasing the size of the "bucket," could facilitate an equitable sharing agreement. They are not an alternative to equitable distribution, as, for example, many of their Israeli advocates seem to suggest. (e.g. Gur, 1992; Kally, 1992) They are one factor among others to consider in the determination of shares. How they affect the equation of equitable apportionment depends on their availablity and comparative costs of harnessing them. Naturally, the relative availability of alternative resources must be assessed first: for a riparian without alternative sources, comparative costs are an academic question. The comparative costs are a yardstick of the parties' ability to harness alternative resources. The party that is more able would be entitled to a smaller share of the common sources (just within the confines of this factor).

There are potentially two alternative ways of obtaining water for Israel and Palestinians: Importation and desalination of brackish and saline water.[20]

Apropos importation, numerous schemes have been proposed for transporting water via pipelines or canals from the "water-rich" countries in the Middle East, to the poorly endowed. The schemes are familiar and require a separate treatment. All that can be said here is that they are last-resort, long-run options to be undertaken after a discernable stabilization of regional politics. Under present conditions, such schemes would, strategically, increase the vulnerability of Israel, but more so of Palestinians since Israel could project its military power far afield to protect the water conduits, whereas the Palestinians lack such an option. At the risk of dramatization, a limited defense force and water from Turkey, for example, would put the Palestinians' very survival at the mercy of the unstable political winds of the region. Be that as it may, the procedure of estimating comparative costs, which I will discuss only in regard to desalination, is applicable to the imporatation schemes as well.

Desalination technology can be used to extract fresh water from either brackish or saline water. In the West Bank, Palestinians could tap brackish water mainly from the eastern aquifer, perhaps less than 50 mcmy. More than one-half of Gaza's aquifer, which I have been counting as a "mainstream" source, has become for all practical purposes an "alternative" source in that it requires desalination to make it fit for drinking, even for irrigation; it may have be to be considered as such in calculating the water shares from common resources. There is much less brackish water in the OPTs than in Israel, where there are scattered brackish water sources throughout; more crucial than these sources, however, is the tremendous brackish-saline aquifer underlying the Negev. That aquifer might suffice the water needs of the Negev region, which was allocated about 20 per cent of the water by the late 1970s, for perhaps a century. It could even be used to irrigate crops in the central coastal area. (Huerta, 1991:117; Nativ and Issar, 1987:128; Issar cited in Pearce, 1992)

Other than underground brackish-saline water, there is sea water. The West Bank is a landlocked territory and does not have a sea front, while Gaza has a modest front which may be able to support a major desalination plant. Israel, on the other hand, enjoys a broad sea front extending from the Lebanese border to Gaza's, which gives it flexibility in plant location.

Desalination technology, both of brackish and sea water is available and represents a viable option, particularly for Israel. As for costs, it is reasonable to suppose that the absolute, micro-costs of desalination (plant and operation costs) would be comparable in both the West Bank and Gaza and Israel. Comparative costs would have then to be evaluated with refernce to the size of investment relative to the size of the macroeconomy as well as consumer prices.

Measured in Gross Domestic Product (GDP), Israel's economy in 1986 was, by official accounts, more than 14 times larger than that of the West Bank and Gaza, and its GNP per capita 3-4 times higher. (Kleiman, 1991:2) The gap has widened after the battering of the Palestinian economy during the intifada. Furthermore, Israel already possesses the industry and technology of desalination, while Palestinians would have to import it. (IPCRI, 1991/92:#14; Keenan, 1991) All of this makes Israel more capable of tapping the desalination alternative than Palestinians in the OPTs.

The other aspect of comparative costs is the relative ability of the consumer to pay for the desalinated water. Based on the present consumer prices in Israel and the OPTs as well as on various estimates of desalination costs,[21] the following can be inferred. In Israel, desalinated brackish and saline water, is affordable for municipal use and economical for agriculture, while desalinated seawater is affordable for domestic use and may be economical for some crops. In the West Bank, desalinated brackish water might be affordable for municipal use, even for agriculture in the Jordan Valley. Gaza consumers, conversely, would be heavily burdened by the costs of desalinated water, even of the brackish type.

All in all, the OPTs have limited brackish water, and only Gaza has access to seawater. Israel, on the other hand, possesses huge quantities of brackish water and practically limitless amounts of sea water. Also, the comparative costs both to the national economy and to consumers are far more favorable to Israel. The situation could be tipped even further in favor of Israel if plant operations costs are lowered by implementing some of the "megaprojects," such as the Red-Dead project (now on the agenda of Jordanian-Israeli bilaterals) that would generate hydropower by harnessing the differential head between the Jordan Rift and the Red and Dead Seas. This reasoning would suggest that, from the standpoint of alternative sources, Palestinians in the West Bank and Gaza would be entitled to a larger portion of the common waters than Israel.

2.4 Avoidance of Appreciable Harm

Appreciable harm refers to costs that can be objectively measured as a result of denial of water rights. For there to exist appreciable harm, "There must," according to the 1988 Report of the ILC (cited in Goldberg, 1992:72) " be a real impairment of use, i.e., a detrimental impact of some consequence upon, for example, public health, industry, property, agriculture or the environment...." The implication of this factor is obvious: no riparian can deny water to a co-riparian if that denial causes appreciable harm, and water must be reallocated in order to stop the infringement. The riparian causing the infringment would in all likelihood contend that it would be appreciably harmed by reallocation. In that case, both claims must be examined and ways found to balance the relative harm incurred by each of the co-riparians.

Palestinians have undoubtedly sustained appreciable harm, and the case for redistribution has been implicitly argued essentially on those grounds.[22] The impact of redistribution on Israel depends on how much water it would have to give up, or rather, give back. The sector most likely to be affected directly is agriculture. Israeli agriculture's share is nearly 5 per cent both of GDP and of employment, suggesting that appreciable harm may not result from the reduction of water allocation to that sector. Those indicators cannot by themselves serve as reliable predictors, and more detailed impact analysis would be required. Nevertheless, an estimate by a study group at the Jaffee Center for Strategic Studies at Tel Aviv University shows that a reduction in the amount of available water by 100-200 mcmy and its replacement by desalinated water would cost the Israeli economy $30-90 million. (Jaffee Center for Strategic Studies, 1989:219-20) Even if the costs were to prove appreciable, the cuts could be phased without causing "shocks" to the Israeli economy while at the same time not unduly hampering the growth of the Palestinian economy: Palestinian water demand is not likely to rise suddenly. Also, part of the increase could be satisfied first from untapped portions of the eastern aquifer and flood run-off, spring rehabilitation, and phasing out the irrigated agriculture of the Settlements. At the same time, Palestinians would agree to sell Israel what remains of their share, reducing the amount over time according to the growth of their consumption--until each party receives its agreed share. This would leave Israel time to make the necessary adjustments in its economic structure and investment in alternative water sources.

Moreover, ways might be found to effect an exchange of various types of water that would reduce the harm even further, if not result in net benefits. Aquifers are functionally less versatile than rivers: they cannot be dammed, generate hydrolectric power or be used for recreation and navigation. This confines the "basket of goods" that can be traded among the conflicting riparians essentially to water, and makes the division appear a zero-sum game: one side's gain is the other's loss. Nonetheless, the water is not all the same. It is differentiated according to several attributes: freshness-salinity, location, renewable-fossil, shallow-deep, upstream-downstream. One side may be willing to exchange a larger quantity of brackish water in one location for a smaller quantity of fresh water from another, or a smaller quantity of the same type of water from a shallow well for a larger one from a deep well, and so on. D. Yaron and A. Ratner (1990) have done a study for regional water exchanges within Israel based on this premise. It goes without saying that the institutional and political context of international cooperation complicates such a possibility and may render it impractical. Nevertheless, the parties may wish to explore further the distinctions among types of water in expanding the realms of costs and benefits. They may be able thus to enhance the efficiency of water use, as well as reach a more ambiguous deal easier to accept politically. And it is here that analytical approaches from welfare economics and cooperative game theory, which I have mentioned earlier, may fruitfully supplement considerations of international water law.

Finally, Israel would be able to capture even greater benefits from regional cooperation in the wake of a peaceful settlement. The benefits would transcend the water sector; but even in the water sector alone and in water-related technology trade Israel could profit. I have already indicated that Israel possesses desalination technology of brackish and sea water. It also runs an advanced research and development (R&D) desalination program. The largest desalination market is in the Middle East, owing to the paucity of water and abundance of energy resources; one would expect that Israel would be keenly interested in such market.

A second area is hydroelectric power generation. I am referring here to megaprojects such as the aforementioned Red-Dead Canal. Jordan would benefit from the projects as well, but not Gaza and the West Bank. The schemes need the agreement of Jordan and the Palestinians. They also require large capital outlays, and no multilateral aid agency, such as the World Bank, would be in a position to assist without the approval of the Arab parties.

In short, Israel not only does not have to sustain appreciable harm as a consequence of redistribution; it also stands to gain in the context of a peaceful settlement through selling desalination technology and tapping hydroelectric power.

Conclusion

Israel's unilateral, lopsided appropriation of the common Palestinian-Israeli has left Palestinians in the West Bank and Gaza with a substandard level of consumption and created a wide water gap between them and Israelis. It runs counter to the doctrine of equitable distribution of international water law. Examination of the factors stipulated in the doctrine as a basis for an equitable distribution with respect to the Israeli-Palestinian common waters reveals several important conclusions. First, Israel's insistence on maintaining prior use and Palestinian demand that water be split according to natural attributes of the water sources lead to irreconcilable claims. Second, Israel's refusal to reach an equitable distribution on the basis of the availability to Palestinians of alternative water resources is untenable. On the contrary, brackish and saline water resources and the economic and technical capability to tap them are far more available to Israel than to Palestinians. Importing water from other countries is also more viable for Israel than for Palestinians: Israel could project its military power to protect the water conduits, whereas the Palestinians could not. Third, the possibility of Israel sustaining appreciable harm can be avoided through an agreement by Palestinians to sell to it, in a phased manner, the part of their water share in excess of their water needs. Nor is it a zero-sum game. In the wake of a peaceful settlement, Israel can greatly profit from selling desalination technology in the principal Middle East market, as well as generating hydroelectric power from projects that require approval of the Arab side. Fourth, the two sides may wish to simplify the negotiations, and thereby reduce the "transactions costs" and speed up reaping the "peace dividend," by agreeing to consider the social and economic needs as the core factor. This has a precedent in the Johnston Plan. It would mean dividing the legitimate water of geographic Palestine among the two parties according to population size. Finally, an agreement on an equitable water-sharing regime is possible, and the key to reaching it lies in Israel's hands; but will it muster the requisite attitude and political will?

Endnotes

1. Singling out the redistribution of the Palestinian-Israeli waters does not preclude or contradict a basin-wide resolution. If those resources are thought of in "drainage-basin" terms, then they belong to the Jordan and Mediterranean basins; and the other riparians, Jordan, Syria and Lebanon would have to be included in the investigation. Depending on the choice the two sides make, the conflict can be resolved on its own, or as part of a basin-wide agreement. This would mean renegotiating the 1955 Johnston Plan, negotiated by the American emissary Eric Johnston among the four countries. The joint Palestinian-Israeli water sources were not covered in the Plan. If a new basin-wide agreement is to be arranged, they would have to be part of it.

2. Various amounts of water were proposed for the West Bank during the negotiations of the Johnston Plan. In the 1954 Arab Plan, for example, the West Bank was to get 305 mcmy from Lake Tiberias (American Friends of the Middle East, 1964:66). In the final Johnston Plan no specific mention, at least publicly, was made of the West Bank; however, the assumption was that the water would be allocated to irrigate the area on both sides of the Jordan River according to estimates made in 1955 by the American engineering firm Baker and Harza. According to those estimates, the irrigable area in the west Jordan Valley was about 29 per cent of the total. (Based on Ibid:79) It therefore would be reasonable to say that the implicit share of the West Bank in the Johnston Plan was 29 per cent of Jordan's total; or about 140 mcmy, since Jordan was allocated approximately 480 mcmy (from the Jordan and Yarmuk; not including the side wadis on the East Bank). Some Palestinian authors estimate that the West Bank share should be as much as 320 mcmy (Center for Engineering and Planning, 1992:25). At any rate, the issue of the Jordan River is complicated by the fact that Jordan received hundreds of thousands of Palestinian refugees from the West Bank and Gaza in 1967 and from Kuawait in the aftermath of the Gulf War, as well as by the unknown number of Palestinians who may return to the West Bank from Jordan and other countries on the heels of a peace settlement. It requires a separate treatment.

3. The discharge of the springs is included in underground water, in order to avoid double counting.

4. My calculation based on statistics in Shuval (1992:3-4) which he attributes to David Gvirtzman at the Earth Sciences Division, Hebrew Uiversity.

5. By official estimates, overexploitation of the coastal aquifer averaged 85 mcmy in the period

1983-86. Some authorities, however, put the average at 150-200 mcmy over the same period. (AMER, 1987:60)

6.The estimate for the Jordan River is based on Kolars (1992:Table 8), Naff (1991a:15) and Tahal (1990:2.4); for the Golan on Alternative Information Center (1988) and United Nations (1992:22). Israel justifies its taking away of the Yarmuk waters by claiming that the water was allocated to the power that had sovereignty over the West Bank, thereby equating occupation with sovereignty. (Nijim, 1990)

7.The GNP/capita in Israel in 1988 was $9,427, in the West Bank in 1987 $1,990 and in Gaza $1,376. (Tahal,1990:1.2 and 1.3) In Gaza, the relative charges are 4-5 times greater than in Israel.

8.WHO's standard is 200 mg/liter chloride.

9.Israeli analysts usually attribute the current problems plaguing Gaza's aquifer to overpumping during the Egyptian administration (1948-67). (Shuval, 1992) It is true that overpumping occured during that period, yet it is equally true that Israel has been managing the water in Gaza for a longer period, from 1967 to the present, and the quality of water consumed by the Palestinian population has only deteriorated. The responsibility for the damage to the Gaza aquifer thus cannot be solely assigned to Egypt; Israel also must acknowledge its own contribution.

10. And while the subsidies may be considered an internal Israeli affair, and they have been heavily criticized by many Israeli specialists and officials, their impact is not.

11.This is not to imply that Hillel Shuval uses water stress as an argument against redistribution. He has been, as we shall see below, one a vocal advocate of an equitable redistribution of the common waters.

12. The notion of water stress is useful when used to quantify societal water needs and when it draws attention to the population factor. We still need, however, the economic concept of scarcity as a supply-demand schedule that directs attention to how water is allocated.

13.Those were formulated by the International Law Association, a nongovernmental body devoted to matters of international law. They have been a primary reference for subsequent factor lists.

14.Drafted by an interdisciplinary team of water specialists in Bellagio, Italy, and meant to serve as a model; it is not, however, international law.

15.There is a second approach for estimating the "needs," namely, projecting future demand. The "baseline" approach is, in my opinion, preferrable. It is premised on equal considerations of human needs on both sides and is ecologically-grounded. In contrast, demand projection is based on prior or existing demand and thus incoprporates "prior inequalities," in addition to sectoral allocations that may not be ecologically and or economically rational. One could go even further and suggest that instead of assuming the population and then assessing water requirements the demographic policy and mode of economic development be compatible with available water. A main drawback of the baseline approach is that it does not account for the costs of adjustment when the baseline needs are smaller than present consumption. This point is addressed below.

16.The assumption of 65 per cent recycled water may be reasonable for Israel, but may be too high for the West Bank and Gaza, even in the year 2022, if we keep in mind the staggering economic demands that the OPTs are expected to face and the deinstitutionalization process they have undergone. Even Jordan, with its viable water institutions, has experienced many problems--social, technical and bureaucratic--with water recycling.

17.The assumption is that this amount would be sufficient for producing food for domestic consumption, not for exports. The total quantity would allow Israel to irrigate nearly 1.3 million dunums, and Palestinians half as much (this is my estimate, assuming an average of 700 cm/dunum/year).

18.In the 1966 Helsinki Rules, the population factor is listed separately; obviously calcualting the social and economic needs incorporates this factor.

19.Shares are preferrable to exact amounts as was done in the Johnston Plan, because of the variability of available water. The shares were calcluated as follows. Israel is estimated to require 1,250 mcmy by the year 2022. If it has 1.1 bcmy from "legitimate" resources (endogenous resources + allocations from the Johnston Plan), then it would be left with a deficit of 150 mcmy. Thus, Israel would need 150 mcmy extra from the common waters in order to secure 1,250 mcmy. Palestinian baseline needs, on the other hand, are estimated at 625 mcmy. Their endogenous resources can supply 200 mcmy or less of that amount, which would leave them 425 mcmy short. If the common waters are divided according to those relative "deficits" of 150 mcmy and 425 mcmy--that is in a manner that would equalize them--the respective shares would be about 74 per cent and 26 per cent for Palestinians and Israelis, respectively.

20.The present discussion considers only brackish water that needs desalination prior to use, not brackish water that can be directly used in industry or even to irrigate some crops.

21.The costs of desalinated brackish water may amount to 30-40 cents/cm, and sea water 60-80 cents/cm. The costs are driven by the price of energy and would change in accordance with the price of oil. In Israel, average costs of production of regular water runs about 33 cents/cm; domestic consumer pay nearly that amount, whereas farmers pay a subsidized price of around 15 cents/cm. Palestinians the West Bank pay $1.0/cm for domestic water and 35 cents for irrigation water. In Gaza, the price of domestic water averages 20 cents, and of irrigation water about 14 cents (because the water table is much shallower and hence pumping costs are lower). (Awartani and Juda, 1991:48; IPCRI, 1992:#14; Keenan, 1991:20-23; Tahal, 1990:9.2 and 9.3)

22.Damage could be quantified in monetary terms for the agricultural sector, but would be hard to quantify for health or quality of life.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

An innovative institutional arrangement with potential for improving the management of international water resources

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Abstract

Capacity Sharing is a new way of defining and allocating rights to flowing and stored water in a river valley. It is as if each user of water, or group of users, has their own small reservoir on their own small stream to manage independently from others. Because capacity sharing minimizes the interdependence of behaviour between users of system water, it provides a very good basis for dividing up large systems among a number of independent, multi-purpose groups each operating their sub-systems. It allows a harmonious mix of private property and common property resource management of the sub-systems in river valley systems within a single county. It has been shown to be superior to traditional allocation methods in Australia, where it has been adopted in some jurisdictions. Diagrams of a stylized reservoir on a river are best to explain the fundamental nature of the sharing of reservoir capacity and inflows. The role of a management body, when the total system is contained within one country, include releasing and recording releases from a reservoir (the bank-teller role), monitoring the passage of releases downstream with enforcement to ensure that released water is received by the shareholder who released it, and ensuring either (i) that no modifications are made to the catchment upstream of the reservoir that will modify the inflows, or (ii) that just compensation is made to the downstream users if such modification is allowed. Most of these enforcement problems exist under any system, but capacity sharing highlights them. The extra challenges involved in defining the nature and role of such an enforcement body in an international system (eg. when all or part of the reservoir and all or part of the catchment is located in one country, and all or some of the users are located in other(s)) do not appear to be insurmountable.

1. INTRODUCTION

This paper introduces the concept of capacity sharing for use within a national economy before discussing its extension to international situations.

2. NATIONAL CAPACITY SHARING

2.1 Introduction to capacity sharing in the national context

Capacity sharing (CS) is an institutional arrangement providing each user, or group of users, of reservoir water with perpetual or long-term rights to a percentage of reservoir inflows and a percentage of empty reservoir capacity or space in which to store those inflows, and from which to control releases. CS is like each user (individual or group) owning their own small reservoir on their own small stream. Their reservoir releases through time can be managed according to their particular supply reliability preferences. The concept can also be extended to include user rights to percentage shares of tributary flows downstream of the reservoir. Under CS, each user's supply-side and demand-side decisions are made by each individual decision-making entity, and the probabilities of (non-transferred) water supply can be calculated directly from historical or synthesized streamflow data alone (Dudley and Musgrave, 1992; Dudley, 1990; Dudley, 1992a).

CS is best described with the aid of diagrams, as in Dudley (1992a). However, it requires too much space to reproduce here. Instead, consider the analogy of the reservoir to a money savings bank in which each account has a maximum to which the account can accrue (which is a percentage of the maximum sum of deposits which the bank can contain), negative balances are ruled out, withdrawals are under the control of the account holder but deposits are made by a stochastic process over which the account holder has no control, although the probabilities of deposits are known. Each depositor seeks a preferred balance between running out of funds periodically due to keeping their average account funds low, and foregoing potential deposits periodically due to high average account contents. Each makes their own choice and each reaps the consequences. Funds can be transferred from one account to another by a joint request by the affected account holders. As well, two account holders may agree to transfer, from one to the other, all or portion of one's rights to deposits and/or account capacity. The contents of each account are known through time by monitoring withdrawals, transfers, interest and deposits with the aid of computers. Similarly, users' entitlements to reservoir inflows would be added to users' reservoir 'accounts' (unless full), withdrawals and share of evaporation and seepage losses subtracted, and periodic adjustments made to ensure that the sum of 'deposits' so computed equal the actual reservoir contents (Dudley and Musgrave, 1988).

The concept of CS has been developed in Australia to overcome limitations of the current water allocation methods, especially in the predominantly summer and uniform precipitation areas characterized by highly unreliable water supplies. In these areas an almost continuous task of water management is the reassessment of the desirable balance between allocating currently stored water to the immediate season versus saving some for future use in the form of reservoir 'carryover'. The more water saved for future use, the greater the reliability of water supply from the system, but at the cost of reduced average supplies because of increased reservoir spills and evaporation losses. This tradeoff between mean quantity and reliability of supply is very important in most of Australia. The main problem with the traditional methods of sharing water supplies among users is that all but a few special users are forced to share equally in whatever tradeoff point is chosen, regardless of their preferences. It is extremely difficult to tailor supply reliability to individual user needs on a large scale, under traditional allocation methods, while preserving flexibility to take emerging demands into account. However, CS easily allows the individual users or groups to choose their own mean/ reliability tradeoff at a point in time, and to re-choose through time in light of changing conditions and preferences (Dudley, 1990; Dudley, 1992b).

It can be shown algebraically that CS is at least as good as the commonly-used method (release sharing) for achieving an efficiency objective in the predominantly winter rainfall area of southern Australia (Alaouze, 1991; Musgrave et al., 1989). Recent legislating in a southern state, Victoria, incorporates provision for its use (Dudley and Musgrave, 1992).

Water markets operate at two levels under CS, (i) to transfer water already in storage, streams or channels, and (ii) to transfer the long-term rights to parcels of shares in reservoir capacity and streamflows. Water users cannot lose water rights to other users or governments without market compensation which they believe to be adequate. This provides two very important ingredients to efficient and sustainable use of water and associated resources in the long term - *security* of tenure of supply rights of known reliabilities to users, and *flexibility* for water resources to move into alternate uses as conditions change. The particular effects on users of the water resource depends on their use and location in relation to the headworks reservoir(s), as discussed in the following sections (Dudley, 1990).

2.2 Implications for downstream uses and users

Water users with capacity shareholdings to supply water for water uses located downstream of the reservoir could include irrigators, urban and industrial areas, mining companies and agencies responsible for wetland management, flood management and instream flow management for recreation and/or water quality requirements (Dudley and Musgrave, 1988). One capacity shareholding could be devoted to each of these uses if the individual users were sufficiently homogeneous in their requirements, so that the shareholding would be held in common by the individual users. Alternatively, for some uses, say irrigation, each individual irrigator may hold and manage their own capacity share, or perhaps groups of irrigators sharing a supply channel, or with similar reliability requirements, may hold a share in common. CS allows a harmonious mix of private, common and state property rights because each user, or group of users, can each manage their reservoir share independently of the others (Dudley, 1992b). If there is interdependence in the management of the reservoir releases through a portion of the water delivery system, a common control of a capacity share may be the best solution for that portion.

The great advantage of capacity sharing to users downstream from the reservoir is that it allows the flexibility of individual users or user groups to choose and modify their carry-over policies to suit their reliability/ mean-supply tradeoff preferences over time, while allowing no flexibility for changing their entitlement structure other than by water market trading. Because water users' probabilities of future supplies are based on historical streamflows and their own carryover policies, rather than carryovers over which they have little or no control, they have much greater confidence in the probabilities and a much better basis for making sound long-term resource management decisions (Dudley, 1990; Dudley and Musgrave, 1992). However, the independence with which the downstream users can operate the reservoir is not shared by within-reservoir water users, as discussed in the following section.

2.3 Implications for within-reservoir uses and users.

Benefits from hydro-electricity generation and reservoir surface recreation are both dependent on the total contents of the reservoir. Hydro-power generation requires large contents for turbine pressure or 'head', and recreation requires large and rather stable surface areas. Hence these uses are not independent from other uses, which makes them less suitable for holding capacity shares than the other users mentioned above (Dudley and Musgrave, 1988). It appears that water for within-reservoir uses would need to remain a by-product of other uses. However, water users upstream of the reservoir present a special case, as discussed in the next section.

2.4 Implications for upstream uses and users

As already noted, CS allocates a percentage share of reservoir inflows to each user or group of users. Dudley (1990) has argued that efficient investment in irrigation land and equipment requires secure rights to water of quantifiable reliability which is either unchanging, or changing in a pre-specified way. The requirement of security of tenure to such reliability of supply means that, although inflow probabilities may change over time because of natural or man-induced climatic change affecting precipitation, no other human events (eg. large upstream water diversions) should be allowed without compensating CS shareholders unless the effects were known to shareholders prior to their initial investments. The most efficient and equitable form of compensation for such changes is achieved by markets where sufficiently non-attenuated property rights can be established. This, in turn, implies that no changes to the above-reservoir catchment which affects the hydrology of it should be made without market transmission of inflow rights so that the reliability and security of the reservoir inflow rights are preserved. That is, upstream water users or runoff modifiers must hold reservoir inflow shares. The total number of reservoir inflow shares may be defined as net of licensed upstream and downstream riparian water usage, or include such usage with those riparian users being required to hold small quantities of reservoir inflow shares. This implies the assignment of implicit rights to runoff all over the catchment. That is, rights would be defined as streamflow (tributary or reservoir inflow) rights, but any land or vegetation modifications which affect runoff, and hence streamflow, would require the entity causing the change to purchase the appropriate amount of reservoir inflow, or tributary flow, shares after correcting for transmission losses.

For example, the original CS paper by Dudley and Musgrave (1988) briefly discussed the building of a new reservoir upstream from the existing CS one. Holders of shares in the capacity of the new reservoir would be required to purchase some of the shares of inflows to the existing reservoir from the existing holders, corrected for transmission losses and flows of tributaries between the two reservoirs, if any. Similarly, if new water rights to private diverters of water upstream of the reservoir cannot be granted without affecting reservoir inflows, such diverters would need to compensate reservoir right-holders for their loss. Requiring diverters to buy inflow rights, adjusted for transmission losses, in a market for such rights would seem a good way to provide compensation and promote efficiency. However, for small diversions it is probably unrealistic to expect individual upstream land holders to purchase rights to the inflows which their planned practices will eliminate, such as soil conservation measures which reduce runoff and streamflows. Rather, estimation of such effect and purchase of rights to the inflows so foregone might best be made by appropriate government agencies, such as a soil conservation agency. Obviously, the effect of a few such measures, and others such as small-scale tree planting, would not be worth considering. But if introduced on a large scale the impact could be considerable. On the other hand, for old reservoir systems, such measures may just return inflows to levels originally anticipated by the holders of inflow rights before extensive land clearing occurred. Alternately, perhaps there would be grounds for some formal trading-off between water quantity and quality with the downstream users. That is, the downstream users may be happy to accept less water if it contained less sediment, because of the associated fall in the reservoir siltation rate.

The above implications pertaining to the catchment upstream of the main reservoir also apply to the catchments of the tributaries of the main river downstream from the reservoir. Hence the above implications apply to the total catchment, both regulated and unregulated.

2.5 Implications for uses and users located between reservoirs

For uses and users located upstream from one reservoir but downstream from another, the opportunities and constraints they face would be a combination of those faced by those uses and users located either upstream or downstream of a single reservoir.

2.6 The role of water rights markets

Economists may advocate relatively unconstrained markets to encourage the transfer, both temporary and permanent, of water from lower to higher valued uses so long as third party effects are taken into account. However, constraints are likely to be placed on the market transfer of rights to water for political reasons, if only to protect the social infrastructure of areas from which water is likely to move. For example, it may be politically acceptable for water rights to move freely over relatively small geographical areas in proximity to a large rural centre, whereas moves to other political jurisdictions within the same country may be banned. Similarly, pressure may be exerted to prevent the decline of some industry, say irrigation of a specific crop.

2.7 Putting capacity sharing into practice

The initial allocation of capacity shares in existing systems could take place in a number of ways. Rights to combinations of shares in reservoir capacity, reservoir inflows and downstream tributary flows could be auctioned. This would encourage the initial allocation to the uses and users with the highest use values. However, it is unlikely to be politically acceptable in cases wherein water users have paid for other resources, notably land, on the expectation of relatively cheap water. If, after the introduction of CS, the markets for transferring the rights are 'thick' (a large number of buyers and sellers) with low transactions costs, those markets can be relied upon to ensure that the rights will soon be in the hands of those who can make the most benefit from them, regardless of the initial allocation. Then the initial allocation could be made on equity grounds, relying on the market to move rights to the most valued uses. However, if the individual capacity shares are held by a rather small number of groups of users sharing them in common, with the potential for uncompetitive behaviour, the market could not be relied on to re-allocate the shares efficiently and the initial allocation would be more critical. The most politically acceptable way may be by 'grandfathering', which is to grant allocations reflecting recent historical water use patterns.

Both individual users and groups of them are likely to take some time to become accustomed to managing their 'own small reservoirs on their own small streams'. They may feel inadequate to make their own carryover decisions until they have some experience with the new system. In such cases each user could follow the previous carryover rules or policies, perhaps with the assistance of the body previously making those decisions, until the user's skills are developed sufficiently to choose their own carryovers to suit their reliability preferences. Furthermore, under CS users may need to order water further in advance of deliveries if the old water supply authority had used local weirs to reduce water travel times between ordering and delivery. Again the previous authority may provide help during the transition period.

For new reservoirs on newly-regulated water resource systems, the idea of users bidding for rights before construction begins, perhaps with sealed bids with commitment to purchase if the reservoir is built, has quite an appeal. Users would then pay for the capital and operating costs of the system, rather than water as such. For new dams adding to existing systems, old storage and streamflow rights would need to be taken into account when determining and allocating new reservoir and streamflow rights (Dudley, 1992b).

2.8 Implications for the river valley management body

Like all water allocation arrangements for river valley systems, CS would need a valley-wide management body with enforcement mechanisms to ensure that CS operates as intended. The role of such a body would include the following duties.

* To oversee the market operations.
* To ensure that the timing and quantity of releases made from the reservoir correspond to the share-holders' orders.

* To oversee the monitoring of release flows along the delivery conduit, ensuring that the released water is received by the shareholder who ordered its release.
* To ensure that any sanctioned modifications made to the catchment by human activity which affect streamflows are matched by market transactions, or that they do not occur if not sanctioned.
* Either to be responsible for settling disputes, or for monitoring the dispute-settling processes and recommending modifications to government legislation where appropriate.

Most of these enforcement problems exist under any system, but capacity sharing highlights some which tend to be ignored under arrangements which treat the water resources as common property resources. For example, when reservoir inflows belong to all users in common, the effect of actions which modify the upstream hydrology tend to be overlooked. However, when a specific percentage of inflows actually belong to a particular entity, the effect of upstream actions is more likely to be questioned because of the heightened perception of it impinging on someone's supply.

2.9 Multi-level capacity sharing

The foregoing discussion has presented CS as a single-level division of reservoir resources, as if each individual or group of final water users would have 'their own small reservoir on their own small stream'. However, there can be multiple layers of such divisions, with groups at subsequently lower levels having 'their own smaller reservoirs on their own smaller streams' (Dudley, 1992b: Dudley and Musgrave, 1992). For example, political jurisdictions within a country, such as states, provinces or counties, may each hold first-level shares. Those entities may then use CS to allocate water among, say, various multi-purpose water storage uses, such as irrigation, flood management, instream flow maintenance, and urban and industrial use. For some of those uses, such as irrigation and urban/industrial, CS may be used again to allocate water among individual end-users or small groups of users in similar locations, with similar use patterns, or who have traditionally managed their allocation as a common property resource. The managers of shares at each level would have security of water supply probabilities with independence from the supply-reliability effects of the reservoir management decisions of others. Each level would use similar techniques for debiting, crediting and monitoring the water 'account' of each shareholder within its level of management. To encourage the transfer of water to its highest valued uses, market freedom should be such as to allow transfers across and between the multiple levels. For example, an irrigation decision maker should be free to buy water rights from an urban decision maker. However, the presence of third party effects may cause restrictions on inter-level transfers to be desirable. Such multi-level CS is particularly appropriate for international water resources management, to which we now turn.

3. INTERNATIONAL CAPACITY SHARING

3.1 Introduction to capacity sharing in the international context

The foregoing discussion indicates that CS has many appealing features for the allocation of water among competing uses and users in river valleys located entirely within one country. The remainder of this paper discusses its application when international borders divide river valleys so that all or part of the reservoir and all or part of the catchment is located in one country or countries, and all or some of the users of the regulated water are located in other(s). Sometimes the rivers themselves, or river banks, form the borders.

In international cases it is likely that CS would operate on a multi-level basis. It seems probable that the negotiation of international water-sharing agreements would require each country to hold a highest-level capacity share, rather than individual agencies or user groups within countries. Presumably, international agreements would be easier to reach this way. Each nation would then have its 'own reservoir on its own stream', with freedom to use CS or other methods to allocate rights to water resources among its users.

Just as in the national case, it is important for individual water users to have secure title to water supplies with known probabilities of supply if they are to make investment and resource management decisions which result in efficient and sustainable resource use. They need to have control of reservoir water carryover policies affecting their reliability/ mean production tradeoff points. Hence it would desirable to have CS extend down to levels as close as practical (ie. so long as advantages exceed the disadvantages) to the final decision makers allocating water and other resources at the final use level.

As in the national case, CS is a mechanism for allocating water essentially automatically, once set up, benefiting both upstream and downstream users with clarification of what are usually very unclear rights to water resources. Whether some users gain at the expense of others, relative to the current situation, depends on the initial allocation of the percentages of shares in reservoir water, reservoir capacity and downstream tributary flows.

3.2 Implications for downstream uses and users

As in the national case, beneficiaries of streamflow regulation located downstream of the reservoir would have secure title to a percentage of reservoir capacity, reservoir inflows, and perhaps downstream tributary flows. Their uses would again include instream flow management, wetland management, and flood control management as well as irrigation, urban/industrial and mining water supplies. Some cultures may require larger shares devoted to riparian or travelling stock and domestic water supplies than others. The secure title would provide access to water with a reliability of supply which could not be changed unless either the international agreement is changed to alter the total allocation to the country, or the intra-national allocation is changed. The latter could be by market transaction to promote flexibility for water to move to the highest valued uses while compensating the sellers. Downstream uses and users may be located across more than one country, which may pose delivery complexities if international borders have to be traversed, but these would not be unique to CS.

3.3 Implications for within-reservoir uses and users

Once again, CS is not well suited to allocating water for within-reservoir uses, such as recreation and pressure for hydro-power generation.

3.4 Implications for upstream uses and users

In the national case discussed above, it was noted that CS implies that water users upstream of the reservoir must not modify either streamflows or runoff into streams without taking the effect on reservoir inflows into account. The mechanism for accounting for the effects is the market - if upstream users want more water or reduced runoff, they need to purchase water inflow rights from other holders of inflow rights, with purchases appropriately modified for transmission losses. However, where all or part of the reservoir catchment is located in one country, and holders of shares in reservoir capacity and inflows are located in another, markets are unlikely to be allowed to play this role because of political constraints on international movement of water rights. In this case the transfer of rights would depend on some form of compensation acceptable to both countries being worked out, with the implementation of the agreed water supply modification procedures and compensation monitored by an overseeing international control agency.

3.5 Implications for uses and users located between reservoirs

For uses and users located upstream from one reservoir but downstream from another, again the opportunities and constraints they face would appear to be a combination of those faced by uses and users located either upstream or downstream from a single reservoir.

3.6 The role of water rights markets

National markets for the water rights defined under CS provide the mechanism to promote the transfer of water to higher valued uses within countries as conditions change through time. Factors such as exchange rate movements and higher transactions costs would appear to make international transfer of water rights more complex than national transfers. However, it is unlikely that countries would want their citizens who hold water rights to be able to trade water internationally. Increasing water scarcity tends to motivate individual countries to treat water as a national resource, and remove its international transfer from the profit seeking motives of individual citizens. Just as there are likely to be politically-motivated constraints on inter-regional water transfers within countries, it appears highly likely that there would be politically-motivated constraints on international transfers.

Markets for exchange of currently-available water in the short term, and rights to future water supplies and reservoir capacity in the long term, could operate nationally. Markets open to all water users may also be trusted for the allocation of existing water internationally, but it is doubtful if political considerations would allow long-term rights to future water resources to be traded by lower-level capacity shareholders, as indicated above. However, an international market for long-term water rights with access limited to the respective countries (ie. highest-level capacity share holders) might be workable, at least to supplement transfers by international agreement.

3.7 Introducing capacity sharing into practice

In an international context, it would appear that markets would be considered to be quite inappropriate for the initial allocation of rights to combinations of shares in reservoir capacity, reservoir inflows and downstream tributary flows. Water being allocated to the richest nations would appear to be completely unacceptable. Similarly, it appears that reliance on markets for acceptable re-allocation can be ruled out. The initial allocation would then need to be by international agreement. With new reservoir systems supplying larger regulated flows than those which existed previously, it may be advisable to introduce the new allocations in two stages. Firm, long-term rights could be granted to a large portion of the new supplies. Some other portion might be allocated either temporarily, or not at all, until some history of the new system is obtained.

The long-term nature of the CS arrangements, necessary if the users are to reap the advantages of secure probabilities of water supplies inherent in CS, means an added responsibility for getting the initial allocations right.

3.8 Implications for the bodies managing international river valleys

For international CS, two levels of management and enforcement bodies are envisaged. At a lower level national bodies would be responsible for overseeing the CS functions which occur within each country's portion of the river valley. This would include overseeing the institution that allocates rights within the country, which may be a national water market. The national bodies' duties would include some of those listed for the national case above, with the relevant mix of duties depending on the geographic share of the river valley falling within the country's borders. The single, upper-level, international body would ensure that the highest-level holders of CS rights (ie. the individual countries) receive the agreed-upon shares of the resources by monitoring the runoff, streamflows, ordered releases, actual releases, receivals and losses of the individual share-holder countries. It would also adjust recorded reservoir contents to match actual reservoir levels through time (for details see Dudley and Musgrave, 1988).

4. CONCLUSION

Capacity sharing is an innovative institutional arrangement for sharing water resources among diverse uses and users. It provides a secure title to both regulated and unregulated streamflows. The result is analogous to each user, or group of users, having their own small reservoir on their own small stream. This allows users to manage their share of the resource so as to satisfy their preferences for reliability of supply at a point in time, and to adjust easily to emerging conditions and preferences through time.

A feature of capacity sharing is its ability to operate at multiple levels simultaneously and harmoniously. In the international case, the highest level would be the national level, with each nation possessing secure rights to shares of reservoir capacity and streamflows. Whether countries then choose to sub-allocate those shares among their water users by lower-level capacity sharing, or by some other means, they can do so with a minimum of interference to their reservoir operations from other nations. Interdependencies may remain in the operation of the water delivery systems, but no more, it seems, than with other methods of water resource sharing.

The successful operation of capacity sharing would depend, like other international allocation methods, on a strong international management and control body. Lower-level, within-country capacity sharing, coupled with competitive water markets, would promote both security of tenure and flexibility for water to move to higher-valued uses as conditions change within countries. Alternately, other cultures may choose other methods for re-allocating water nationally under changing conditions through time. However, it appears that flexibility of international water allocation through time under capacity sharing would depend on re-negotiation of international agreements, as with other allocation mechanisms.

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Isaac/Shuval (Eds), Water and Peace in the Middle East

PROPOSED PRINCIPLES AND METHODOLOGY FOR THE EQUITABLE ALLOCATION OF THE WATER RESOURCES SHARED BY THE ISRAELIS, PALESTINIANS, JORDANIANS, LEBANESE AND SYRIANS

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Abstract

This paper presents a methodology to analyze the water needs of the five riparians--Israel, Jordan, Syria, Lebanon and the Palestinians, sharing the international water resources of the area. There are a number of factors that can be considered in studying possible allocation of shared water resources including among others: de-facto historic use, amount of the shared resource which arises in an up-stream territory or that naturally flows through a down-stream territory, alternative water sources, and the legitimate present and future human needs of each of the parties. The methodology proposed concentrates on evaluating the human needs of each partner in an equitable manner. The basic principle is drawn from Article IV of the Helsinki Rules--that each party is entitled to a "reasonable and equitable share in the beneficial use" of shared international water resources. A "Minimum Water Requirement" (MWR) allocation of 125 cubic meters/person/ year, needed to meet minimum human needs for domestic/urban and fresh food of each party is proposed. When the currently available water resources of each partner are compared to the estimated populations for the year 2020 it is apparent that the Palestinians and the Jordanians will suffer from severe water shortages. Israel will just be able to meet its minimum water requirement needs, while Syria and Lebanon will have considerable excess water resources above the amount required for their minimal needs. It is proposed that one of the prime considerations in determining the degree of obligation of potential donor riparians, in assisting water short parties sharing the same resource is the extent that they are able to meet their own minimum needs. The degree of assistance should be, among other things, proportionate to the amount of excess water resources above the amount needed to meet their own minimum survival needs. Accordingly Syria and Lebanon are the countries with the greatest excess.

1. INTRODUCTION

Adequate supplies of good quality water are an essential element for the survival, economic welfare and prosperity of Israelis, Palestinians, Jordanians, Lebanese and Syrians and a cause for deep concern and fears for the future by all the parties in the Middle East who are currently searching for a peaceful resolution to their long standing conflicts. For better or for worse the Israelis and the Palestinians in the territories are bound together by common geography and hydrology in their shared use of the trans-boundary waters.

Jordan,and Syria are likewise partners in this shared use of the Jordan and Yarmuk River system. Lebanon is no less a partner, since a portion of the sources of the Jordan River, the spring soúrces of Hasbani River arise in Lebanon (Naff and Matson,1984). This common geography ties the fate of all five peoples together and requires that they find a common solution based on equitable apportionment and mutual help to meet the legitimate needs of all peoples.

One of the existential concerns of the Palestinians is their fear that they will not have adequate supplies of water to assure their economic and social development and to meet the needs of the expected major increase in population. Jordan and Israel are likewise deeply concerned about their limited water resources and need to find assured solutions to their future water needs. Syria and Lebanon are in relatively stronger positions as far as water resources are concerned but Syria faces insecurity on the water question, particularly in relation to the fears concerning their sources of water that arise in Turkey.

There are already claims and counter claims concerning the shared use of the transboundry waters common to Israel, Syria, Jordan, Lebanon and the Palestinians in the occupied territories and finding a just and lasting solution to these water issues will be one of the preconditions for the successful conclusion of the peace process.

It is the objective of this paper is to analyze the nature of the water problems faced by the parties to this dispute and to suggest some basic principles and a methodological approach for analyzing water needs on an equitable basis and the degree of obligation of potential water donors for consideration of the negotiators on all sides.

2. THE SHARED TRANSBOUNDRY WATER RESOURCES UNDER DISPUTE

The water resources under consideration in this paper are the Jordan-Yarmuk River Basin, the mountain aquifer (in the West Bank and Israel) and the Gaza Strip aquifer. Prior to the Israel occupation of the territories in 1967, these water resources would have been considered, under international law, as shared international water resources (Caponera, 1992) and we have assumed that under international water law they should be dealt with as such in the current peace negotiations(see Figure 1.).

Israel, Jordan, Syria, Lebanon and the Palestinians, would then all be considered riparians in the sharing of the resources of the Jordan River basin, while in addition the Israelis and Palestinians share the transboundry waters of the mountain aquifer and the Gaza aquifer.

The nature of the claims and counter claims of the parties to the dispute have previously been described in detail (Shuval, 1992). In brief the Jordanians and Palestinians claim that based on historic rights and current and future needs they should be allocated a greater share of the Jordan River and shared ground water aquifers and that Israel should reduce its withdrawal of water in their favor. Israel claims the right to continue to use their portion of the shared water resources based both its legal rights derived for its historic use going back some 70 years, and its presents and future needs. This is a zero sum game since there are little or no unutilized water reserves directly available to these three parties. Israel, Jordan and the Palestinians will all face severe water shortages in the future and any reduction in their resources is perceived as a serious threat to their survival.

3 INVENTORY OF WATER POTENTIAL OF THE THREE SHARED WATER RESOURCES AND WATER USE IN 1992

For purposes of general orientation we shall present in Table 1. a summary of the estimated water inventory and water use by the Israelis,the Palestinians and Jordanians as of 1992 from the three shared water resources. These data are drawn from a yet unpublished report which is another part of this joint water study. The figures presented in Table 1 are estimates based on the best available sources including Israeli, Palestinian, Jordanian and other international sources (El Khatib,1999;Abdulhadi, 1991;BaniHani, 1992;Benvenisti and Gvirtsman ,1992;Bilbeisi, 1992;Bruins etal,1991;Goldberger,1992;Gruen,1992; Hydrological Service, 1991; Kahan,1987;Rosental,1987; Salameh,1992; Shawwa, 1992;Tahal,1990;Tamimi,1992; and USACOE,1991).The estimates presented in Table 1 have been critically reviewed by leading Israeli and Palestinian hydrologists and are considered to be the best available at this time. Some of the data, such as water sources and water usage by new Israeli settlements on the West bank are not available from open sources and are thus only estimates.

TABLE 1- The Estimated Water Potential and Use Inventory for the Three Shared Water Resources Serving Israel, Jordan, Syria and the Occupied Territories(Fresh and Brackish water)

Resource	Tot Avail MCM/Yr	Used by Israel MCM/Yr	Used by Palstn MCM/Yr	Used by Jor(Syr) MCM/yr	Unused MCM/Yr
1.Mountain Aquifer	632**	463*	110	---	***59
2.Gaza Aquifer	60(or 35)	4	90		(minimum deficit)-36
3.Jordan + Yarmk basin	1,060	640		150(170)	100
4.Lower Jordan	210				****100
4.Totals	1,962	1,107	200	320	223

*Including an estimated 50 MCM/Yr used by Jewish settlements built after 1967 in the West Bank.
** Includes an estimated 180 MCM/Yr of brackish water
*** Mainly brackish water some of which could be diverted upstream as fresh water or desalinated for domestic use..
**** Mainly irregular. brackish return irrigation flows and from saline springs with particularly low flow in summer, which could be desalinated for domestic/urban use.

From the above inventory ,tentative as it may be, it appears that based on the present historic de-facto use of the shared water resources serving the Israelis,Jordanians and the Palestinians, the amounts of unutilized water available in the occupied territories for further economic development and population growth are limited and/or of poor quality. Gaza already faces a severe deficit of at least 36 MCM/Yr but possibly as much as 55 MCM/Yr (Bruin et al, 1991) as a result of years of over pumping.

We have assumed here that no party to the shared water resources will agree to forgo their present de-facto water extraction rates through unilateral action by another party and that changes will take place only as the outcome of negotiations and mutual agreement in the frame work of a general peace agreement. Thus, assuming for the moment no changes in water allocations, then the potential of unused water in the West Bank mountain aquifer is limited to about 60 MCM/Yr of brackish water, part of which may be extracted as fresh water at higher upstream locations if sufficient effort is devoted to its development. The optimistic estimate of 100 MCM/Yr of unutilized water in the Jordan

River Basin including the Yarmuk would require the construction of a major dam to store it. This water is needed both by Jordan and the Palestinians and only through negotiations will it be possible to determine its final allocation. If, however, Syrian diversions are as great as those reported from some sources than even this potential source is no longer available. With proper investments in development some 100 MCM/Yr of brackish water from the lower Jordan could utilized for domestic purposes after desalination by the RO process which is considerably cheaper than sea water desalination. A larger quantity might become available for utilization with the completion of the Mediterranean-Dead Sea Canal.

A word of caution involving the use of above figures, since many of them are difficult to validate at this time. The candid sharing of accurate and detailed hydrological information is essential to clarify these vital matters. One of the important early steps in a frank and open negotiation process aimed at reaching a just and honorable settlement should be the full sharing of accurate information concerning water quantity, quality and utilization from all sources.

From the above brief presentation it is clear that there are major claims and counter claims concerning the water rights and water quality on the above three transboundry water resources which must be resolved in the framework of the peace treaty outlining the agreed upon share of the water for each side and mechanisms for its management, environmental protection and control.

4. INTERNATIONAL WATER LAW

It is beyond the scope of this paper to present a detailed analysis of international water law. Caponera(1992) has suggested that the essence of international water law is summed up in the "Helşinki Rules" of 1966-- recommendations of the International Law Association which holds that water disputes be settled equitably through direct negotiations. Article IV of the Helsinki rules state that "Each basin state is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters on an international drainage basin". These rules further provide for taking into account, among other means, possible alternative water sources that might be available to one of the parties, the possibility of economic compensation and the economic and social needs of each partner.

Thus,based on modern principles of international water law, both the historic water rights of Israel as one of the defacto users of the shared transboundry water of the Jordan and Yarmuk Rivers,the mountain aquifer and the ground water and surface runoff in the Gaza area and the rights as well as the growing human needs of the Palestinians on these shared bodies of water must be considered on the basis of equity and legitimate needs. All the parties to the conflict would be expected, in the first instance, to negotiate directly between themselves to arrive at a settlement based on the principles of "equitable apportionment" and "community of interest" rather than to enter some type of confrontational litigation, expecting some supra-government authority to enforce a judgement based on what each side views as their legitimate rights (Shuval, 1992).

The Helsinki Rules give particular weight to the priority of historical use. However they clearly state that each partner to a shared resource in entitled to "...a reasonable share of the beneficial use of the water." This principle clearly suggests that each partner must share in some equitable way in assisting those partners who face severe water shortages to meet their minimum human and social needs for survival. The concept of "equitable apportionment" and "reasonable and equitable share" is not clearly defined and there are many conflicting factors and considerations in determining it under present international law.

Whether or not international law is actually binding at this time, the community of nations will undoubtedly expect that Israel and her neighbors negotiate a settlement based on the mutual recognition that they do share common surface and ground water resources and that an accommodation should be reached in the spirit of the principles of "equitable apportionment" under international law in such a manner that the legitimate needs of each partner sharing the transboundry water resource will be met.

5. PROPOSED BASIC PRINCIPLES FOR PEACEFUL COOPERATION BETWEEN THE PARTNERS TO SHARED WATER RESOURCES

There are a number of factors than can be considered when studying possible options for allocation and reallocation of shared water resources including: defacto historic use; the quantity of water arising in an up-stream territory and the amount of water that naturally flows through and is used by a down stream territory, alternative water sources available to each partner and last but not least the legitimate present and future needs of each partner sharing the resource regardless of the other factors.

The "Basic Principles" proposed in this study are aimed at providing the parties to the dispute with a proposal, for their consideration, of one possible approach to assuring the minimal human needs of the parties, which could meet the criterion of a "reasonable and equitable share" under international water law. Our proposed Basic Principles could hopefully serve as a point of departure for negotiations and agreement, while it is recognized that the other factors mentioned above may also play a role in any negotiations.

PROPOSED BASIC PRINCIPLES FOR SHARED WATERS
(IN HIERARCHICAL ORDER)

1.Water rights should not be taken or changed by force or without mutual agreement

2.The "Minimum Water Requirements"-(MWR) of the partners to the Israeli-Arab conflict should be determined in the spirit of international water law based on the principle of equitable apportionment of the shared water resources and the other water resources available to each, in order to meet the legitimate human and social needs, with a minimum of an equal water allocation per person for domestic, urban, industrial and minimal fresh food use required for survival.

3.Water resources within the territory of a partner will first be allocated to meet the present and future "Minimum Water Requirements"-(MWR) of that partner and after that the other water uses within the same territory.

4.Historical, actual, water usage from shared resources should be maintained and normalized through mutual agreement on condition that the "Minimum Water Requirements"-MWR can be met from sources within each territory sharing the water resource, or from adjacent sources to which the territory has obtained the rights of use through agreement with another entity.

5.Unused water in one or more territories on a shared international drainage basin, that can meet all of its own present and future, "Minimum Water Requirements" from its own local sources should be the prime candidate for negotiations and agreements aimed at the sale and/or transfer of water to its neighbors on the same international drainage basin, who cannot meet their "Minimum Water Requirements" from local or other available sources which it has historically used or has gained the legal rights to use through agreement.

6.In the case where there are more than two entities sharing a water resource and one of them cannot meet all of its own present and future "Minimum Water Requirements" and the other two or more entities can meet their own MWR then the degree of liability of potential donors to the water short entity shall be proportional to extent of unused water resources and to the excess water above the amount needed to meet its own minimum water requirements.

7.Unused water in a non-contiguous territory, in the immediate region, that can meet it own present and future MWR from its own local sources should also be considered as a potential candidate donors for water sale and transfer to its neighbors in need of water as a function of their own unused water resources or the excess water above the amount needed to meet its own MWR.

8.The permanent or temporary transfer of water and/or water rights from one territory to another should be arranged through negotiations and mutual agreement. Compensation for transferred water or water rights must be determined through negotiations and agreement.

9. Every agreement involving the establishment of allocations, normalization, transfer or reallocation of water or water rights on a shared water resource should include factors such as financial or other forms of compensation, such as water exchange, or water import from external sources. Other factors in such agreements should include: environmental protection, pollution control standards and guidelines, information sharing, joint commissions for inspection, monitoring and control of both quantity and quality on both sides of the border and agreed upon, binding methods of settling disputes including arbitration and/or adjudication.

6. PROPOSED BASIS FOR CALCULATING THE "FUNDAMENTAL MINIMUM WATER RIGHTS"

It is generally agreed that the absolute minimum water requirements to meet basic human needs are those needed to for "domestic consumption". However we suggest that the broader concept of "urban consumption" is more appropriate. Urban use includes both the actual domestic or household consumption, which is usually only about 50% of the total urban use, as well as the water of drinking water quality needed to meet normal public uses for schools, hospitals, services, commerce, trades, and industry.

The "Minimum Water Requirement" proposed for consideration is 100 cubic meters/person/year (CM/P/Yr) for domestic, urban and industrial use(Shuval,1992). This amount of water per person per year has been found to be generally adequate in Israel and other water short areas with similar climate for the maintenance of a reasonable hygienic level and a high standard of living based on employment in the urban/ industrial sector not including agriculture.

In light of the agricultural tradition of the area and the high social and cultural value placed on the availability of fresh garden vegetables for consumption of the local population we propose for consideration, that despite the fact that fresh water allocations for general agricultural purposes are most likely not feasible for those entities facing serious water shortages, that if the available water resources allow for it, that there be a symbolic additional allocation of 25 CM/P/Yr of fresh drinking quality water for minimal growing of fresh vegetables (such as in vegetable gardens adjacent to homes) that require the use of fresh water of drinking water quality. While we recognize that this allocation is not strictly speaking for domestic consumption, we feel that it is justified since, for public health reasons, fresh water of drinking water quality is normally required for such vegetable gardens growing salad crops and vegetables eaten uncooked, adjacent to homes in peri-urban areas and villages.

The "Minimum Water Requirement" calculation does not include any other direct allocation of fresh water for agriculture, but does assume that additional water for agriculture and/or other uses can be made available through the recycling and reuse of some 65% of the water allocated for domestic/ urban/industrial use. In other words there will be, in effect, the possibility of generating another 65 CM/P/Yr, if an effective, total water recycling program is introduced. Thus, the total effective allocation of water could reach 190 CM/P/Yr (125 CM/P/Yr from fresh water sources and 65CM/P/Yr from recycled wastewater)(Shuval, 1992).

It is also assumed that while the present domestic/urban/ industrial water use on the West Bank and Gaza and in Jordan is only about 35-50 CM/P/Yr and even less as compared to 100 CM/P/Yr in Israel that the water consumption levels will, in time, be the same in all urban communities and thus it is justified and necessary to recognize the need for an equal water allocation from the beginning. It is understood that this might provide for a larger allocation of fresh water for agricultural purposes for the Palestinians and Jordanians during the interim period which is in recognition of the reality that some 30% of the Palestinian population and more in Jordan, currently make their living from agriculture compared to less than 5% in Israel.

In time, with increased standards of living and improved socio-economic conditions, domestic, urban and industrial use patterns will grow among the Palestinians and Jordanians so that all of the allocation of " Minimum Water Requirement" would be used for its intended domestic/urban purpose with essentially no allocation of fresh water for agriculture. The agricultural population in the future will be reduced proportionately and what agriculture will remain will be based mainly on the use of recycled wastewater. Wastewater will have to be purified to a very high level. This will be essential both to prevent pollution of the vital ground water sources under the various aquifers, most of which are karst and highly sensitive to contamination from surface pollution, and to allow the growing of unrestricted crops of maximum economic value to the farmers.

However, if part of the Minimum Water Requirement-MWR is to be supplied to one partner to the dispute who suffers from a shortage of water to meet domestic needs, by another from the stock of resources covered by its recognized historic use, then, only the actual domestic,urban and industrial requirements at any given time would be transferred, up to the full allocation as real demand grows.

7.ILLUSTRATION OF APPLICATION OF PRINCIPLES AND METHODOLOGY

As an initial trail illustration of the application of the above principles and methodology (See Table 2) we will estimate the present and future populations to the year 2020 of the five direct riparian parties to the dispute in addition to the two near-by countries, Turkey and Egypt (column 1) and their estimated known renewable fresh water resources potential (column 2). The current and estimated 2020 population figures for Syria, Lebanon, Turkey and Jordan are from the US Army Corps of Engineers study (1991).The water potential of Turkey, Syria,and Lebanon are from Kolars(1992). These figures are not all verifiable. The estimates for the year 2020 may be high and are used for illustrative purposes only, The population growth estimates for Israel and the Palestinians are from our own study (Shuval,1992). From these estimates we can calculate the available fresh water per capita per year for 1992 and the year 2020 (column 3) and the "Minimum Water Requirement" MWR for the year 2020 (column 4). From these figures we can calculate the total excess (or shortage) of water for each party (column 5) in relation to the MWR for each of the partners.

From this presentation it is clear that the Palestinians suffer now and will suffer in the future from serious water shortages. Assuming, for the moment, that they have available only the water resources that they currently use and those unutilized resources in the territories, then their per capita water resources would be reduced from 150 MC/P/yr in 1992 to 60 MC/P/Yr in the year 2020. The total amount of additional water required just to meet the MWR of the Palestinians in the year 2020 is estimated at some 325 MCM/Yr. The situation for Jordan is similarly bleak. Assuming no increase in their water potential above 1100 MCM/yr, then their per capita water resources will be reduced from 315 MC/P/Yr in 1992 to some 110 CM/P/Yr in the year 2020. The amount of additional water required just to meet their MWR is some 150 MCM/Yr. By the year 2020 we estimate that the Palestinians and Jordan together may have a total water deficit of 475 MCM/yr just in order to met the very modest water allocation for survival which we have defined as the MWR of 125 MC/P/Yr. This does not include any allocation for agriculture other than the absolute minimum symbolic allocation of 25 CM/P/Yr for fresh vegetables.

	1 POPULATION 1992	2020 Millions	2 WATER RESOURCES POTENTIAL MCM/Yr	3 TOTAL WATER CAPITA/YEAR CM/P/yr 1992	2020	4 TOTAL MWR IN 2020 MCM/Yr	5 TOTAL EXCESS OR SHORTAGE MCM/YR
Israel	5	10	1,500	300	150	1,250	+250
Jordan	3.5	10	1,100	315	110	1,250	-150
Pales-tinians	2	5	300*	150	60	625	-325
Syria	12	26	10,500	875	400	3,250	+7,250
Lebanon	3	4.3	3,700	1,230	860	540	+3,160
Turkey	55	83	105,000	3,300	1,910	10,400	+95,000
Egypt	50	120	60,000	1,200	500	12,800	+47,000

TABLE 2.Can Available Fresh Water Resources Meet the Minimum Water Requirements(MWR) of Middle Eastern Countries? Estimated fresh water resource potential, estimated population in the year 2020,and ability of water resources to meet Minimum Water Requirements-MWR. It is assumed that the Minimum Water Requirements-MWR for survival are 100 cubic meters/ person/ year for domestic,urban and industrial use and 25 CM/P/Yr for minimal growing of fresh food for local consumption. It is assumed that recycling of all urban wastewater will generate another 65 CM/P/Yr. for additional agricultural, industrial and urban non-potable purposes. *Includes an estimated additional 100 MCM/Yr over current usage from locally available unutilized sources.

Assuming that Israel continues to utilize the water resources that it is currently using, than by the year 2020 it too will find itself with just a bit more than the MWR. Israel's per capita water resources will go from 300 MC/P/Yr to 150 MC/P/Yr by the year 2020. The total excess of water resources above the amount required for domestic, urban/industrial use to met the MWR will be 250 MCM/yr.

Syria, Egypt an Lebanon will, in the year 2020, still have 400, 500 and 860 MC/P/Yr. respectively. While Turkey will remain in the water abundant range with about 2000 MC/P/Yr .

If we now examine the situation as presented here in terms of the general principles we have proposed in the spirit of the Helsinki Rules we find that of the five parties who share in the transboundry water of the area ,two (Jordan and the Palestinians) will face serious water shortages and will not even be able to meet their Minimum Water Requirements-

MWR for drinking water unless their water resources are increased. Israel will just be able to meet its MWR and will have only a minimum amount of about 25 MC/P/Yr of fresh water left for other purposes, while Lebanon and Syria will be able to meet their MWR without any problems and will have considerable amounts of water in excess of the MWR other purposes including agriculture.

Let us assume for a moment that Israel alone is called upon to contribute water to the water short parties. Even if it transferred 100% of its excess above the MWR it still would only cover about 50% of the needs of Jordan and the Palestinians (475 MCM/Yr.). See column 2 in Table 3.

TABLE 3.
Proposed Ranking of Potential Donors to the Water Short Parties (Jordan and the Palestinians) Based on the Estimated Degree of Excess Water Resources in the Year 2020, Above the Minimum Water Requirement of 125 CM/Person/Year

	1	2	3
	EXCESS ABOVE MWR	%OF EXCESS TO MEET DEFICIT	% CONTRIBUTION IF SHARED S+L+I
1 Syria	7,250 MCM/Yr.	6.5 %	68%
2 Lebanon	3,160 MCM/Yr.	15.0 %	30%
3 Israel	250 MCM/Yr	190.0 %	2%
Turkey	95,000 MCM/Yr	0.5%	--

If Syria, which is no less of a party than Israel to the shared water resources, contributed all of the water needed to cover the deficit of the Jordanians and Palestinians, it would amount only to a reduction in its excess resources of 6.5%. If Lebanon contributed all of the water needed it would represent 15.0% of its excess resources. If However Turkey agreed to contribute, or sell, the water needed it would only represent a reduction of about 0.5% of its excess resources.

If however, for example, three out of the five riparians, Syria, Lebanon and Israel are together asked to contribute to the meet the water needs of the two water short partners who are riparians on the water resources, proportionately to the amounts of excess water that they are estimated to have in the year 2020, above that needed to meet their own MWR needs, then the calculated percentage of the contribution of each of the three countries would be as shown in column 3 in Table 3. Under such a proportional allocation Syria would be expected to contribute 68% of the total defici, Lebanon 30% and Israel 2%.

This example calculation has been presented for illustrative purposes only. It is recognized that the estimates of potential water resources and present and future populations are rough approximations at best and need to be refined. This approach is based on the "equitable utilization" principle of the Helsinki Rules. It is designed to meet the minimum water requirements- MWR for survival of all partners. It should provide one possible method for analyzing the degree of need of the water short riparians and the possible degree of obligation to assist the water short riparians by the others who at least can meet their own minimum water requirements-MWR. It can be used alone or in combination with other factors and criteria.

Obviously none of the partners will be satisfied with an existence based only on the above Minimum Water Requirement-MWR allocation. A bold regional Water-for-Peace Plan for increasing the water resources of the area for all, by importing water or desalination sponsored by the major powers could become an important impetus to the peace process. It will be easier to agree on equitable reallocations with a larger pie to devide up(Shuval, 1992). However, there must be a recognition that imported or desalinated water will, in general, be costly and can be justified only for rational economic uses, which most likely will not include agriculture.

This methodological approach may be one way of approaching the problem of water allocations to water short partners and hopefully will provide some input into the negotiating process. It will certainly be controversial and raise many objections, however it is presented as food for thought. There are of course other factors that can be considered in studying the question of water allocations on a shared aquifer but the concept of equitable allocation based on meeting minimal human needs should be of prime importance. In the final analysis it is only through direct negotiation that an eventual agreement can be reached and it is not the task of this paper to prejudge the outcome of that process.

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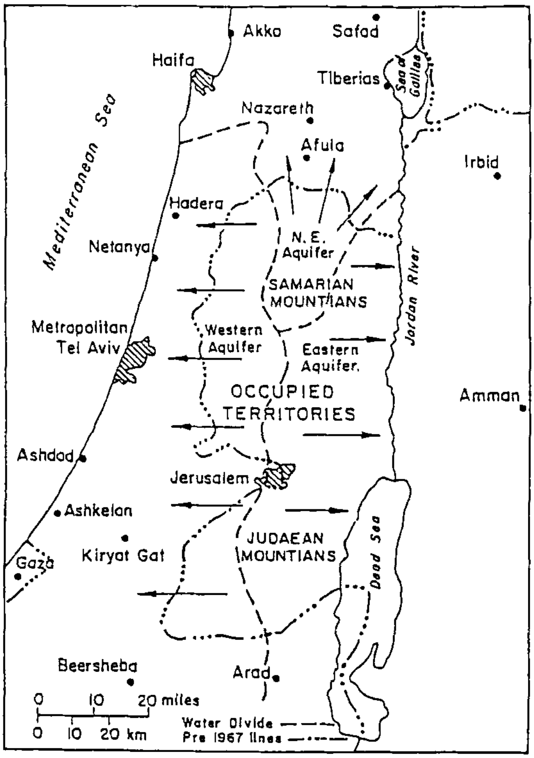

Figure 1.The Mountain Aquifer-A Schematic Presentation: The pre-1967 cease fire lines which serves as the border between Israel and the occupied territories (West Bank), mainly inhabited by the Palestinians, is shown with a heavy dashed and dotted line. The hydrological divide between the three subdivisions within the mountain aquifer is shown by the dashed line.The arrows show the general direction of the flow of the ground water.

The development of a water resource management infrastructure for the West Bank and Gaza

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Abstract

The lack of any of the usual methods for water management within the occupied territories of the West Bank and Gaza leads to many, well documented problems. Realistic methods to move from the present situation to one of meaningful water management are *not* well documented. A recent visit, sponsored by the British Council, has allowed the opportunity to meet many people working within the water sector in the occupied territories, and some ideas on how to develop training programmes to improve water management capabilities have emerged. This paper outlines the perceived needs for scientific water management, and the components necessary for developing an indigenous management capability that can tackle the pressing water related problems of the region.

1. INTRODUCTION

I had the privilege of paying a visit to the West Bank and Gaza regions last year, sponsored in part by the British Council. The purpose of my visit was to try to identify what training is needed to develop the water management capabilities of the populations of these regions. This paper develops some ideas in this direction.

2. THE WATER RESOURCE SYSTEMS OF THE WEST BANK AND GAZA

The water resource systems of both the West Bank and Gaza are hydrologically complex, and therefore require a high degree of technical knowledge to develop optimal management techniques.

Surface water availability within these regions is very small, and so not examined in detail. The international River Jordan lies along one boundary of the region, but its exploitation is a matter of international agreement, not internal resource management, and limited by its increasing salinity. Apart from infrequent storm rainfall discharges, the surface water consists of groundwater outflows - either as springs or seepages - and can be considered as part of the groundwater system.

The West Bank groundwater resource mostly lies within a "karst" limestone aquifer system, with well developed, high transmissivity pathways leading to established spring locations within the fault-controlled and deeply incised valleys. The zone of "active" groundwater movement is deep, extending many hundreds of metres below ground level in many areas, taking place in a succession of chalks, marls, limestones dolomites and sandstones. A consequence of this is that the groundwater body does not behave as a true "regional" aquifer system, but is much more unpredictable, and variable.

The groundwater flow is considered to occur in a multi-layer, partially karstified aquifer system. Continuity of aquitards separating aquifer units within the system is doubted. Evidence for this complexity of flow can lie in the hydrochemistry of water samples obtained, and is borne out by piezometric data where they are obtainable.

Evaluating the total, exploitable groundwater resource of such a system will require a very large investment to fully appreciate the intricacies of the flow systems involved. The prediction of the impact of any change in current abstractions on the natural outflow systems - the springs - will require very close investigation, because of the doubts about the inter-connectivity of the various aquifer and flow systems.

The Gaza aquifer is much simpler hydrogeologically, but its management problems are not proportionally smaller. The aquifer consists of recent, unconsolidated alluvial deposits, with a water-table at a depth of a few metres. Difficulties arise because exploitation of the aquifer is very simple - the construction of a shallow well to exploit the sandy, unconsolidated aquifer is cheap, and requires little advanced technology. The sinking of a well will also bring immediate benefits - either an improved, reliable water supply or supplementary irrigation water to improve crop yields. As a consequence, there are very great numbers of wells in the region, and regulation of these abstractions is made administratively very difficult.

3. CURRENT PROBLEMS

Within the Occupied Territories, the present range of problems that are related to water is very wide. The problems basically stem from three difficulties:

- there does not appear to be enough water to meet existing demand levels, and demand is deliberately suppressed to reduce this imbalance;
- the quality of the water resource is deteriorating significantly in many areas;
- there is enormous difficulty in obtaining sufficient hydrological information to fully appreciate the current problems, and how they may be solved.

The current water management issues that need to be addressed differ between the West Bank and Gaza. In the West Bank the most pressing problems appear to be:

- concern about over-exploitation of the groundwater resources, producing a partial moratorium on new well construction, and emergency restrictions on rates of abstraction in many areas;

- changes in apparent behaviour of springs, especially a seeming drastic reduction of their discharge, as a consequence of decline in the piezometric pressures in the upper aquifer system;
- management of competing abstractions from different levels within the groundwater system - especially the impact of deep abstractions on piezometric levels in higher aquifer systems;
- the encroachment of saline water into the shallow aquifer systems in the Jordan Valley;
- the control and regulation of water demand and abstractions from the water systems is not equitable, and not administered openly.

In Gaza, the problems focus more on water quality issues. Again, the main management problems appear to be:

- demand, especially for irrigation, is much higher than the supply, and is very difficult to regulate;
- increasing levels of nitrate in the groundwater system, probably arising from waste water disposal systems;
- increasing salinity of the groundwater systems, due, in part to saline encroachment from the sea, and
- falling groundwater levels, and resource over-exploitation.

When the political climate changes, and impetus grows to solve these problems, solutions will be severely constrained by the lack of detailed monitoring data obtained during the development of the problem. Any new management system *must* address this area with utmost urgency.

4. THE NEED FOR SCIENTIFIC WATER MANAGEMENT

Current responsibilities for water management appear to be distributed amongst a number of agencies, but ultimately held by the military authorities. No attempt is made to regulate the water resources using agencies that are answerable to the communities that they serve, and policies for regulation are not developed openly. Most remarkable of all, hydrological information is kept a closely guarded secret, and the communities are not encouraged to participate in monitoring schemes.

Current water management practices focus on the restraint of demand for water - principally through the device of limiting the granting of licences to construct boreholes. Management *should* encompass more roles than this, such as:

- development of long-term planning for the water resource, especially the evaluation of the full resource potential;
- monitoring of the resource, developing reliable indicators of how the resource changes from season to season, and year to year. This should involve both quantity and quality aspects;
- taking measures to protect and augment the size of the resource, through such measures as catchment conservation and artificial recharge, where these can be financially justified;

- providing unbiased information for managers and politicians, to allow policies to be discussed and agreed in the light of accurate and reliable technical data;
- the implementation, and possibly the policing, of agreed management policies for the conservation and protection of the resource.

The solution of the current water resource problems will require major efforts to educate the population to the realities of the water resource situation, and to win over their full co-operation in efforts to conserve resources. There will also be the need for major investigations of the aquifer systems before sufficient understanding of the behaviour of the groundwater resource is gained such that the impact of groundwater management policies can be confidently predicted. Time and funding will also be needed to establish a representative monitoring network, and to establish records over a long enough period to be represent the seasonal and year-to-year variability of parameters.

As a consequence, there will, of necessity, be a relatively lengthy period at the beginning of the Agency's existence when sufficient information, experience and knowledge is being gained before the Agency role can be carried through with full authority. The need for this interim period must be recognised, and the Agency should not be judged too harshly, too early.

5. COMPONENTS FOR AN INDIGENOUS MANAGEMENT CAPABILITY

Any Water Resource Management agency should fill the following roles:

5.1 Information Collection

The agency must collect basic hydrological data, both through its own resources, and from all other institutions that measure hydrological parameters. The measurements must include meteorological variables, streamflow (especially spring flow), piezometric information, and water quality data. Information should include "baseline" data of relevance for potential future development, variables indicative of current climate conditions and representative parameters for resource evaluation, as well as specific information for monitoring specific problems, such as contamination encroachment in aquifers.

5.2 Information Storage

The agency should be responsible for the maintenance of all records, and so be the access point for users of the information. This role must also include the quality control of the data collected - checking to make sure that the data stored are accurate and representative. The role should also include the collation of historic information, from all possible sources. This is a particular problem in the region, and one that is vital to solve. In addition to data storage, the agency must have the facilities to disseminate summaries of information collected, and welcome users of information to access the data archive.

5.3 Information Analysis and Processing

Development and use of hydrological information is helped if the water resource agency has a budget and a brief to analyze and process the information collected. The current problems facing the Agency will require a lot of data analysis, and expediency might suggest that the employment of Consultants to look at these problems is the simplest way of identifying solutions. However, the long-term development of an indigenous water management capability crucially depends on practice at analyzing these problems, and it should remain one of the agency's tasks to study water management problems in detail.

5.4 Policy Development

Priorities for water resource use, how water should be conserved and long-term management strategies cannot be identified purely by hydrologists. What the water management agency must provide is the hydrological background information and detail to allow managers, politicians and the like to evaluate the effect of management strategies, and so select the policy to adopt. This is a very demanding role, and requires a deep understanding of the water resource systems, probably obtained through in-depth analysis of hydrological information and detailed hydrological simulation techniques.

5.5 Water Management Administration

The Agency must also supply the facilities for the day-to-day regulation of the management policies. This may include processing of abstraction licence applications, and making sure that any abstractions are in accordance with the licence obtained. This will apply equally to discharge permits if the licensing of waste water disposal practices is also to be included in the Agency responsibilities.

6. DEVELOPMENT OF A WATER RESOURCE MANAGEMENT INFRASTRUCTURE

The development of a water resource management agency will require important decisions to be made at the outset. These must include:

- definition of the agency's objectives, its terms of reference and its methods of operation;
- commitment to the empowerment of the agency - providing adequate funding over a long-term period for financial stability and realistic planning, and providing it with sufficient authority and resources to carry out the work required of it;
- providing the resources to procure the equipment needed to measure, collect and process information, and maintain the equipment, as early as possible, to develop the data-base as rapidly as possible;
- providing facilities to attract the right calibre staff, at all levels of seniority, to carry out the vital work of the agency, and to provide a commitment to the technical development and advancement of the skills of the staff.

In practice, the development of such an Agency will probably have to be evolutionary. Work should commence on more general, regional resource issues, coupled with the development of a detailed monitoring network and investigations initially being focused on the immediate problem areas, then being extended to provide coverage of the remainder of the region. With evolutionary development, however, it will take longer for the Agency to provide detailed expert advice on all water related problems, and the period of learning might be longer.

7. TRAINING PROGRAMME

The region's recent political history has meant that the opportunities for the development of water management capabilities are few and far between, and much work is needed if the skills and information are to be brought together in a plausible management framework.

There are considerable hydrological skills, and water resource management experience, in the Palestinian communities abroad, and this will be invaluable in the years ahead. One fundamental problem is the hiatus in education in recent years, leading to the present shortage of young professionals. A prime objective of any training must be the "bringing on" of this generation.

A training package to develop water resource management expertise within the Occupied Territories should include the following strands:

7.1 Academic Education

Selected young people must be provided with the specialised education of post-graduate training in hydrology, water resources and related fields.

7.2 In-country Training Courses

In-country courses should be provided to allow wide attendance, and to promote the interest of a wider body of scientists and engineers in the study of hydrology, and the fundamental issues of water resources management. This will allow water resources issues to be debated with more clarity throughout the scientific community, and lead to a wider understanding of the basic issues involved.

7.3 Hydrological Information Collection

Experience with the operation of hydrological instruments, the recording, processing and analysis of the data they generate is an indispensable educational experience for a fledgling agency. These disciplines should be included in the training programme, if at all possible. The use of hydrological instruments would also provide valuable experience in equipment maintenance techniques for young technicians. Compilation of historic data from a variety of sources should also be undertaken, and efforts should be made to provide quality assurance information on the compiled data.

7.4 Water Resources Investigation

As a coherent thread to tie the training programmes together, the target of a detailed water resource assessment of one area should be used to demonstrate techniques, promote scientific investigation and lead to a closer understanding on the hydrological controls on the magnitude of the resources available. The hydrological data collection could also focus on this one region.

8. CONCLUSIONS

There is an enormous amount of work to be done before an effective and efficient water resource management agency, responsive to the needs of the inhabitants, can be operating within the Occupied Territories. The size of the task demands that the planning for the establishment of the Agency begins as early as possible, in order that the objectives, authority and *modus operandi* of the agency are established to greatest effect at the outset. Once established, it must again be recognised that there is a very important "learning" phase for the Agency, and it cannot be expected to immediately answer all the vital questions concerning water resources management. Accurate answers to these problems can only be obtained after a period of intensive investigation and study.

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Conflict over water in the Middle East: From a security and strategic point of view

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Abstract

In modern times, where droughts claim thousands of human lives every year and farmers in many parts of the world give up their means of livelihood for the lack of rain, water has become an issue over which nations may conduct wars.

In the Middle East, already at the end of the 19th century and more so during the mandatory period, Jewish strategic planners were aware of the fact that control over water resources in the region was of vital importance to their respective plans.

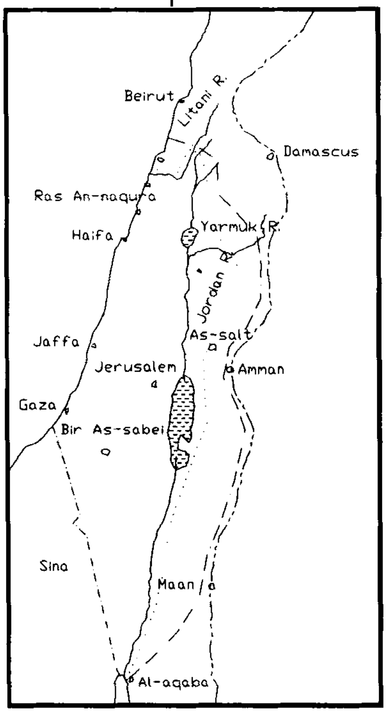
To analyse the developments relating to the water issue in the Middle East we first look at the main events of the period of the British Mandate over Palestine from 1917 until 1948.

INTRODUCTION

The first political battle over water occurred in 1917 when General Allenby announced the partition of territories (occupied by Allenby) into three zones in accordance with the Sykes-Picot Agreement. Zionist leaders protested against this partition claiming it contradicted the Balfour declaration and impeded the accomplishment of the Zionist settlement project. They demanded that the Yarmouk River, the Sea of Galilee and the Golan Heights, as well as the Litani River in the north be added to Palestine (see map no. 1). The Zionists considered this expansion of boundaries necessary for the economic viability of the promised Jewish state. This line of thought found some symapathy in Britain but France insisted that the waters in question remain within its mandatory borders. As a result of five years of British-French, British-Jewish and later French-Jewish negotiations (1918-1923) the Zionist movement made important gains in respect to water resources even though they had to give up some of their demands (the Sea of Galilee but not the Yarmouk and the Litani).[1]

The special significance of the water issue was obvious during the numerous partition proposals in the period of British Mandate, such as the Royal (Peel) Commission (1937), the Woodhead Commission (1938) and the Anglo-American proposals (1946). While Palestinians strongly rejected the partition plans which were being presented by various commissions, researchers for the Jewish Agency were busy locating the underground water reservoirs of Palestine and preparing a policy to guarantee that these would be situated in the Jewish state once a partition be brought into effect. As a result, when partition was proposed by the Peel Commission, Jewish demands included those areas where the main water resources were located in the Galilee, the mountains from Haifa to the South of Lod

Map I



- - - - Boundaries according to Zionist suggestion to the peace conference (1919).

Boundaries according Mainerzhagen suggestion.

—·—·— International borders according to Sykes–Picot.

------ Othman Railway

and Ramle with its groundwater reservoirs, the Sea of Galilee with the natural springs, in its surroundings and the largest part of the Yarmouk River (see map no. 2).[2]

Given these conditions and the Arab rejection, Britain dropped the proposals of the Royal and Woodhead Commissions on partition and resumed its mandate. In 1946, the Anglo-American Committee of Inquiry was established to study possible solutions to the problem of Palestine. The Jewish Agency submitted a proposal (Hays Proposal) regarding the water division. This proposal included that the waters of the Jordan, the Yarmouk and Litani Rivers were indispensable for the Jewish state as resources for drinking water, agriculture and hydro-electric power.[3] Also, it contained suggestions regarding the use of groundwater and floods.

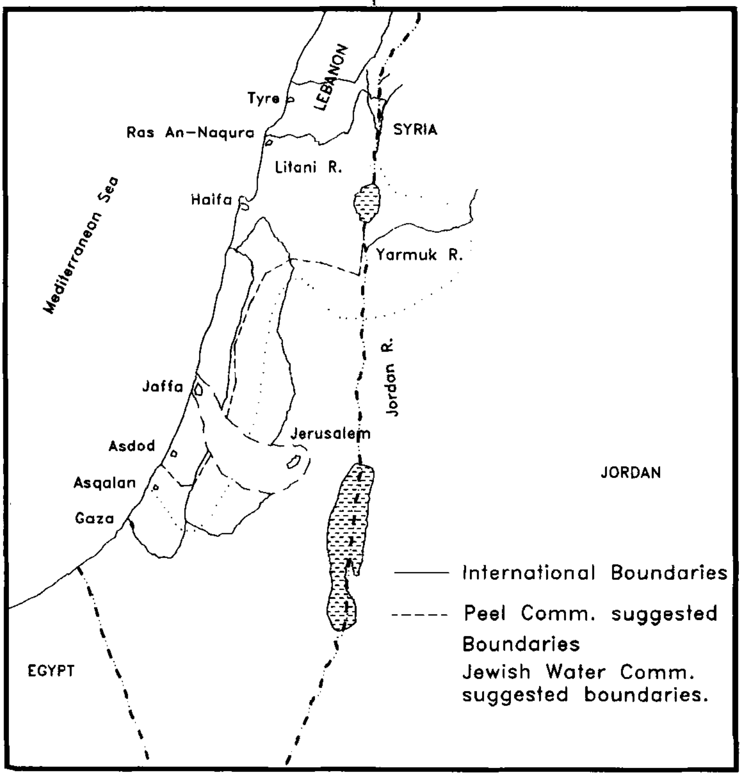
To support their proposal, the Jewish Agency had carried out an intensive settlement operation in the Galilee close to these water resources during the Second World War and had prepared itself to annex the entire Galilee to the Jewish state.[4] However, the Anglo-American Committee rejected the Hays Proposal since it disregarded the Jordanian and Palestinian needs of water and, moreover, it required a high level of cooperation between Jews and Arabs, which was impossible then and for a long time afterwards.[5]

According to main Jewish water engineer, S. Blass, the partition (181) proposal of November 29, 1947, took into account the future Jewish plans and the future Israeli needs of water. According to the proposal, the Negev and Batouf Valley in Galilee were annexed to the Jewish state. Moreover, the first Israeli Prime Minister, David Ben-Gurion, tried during the 1948 War to gain resources which had not been attributed to the Jewish state in the partition plan. He made the Minister of Foreign Affairs, M. Sharit, demand from the U.N. that they modify the boundaries of the partition plan and add the Lod and Ramle region, which holds a large groundwater reservoir, to the Jewish state. In the meantime, he ordered the Jewish army to occupy these two cities and to evict the Arab inhabitants.[6] Later he proceeded with the occupation of the western Galilee, which according to the partition plan was part of the Arab state. In short, whatever Ben-Gurion was not able to achieve through diplomacy, he brought about by military means.

During the British Mandate, when the Jewish Agency had neither political power nor military or judicial force, they used water as an important element to successful agriculture, as against insolvent Arab, water-poor agriculture. This situation helped the Jews to acquire as much land as possible. In doing so, they were supported by the first British High Commissioner to Palestine, Lord Herbert Samuel (1920-1925), himself a Zionist Jew, and by the British House of Lords. High Commissioner Samuel issued a special decree which liquidated the Ottoman Agriculture Bank in Palestine in 1921 under the pretext that this bank was in "confusion".[7] This meant that Palestinian farmers in debt had no other recourse than to go to the Jewish Bank which, under control of the Jewish Agency, charged high rates of interest. Palestinian farmers strongly demanded that the authorities reopen the Ottoman Bank but to no avail.[8]

During this period Zionist institutions, especially the Jewish Agency, made intensive efforts, both locally as well as internationally, to obtain power over or at least access to water resources outside of Palestine, or the promised Jewish state. Water became an ideological issue to the Zionist movement and strategic planning was conducted with the farmers' need of water in mind. As a result, Jewish farmers produced larger and better crops than their Palestinian counterparts and this eventually led to the bankruptcy of many Palestinian farmers, who had no other choice than to sell their land to always-ready-to-buy

Map 2


LEBANON
Tyre
Ras An–Naqura
SYRIA
Litani R.
Mediterranean Sea
Haifa
Yarmuk R.
Jordan R.
Jaffa
Jerusalem
Asdod
JORDAN
Asqalan
Gaza
International Boundaries
Peel Comm. suggested Boundaries
Jewish Water Comm. suggested boundaries.
EGYPT

Zionists. More water meant an increase in agricultural produce, profits and land, and ultimately a higher capacity for the absorption of Jewish immigrants to Palestine.

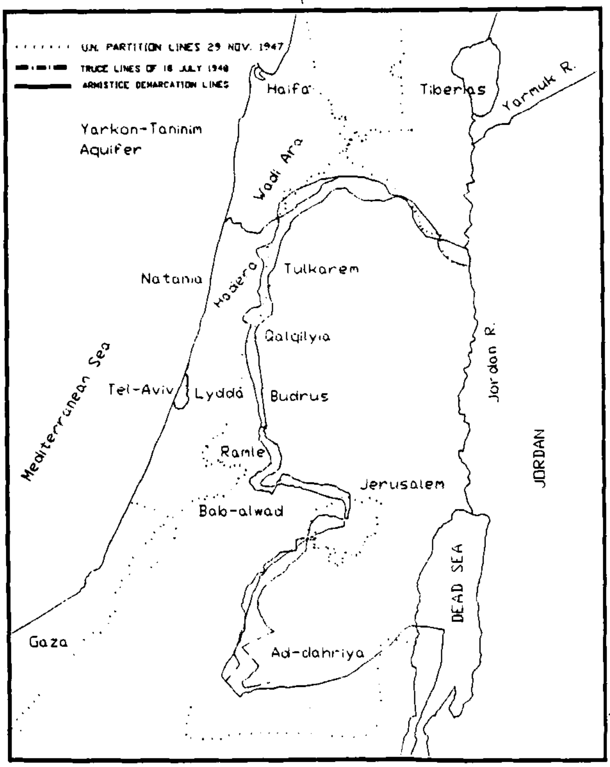
UNDER ISRAELI AUTHORITY

After 1948, Jewish institutions attained full political and judicial power over most of the Palestinian land and water resources. It also had the military power to achieve what was not able to be achieved by peaceful means. When Ben-Gurion entered peace negotiations with Jordan and Syria in 1949, one of his objectives was to obtain the land of Wadi Ara, which would make it possible for Israel to reach the Yarkon-Tinimim groundwater reservoir in the western mountain chain. Rather than bringing the issue of water into the negotiaitons, Ben-Gurion told King Abdallah of Jordan that Israel needed to expand its borders for security reasons and offered Jordan two pieces of land in return, one near Hebron and the other in the north of the Jordan Valley. It was made clear to the King that if he did not agree to the deal, Israel would use its military means (seemap no. 3).[9] At the Syrian border the matter was more complicated. Israel had hesitated to use military force against Syria, while the Syrians showed no willingness to surrender water to Israel. Negotiations, supervised by a reconciliation committee of the U.N., resulted in specifying three demilitarized zones of land in Palestine occupied by the Syrian army during the war (see map no. 4). However, shortly thereafter, when American engineer M.G. Banger presented a proposal to use Yarmouk water to alleviate the water crises in Jordan and Syria without attributing a share to Israel, the latter related every solution to her sharing the water as well as direct or indirect recognition of the Jewish state by the Arabs. For this reason Israel managed to persuade the USA not to finance the project.[10]

By the end of 1953, American President Eisenhower appointed Mr. Eric Johnson to the role of special envoy to the Middle East in order to reach a settlement on the water issue. Despite earnest efforts from the side of Johnson, who paid four visits to the region over a span of 2 years, all of his attempts to reach a solution appeared doomed to failure for the following reasons:

1. As long as the Arab countries approved of the Johnson proposal, Israel rejected it, claiming that Israel would only agree if She recieves a share of the Litani waters. When, however, due to internal political changes, Syria and Lebanon no longer approved of the proposal, Israel then announced her "conditional agreement". On the other side, political changes in Syria and Lebanon banned the Arab League from taking a final decision at the end of 1955. Israel used the Arab disagreement to announce an Arab disapproval of the proposal, while "she has no time to wait" for starting her water projects. According to S. Blass, Israel's "conditional agreement" to the proposal was a tactical move aimed "to frustrate every suggestion which did not serve Israel's strategic interests". He added, "Israel preferred disagreement than agreement, that allowed Israel to still gain more water that she would if the proposal had been accepted".[11]
2. Tension at the Egyptian-Israeli border before and after the Sinai War in 1956 was an obstacle to the resumption of Johnson's efforts.
3. When in 1956 the USA withdrew from financing the construction of the Assoean Dam, the USSR showed willingness to take its place. From then on, the Middle East became an area of increased importance to the superpowers, making the solution of regional problems

Map3



Jordanian-Israeli front and Armistice lines (north)

even more complicated.
4. The fact that the Johnson proposal included a notion that Palestinian refugees should settle outside their homeland and a condition that the Arab countries officially recognize Israel, gave local opposition parties in the Arab countries power to cause drastic changes, as happened in Syria and Lebanon. In this situation a united Arab positive stance towards the Johnson proposal was out of the question.

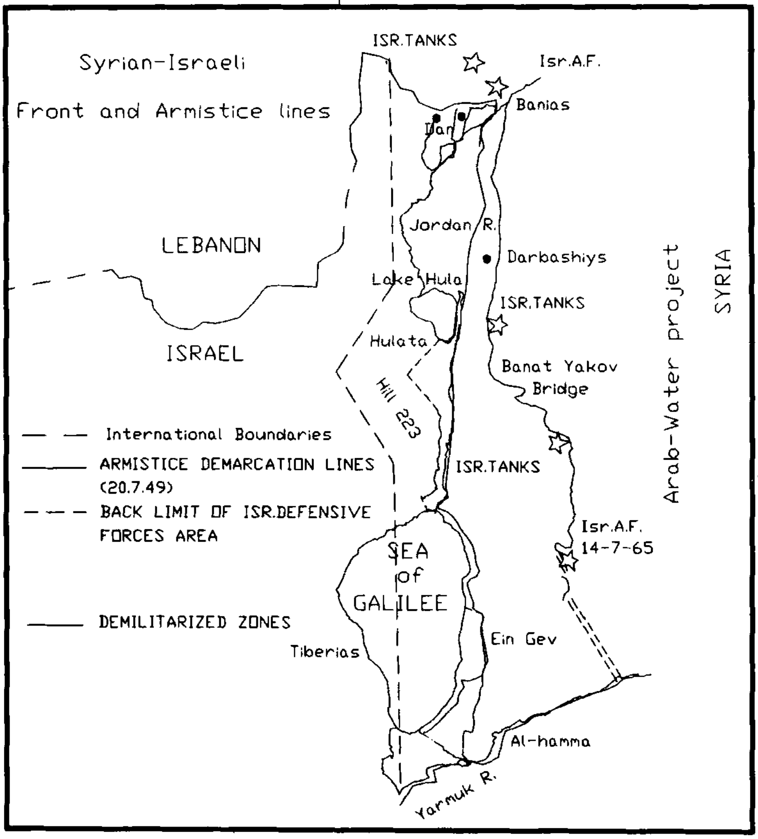
The USA, meanwhile, in an effort to implement the proposal tacitly, even though an official consent between the parties had not been reached, supported Jordanian-Syrian projects as well as projects in Israel and Jordan, all based on verbal agreements, especially between Israel and Jordan. Besides projects in the line of the Johnson proposal, Israel executed its own privately planned water projects with subsidies from the USA and the International Bank.

Since the early 1950s, armed clashes had occurred along the Syria-Israel border because of Israeli excavations in the demilitarized zone near the Jordan River. Israel increased her work intensively after the Johnson mission's failure at the end of 1955 while Syria became more worried about the newly created facts, made by Israel, especially concerning the fact that Israel was granted unconditional American support. In this context, Egyptian leader Jamal Abdul Nasser called for a special Arab summit in Januray, 1964. The summit decided to counter Israel's violations in a practical rather than military manner and ordered engineers to start works on an Arab water project, which would derive water of Jordan branches passing Syria and Lebanon for Arab use. This project, called "a deriving of Jordan river branches", was meant to annually derive around 125 million cubic meters of water, what is not counter with the Arabs' proportion of Jordan river water in the Johnson proposal. Israel considered the project a danger to its nation security and decided to use all its means, including military, to impede the Arab project. Far from being a danger to its security, the plan was rather a danger to Israel's own future water-related plans, namely the transfer of water from the Litani river for drinking, irrigation and electric power production.

Another thorn in Israel's flesh was the fact that the Arab project bystepped the two issues which made the Johnson proposal unacceptable to the Arab countries: the settling of Palestinian refugees outside their homeland and recognition of Israel. Thus, she decided to obstruct the Arab project, no matter what the price. According to Sh. Golan (an Israeli researcher): "Israel organized provacative operations against Syria between November, 1964 and the summer of 1965." The operations were led by the Chirf-of-Staff, Yitzhak Rabin, and aimed at provoking Syria into a military response which would provide Israel with a pretext to beat and to demolish the works of the Arab water project. At least the Israeli military forces succeeded in achieving their goal (see map no.4).[12]

By mid-1965, Syria realized that the project needed constant military protection and in 1966 she formed a military alliance with Egypt. Syria also followed her military readiness with threats expressing the intention to attack Israel. Israel used these threatsto prove to the world opinion that it was in danger of becoming victim of Arab agression. Then on June 5, 1967, she launched a "defensive" war against them. This war signified the end of the Arab water project.

Map 4


Syrian-Israeli
Front and Armistice lines
ISR.TANKS
Isr.A.F.
Banias
Dan
Jordan R.
LEBANON
Darbashiys
Lake Hula
ISR.TANKS
SYRIA
Arab-Water project
ISRAEL
Hulata
Banat Yakov
Bridge
Hill 223
International Boundaries
ARMISTICE DEMARCATION LINES
(20.7.49)
ISR.TANKS
BACK LIMIT OF ISR.DEFENSIVE
FORCES AREA
Isr.A.F.
14-7-65
SEA
of
GALILEE
DEMILITARIZED ZONES
Ein Gev
Tiberias
Al-hamma
Yarmuk R.

WATER AS A SECURITY ISSUE

Water has always been an ideological and strategic case for Israel. The military control over water resources was related to the possibilities of more Palestinian land seizure by different means. Water considered as a Security issue particularly in 1967, whereas the issue of security becomes understood and accepted in the international political spheres, especially in the Israeli society.

The phenomenon of water crisis in Israel came to be clearly expressed since 1948 until today. It renems whenever the number of Jewish immigrants raises. The Israeli solution to this crisis has always been through depriving more Arab farmers of water using new technology and military or judicial powers, whether this depriving was inside Israel or in the occupied territories of Palestine, Syria or Lebanon. Since 1948 and particulary after 1967 Israel had confiscated and had controlled most of the Arab lands and water resources under the title of "security reasons" or "security needs". Palestinian farmers, being deprived of water, were pushed to leave part or all of their lands and turned to the Jewish projects of building or looked for work in the neighboringJewish settlement which was based on Arab confiscated land and getting all water supplies. Consequently, the Palestinian farmer had to bear losses because of the unequal competition with the Israeli farmer who had the lion's proportion of water in addition to the government financial and judicial support. Under the title of "security", water issue appeared to be a means of settlement expansion. Mr. Y. Shamir, P.M. of Israel in 1990, summarized this policy in the sentence: "Great Aliya (immigration) needs great Israel."[13] This means that great immigration needs all water resources in the occupied territories to still be under the control of Israel. On the same principle "Aliya" in the suture needs new water resources and new lands, otherwise Israel will be in a water crisis! This is what the Palestinians call the record of the Israeli expansion policy.

It is obvious for objective researchers that, while the water forms a means of nutritional security in the all Arab strategic plans, for Israel water forms a means to achieve ideological goals in the "All Zionist Project" in the Middle East. But for the Palestinians, keeping water rights forms a guarantee to keep their own agricultural land and at all their existing in the future on their homeland.

SUMMARY

The Arab countries' refusal to recognize Israel was undoubtedly one of the main reasons for failure of water reconciliation between the Arab states. CUrrently, however, Egypt is in a peaceful relation with Israel. Jordan, Syria, Lebanon, and the PLO sho willingness to recognize Israel officially andpractically according to conprehensive peace agreements including a settlement to the water dispute. In return Israel still ignores the national rights of the Palestinian people.

From the last Israeli water projects can be learned that Israel does not look for a way to return water to its owner but looks for additional resources that could be achieved by international and Israeli technology with Arab capital, used in a common water projecrt under the control of Israel. Israel tries to practice the prinicple, "whatever I won from you is mine so let us make peace by sharing yours."

According to obvious facts, Israeli policy at the peace process seems based on international guarantees and the Middle Eastern military balance. This policy makes such a settlement a form of surrendering and making the negotiations difficult and threatened with failure. Any agreement based on military balance is definately temporary because the military balance is a changeable matter within a short period of time. New military balance leads to a new war for regaining either deprived rights or claiming new rights according to new future plans.

The history of the conflict over water in the Middle East teaches that water settlement must be a main part of a comprehensive national and political reconciliation. It requires a mutual recognition of rights between Israeli people and Arab peoples as a main political condition. It also needs at least an end to the military threat and political blackmail. Such an agreement of peace needs also to establish common and local (national) water projects. FOr all of this it is necessary to establish a bank of science and technology, as well as a development finance bank to support such project sin all of the Middle East. These banks can be provided by the USA, Europe, Japan, and the Middle East states (Arab states and Israel). Banks should be under the supervision of the UN, at least in the first phase and later under common authority. Peace projects then can be successful if based on the principles of the mutual interests and will fail on the principles of the military balance.

ENDNOTES

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13. Israeli TV, November 15, 1990.

Isaac/Shuval (Eds), Water and Peace in the Middle East

Legal Aspects of International Cooperation on Transboundary Water Resources

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Abstract

This paper intends to provide a concentrated overview of the ways and means the Swiss authorities handle transboundary affairs in the domain of water resources. Emphasis is put upon some basic aspects of international cooperation, the legal framework and legal acts. An illustrative example, the hydropower plant of Rheinfelden, serves as a guideline. This project is now in the design phase of renewal.

1. INTRODUCTION

Switzerland shares its borders with five countries: Austria and the Duchy of Liechtenstein in the east, Italy in the south, France in the west and Germany in the north. A great variety of interests on transboundary water resources , such as the use and protection of lakes, rivers and underground aquifers on the common border with our neighbours have always been, are today and will certainly also be in the future subject of bilateral and multilateral cooperation.

The hydropower plant of Rheinfelden, taken as an example, is situated on the river Rhine, which marks the border between Germany and Switzerland. It is one of the many projects, which required intensive international cooperation. The plant has a representative history and is now in the interesting phase of beeing replaced and renewed.

The plant was build in the years of 1895 to 1898 as the first low pressure hydropower station on the upper Rhine river between the Lake of Constance and the city of Basel. International negotiations on this project started in December 1890. Bilateral talks and negotiations were carried out by a permanent commission, which has been installed according to a treaty between the Grand Duchy of Baden (today a state of the Federal Republic of Germany) and the Confederation of Switzerland in 1879.

Later, 10 more plants were constructed such that the power of the Rhine river is now used by a chain of such stations.

The Rheinfelden Power Company is a private company with German and Swiss shareholders.

The first concession with a duration of 90 years expired in 1988. In 1984 the company submitted a project for a new plant. It received a new concession in 1989 with a new duration of 80 years.

2. SOME BASIC REQUIREMENTS FOR INTERNATIONAL COOPERATION

There is no doubt, that legal aspects play a vital role in the development and settlement of international treaties. However, from a more general point of view we have experienced, that some basic requirements must be fullfilled in order to successfully pursue and set up bilateral or multilateral legal acts. A very brief comment on these requirements may be useful for any planned international cooperative activities.

2.1. Common Interest

At the beginning of any international cooperation, which finally leads to agreements or treaties, there is an intention of one of the parties involved, be it an interest to protect people, goods and nature from the dangers of water, be it the use of water resources for a specific purpose or their protection against contamination or misuse.

At this point of the development, international contacts concentrate primarily on the issue of common interests, which finally may lead to a legal act.

In our example, the common interest was originally the use of the Rhine river as a waterway for shipping purposes, not yet the water power to generate electricity. This common interest lead to an agreement on river traffic on the Rhine river in 1879 between the Duchy of Baden and the Confederation of Switzerland.

However, Article 5 of this bilateral agreement, which, by the way, is still in operation, commits the two countries:

"to ensure, that none of the signatary countries undertakes any kind of construction, that considerably influences the water current regime, without consultation of the other partner. "

2.2. Coherence of Laws

Switzerland and its neighbouring countries are in the comfortable situation, that their legal systems have common roots, the roman law. Upon this common basis these central European countries developed similar legal cultures. Although the coherence of laws is not an absulutely nessesary prerequisit for the successfull developement of bilateral or multilateral legal acts, more or less congruent legal systems and practice have proven to be of great advantage.

2.3. International Liability

International agreements are finally put down in some form of a legal act: a treaty, a bilateral licence, a protocol, common statements, action plans, resolutions etc.

None of these different forms of agreements are of any value, if international liability concerning the maintenance of these acts are disturbed or injured.

In our example, the agreement between the Grand Duchy of Baden and the Confederation of Switzerland from May 1879 has strictly been maintained until today, allthough there have been two world wars and several changes of the form of governments, constitutions and laws in between.

2.4. Transparent Procedures

International agreements always contain certain procedures, be it for the developement, the maintainance or control of regulations, be it for the processing of projects or the treatement of controversial issues or conflicts.

It is up to the partners of the treaty to decide upon existing procedures, taking for instance the procedures of the treaty partners or to define new mechanisms which are to be followed.
In any case, the procedures to be chosen must be fully transparent for all participants.

2.5. Transparent Interpretability

What has been stated for transparent procedures also holds for the interpretability of legal processes and legal practice.

2.6. Flexibility

We have experienced, that flexibility plays a vital role in international agreements. Most of the bilateral or multilateral treaties or agreements the Swiss Federal Office of Water Resources Management originally developed and today maintains and supervises have been in operation for dozens of years. Some originated in the late 19th century, many of them in the early 20ies of this century. All of them have ever since worked to the satisfaction of the treaty partners . The secret behind this continous applicability may be attributed to the fact, that only the necessary principles in the sense of framework legislation have been introduced in the agreements.

2.7. Transparent Institutional Interdependences

We have always followed the practice that institutional interdependencies are exposed and be clearly defined. Schematically this may be shown in the following diagram:

Table 1
Typical Structure of Institutional arrangement

Structure of Swiss Institutions	Permanent or ad hoc structure of Project Coordination	Structure of Partner Institutions
Confederation	Commission	Country
Cantons	Permanent Working Groups, Task Groups etc.	States
Communities		Communities

In reality, the institutional structure and the network of interactive relationships within governmental and administrative organizations as well as the vertical and horizontal interconnections among the various organizational systems are much more complex. In our example, on the level of the confederation alone no less than 21 organizational units were involved in the process of international cooperative work.

2.8. Transparent domain-configuration

In addition to the structure of the institutions on the different governmental levels, the breakdown of the numerous tasks, activities, competences and resposibilities in the domain of water resources and related fields like urban planing, environmental protection, infrastructure, energy, sanitation etc. is important for common undertakings. It must be visible for all treaty partners how and where the different tasks are placed within the system of the governmental structures and their administration. If possible, the participating parties should have access to the description of duties of the various institutions involved.

The duties of the Swiss Federal Office of Water Management for instance consists of twelf clearly defined tasks such as:

- Preparation and execution of federal legislation for the use of hydro power,
- Preparation and execution of federal legislation for the safety and security of dams,
- Examination of flood control projects and their supervision,

  etc.

2.9. Conflict Handling

It is essential that also less agreable things, such as conflict handling, are thourougly analysed and defined.

3. THE LEGAL FRAMEWORK

3.1. Arrangement

There is no binding system of international public legislation similar to legal systems on a national level in the domain of water resources. However, there are certain generally accepted and widely respected maximes concerning territorial aspects, quality requirements and quantitative aspects.

This situation is often called: lex imperfecta. It means, that above the various national legal systems, there is no prescribed legislatory framework for international water resources affaires. Thus, the partners must chose and decide on a suitable way to develope international legal acts. Basically, there are four possibilities of arranging a legal framework:

1. taking the national legislation system of *one of the partners* and add negotiated agreements and regulations,
2. taking the national legislation system of *each partner* and add negotiated agreements and regulations,
3. taking the national legislation of a chosen *third country* and add negotiated agreements and regulations,
4. developing a system based upon negotiated agreements and regulations only.

For practically all bilateral or multilateral legal acts, Switzerland and its partner countries have chosen strategy No. 2. This choice is mainly due to the fact, that the legal systems of Switzerland and the other countries have undergone a consequent developement, which has proven to be suitable to the needs of the nations, have a systematic basis and a long, well developed interpretable practice.

Table 2
Development of Water Legislation in Switzerland

1. Protection of men and nature against water hazards
   - *1804* First resolution of the Federal Assembly to realize a river correction under common mamagment
   - 1848 Constitutional article assigns the right to dispose of the water resources to the cantons (CON)
   - 1874 Constitutional article assigns the supervision of waterworks to the Federal Government
   - *1877* Law on the protection measures against floods (flood protection law) (FPL)
2. Use of water resources (mainly hydropower)
   - 1908 Constitutional article assigns the right to set up principles about the use of water resources to the Federal Government
   - *1916* Law on waterrights (mainly use of hydropower) (WRL)
3. Protection of water resources
   - 1953 Constitutional article assigns the right to enact regulations concerning the protection (Quality) of water resources to the Federal Government
   - *1955* Water protection law (Quality) (WPL)
   - 1971 Revised Water protection law (Quality)
   - 1991 Revised Water protection law (Quality and Quantity)
4. Water resources management (Art 24 bis)
   - *1975* New constitutional article upon initiative of the Swiss people to regulate all matters of water resources management on an integral basis:

" For the economical use and the protection of the water resources as well as the protection against water hazards the Federal Government enacts *principles* on the basis of integral views and in common interest for:
a) the preservation and the exploitation of the water resources, especially for the provision of drinking water and the enrichment of aquifers,
b) the use of water resources for the production of energy and for cooling purposes,
c) the regulation of water levels (lakes) and run off (surface and subterraneous drain), water runoffs from natural flow, irrigation, drainage as well as further operations in the natural water cycle;
for the same objectives the Federal Government enacts *regulations* for:
a) the protection of surface and subterraneous water against pollution and the ensuring of adequate residual water quantities,
b) the supervision of river corrections and the safety of water retaining facilities
c) the operations to influence precipitation,
d) the right of the confederation to claim the use of water resources for the purpose of its transportation facilities (Federal Railways), etc.

3.2 Structure of the Swiss water legislation system

Today the Swiss water legislation system has the following form:

Table 3
Structure of the Swiss Water Legislation System

Objective	Subject	CON	Law
1. Protection against water hazards	Maintenance	24, 24 bis	FPL
	dams (flood control)	23,24	FPL
	retaining dams	24 bis	FPL
2. Use of Water	hydropower	24 bis	WRL
	"drinking" water	24 bis	WRL
	drainage	24 bis	WRL
	irrigation	24 bis	WRL
	heat transfer in/out	24 bis	WRL
	recreaton		
	fishery	25	FL
	shipping, navigation	24 ter	SL
3. Protection	against pollution	24 bis	WPL
qualitativ	physical influence	24 bis	WPL
quantitativ	residual flow	24 bis	WPL
	aquifers, groundwater	24 bis	WPL
	other operations (construction)		WPL
4. Water cycle	preservation of resources	24 bis	
	change of water resources	24 bis	
	by-passes, diversions	24 bis	
	water resources management	24 bis	
	hydrology	24 bis	
	as part of area planning	22 ter	LDL, NCL
	as part of ecosystem	24 bis	EPL, FL, WPL, NCL

CON = Constitution
FPL = Law on proctection measures against floods (flood protection law)
WRL = Law on waterrights
FL = Fishing law
SL = Shipping law
WPL = Water protection law
LDL = Law on land development
NCL = = Law on nature conservation
EPL = Environmental protection law

4. EXAMPLE OF A CONTEMPORARY LEGAL ACT (CONCESSION)

Based upon the treaty between Germany and Switzerland from 1879 and the former concession of the hydropower plant of Rheinfelden from 1890, the two governments issued a new concession to the company in 1989 for the construction of a new plant. The contens of this legal act, which is valied for 80 years, has been arranged within the following framework:

Table 4
Structure and main contents of a Concession (Example)

	Chapter	Main contents
1.	Scope and duration of the licence	- scope of the water right, duration - relation to upstream installations - relation to downstream installations
2.	Ownership	
3.	Design, Construction, operation and maintenance	
4.	River correction and water works	
5.	Public interests	- flood control - protection of urban areas - protection of cultivated areas - environmental protection - protection of water resources - hydraulics - fishery - navigation, shipping - military aspects
6.	Economical	- distribution of water power - water rates - contracting
7.	Termination and renewal of the licence	
8.	General regulations	

5. CONCLUSION

International cooperative work starts with the requirement or demand to solve a problem or the desire or need to come to an agreement concerning a particular or common interest. In the domain of water resources, demands and needs may be subdivided into three major categories: the protectioin against the dangers of water, the use of water resources and their protection. The definition of a commonly accepted legal framework is of great importance. But apart from the legal aspects, basic requirements for cooperative work as briefly explained in chapter 2 must be kept in mind.

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A General view of the water situation in the occupied Palestinian territories (OPT.)

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Abstract

Israeli control over water resources and services favor the growth of Israeli agriculture and industry at the expense of these sectors of the Palestinian economy. Palestinian households also suffer from poor quality water which do not always meet the specifications of international health organizations and from Israeli restrictions limiting consumption. Military orders and obstacles obstructing the provision of quality drinking water and sufficient quantities for agriculture and industry are analysed.

In the OPT, Israel exercises total control over all issues relating to water resources and its usage. This enables the Israeli occupation authorities to manipulate the water situation in a manner which has had a severe impact on the economy of the OPT, particularly its most important sector being that of agriculture.

In addition to this, most of the Palestinian population, be they in villages, towns or refugee camps etc.., suffer from an insufficient water service both in quantity and quality of the water supply, because of ineffective, inadequate water and water networks. To supplement their water supply, the population, particularly in towns and villages, relies on spring and rain water, both of which are susceptible to contamination.

Most water wells used by Palestinians were dug before 1967. Many of them have since dried up and cannot be used. The Israeli authorities constantly refuse permission for the digging, repair, and maintenance of wells.

The total volume of water pumped from wells in the West Bank is 84 million cubic meters per year. There are 294 Arab wells from which 18 million cubic meters is pumped for drinking water, and 26 million cubic meters for irrigation per year. There are 34 Israeli dug wells from which 40 million cubic meters is pumped for drinking and irrigation water.

Figures show that in 1985, 47% of the pumped water was used by 50,000 settlers in Israeli settlements in the West Bank, while the remaining 53% was used by one million Palestinian inhabitants of the West Bank.

It is estimated that the maximum amount of water available within the West Bank is approximately 850 million cubic meters.

- 600 million of this is form underground water, of which 60 million cubic meters is salt water.
- 40 to 50 million cubic meters is from surface water.
- 200 million cubic meters is from river sources, mainly from the River Jordan and its tributaries. More than 470 million cubic meters of this supply ends up in Israel.
- 320 million cubic meters ends up in the reservoir of western underground water supply.
- 110 million cubic meters is from the north eastern reservoirs.
- 30 million cubic meters of surface water.
- 10 million cubic meters pumped from the Jordan River.

The remaining 380 million cubic meters is used as follows:
- 40 million cubic meters is consumed by settlers.
- 44 million cubic meters is used by Palestinians. 20% of the remaining amount is salt water, the rest is too costly to be drawn out.

PROBLEMS WITH DRINKING WATER.

Many cities, villages, and camps suffer from a shortage of drinking water, as the needed water is not available from reservoirs or water networks. Therefore, most Palestinian villages depend on rainfall collection in cisterns or on spring water. An example of this is the Tulkarm district which has 83 cities, towns, villages, and camps. 53% of these places are not provided with piped drinking water. 28% have water networks but water is not available all day long. The reasons for this are:

1. An increase in population resulting in increased demand.
2. Most of the wells constructed before 1967 now do not reach the underground water levels.
3. Military orders and restrictions on Arab wells with regard to water quotes and maintenance.
4. Municipal budget for development was cancelled by the Israeli authorities, thus preventing the progress and development of water projects.
5. The municipal councils are unable to afford financing any water projects.
6. The military order issued in August 1967 completely removed all authority from Palestinian committees and organizations which administered water projects.
7. Permission from the Israeli military governor and from other specific Israeli departments is needed before any water project can ever be started.
8. Government control over water resources through the Israeli Mekorot company.
9. The limitation on drinking water quantities, and the increase in its cost after the allotted amount has been used.

Table 1 shows the volume and cost of drinking water for the year 1992.

Table 1

Area	Pop.	Allotted amount m3/y	Cost price NIS	Selling Price 1-4m3	4-16m3	>16m3	Location
Tulkarm	50,000		0.50	2.50	0.60	0.80	W. Bank
Anabta	7,000	170,000	0.50	2.08	0.72	1.44	W. Bank
W. Baga	16,000	800,000	1.00	1.77	2.61	4.09	G. Line
Qalansawa	11,500	550,000	1.00	1.77	2.40	3.50	G. Line
Makhmoret	900		0.50	0.60	0.60	0.60	Israel
Kfar Olesh	300		0.50	0.80	0.80	0.80	Israel

PROBLEMS IN PROVIDING DRINKING WATER.

The Israeli occupation authorities in the West Bank and Gaza Strip have limited the volume of water available from wells for irrigation. In 1976, water meters were fixed on each well to prevent the farmers from exceeding their allotted limit. Any farmer who exceeds the limit was and is subjected to punishment.

To illustrate this, a farmer in the Tulkarm district owns a private well for irrigation. This well irrigates 2,000 dunums of the surrounding agricultural land. The allotted amount of water is 269,000 cubic meters per year. He exceeded this amount by 4,000 cubic meters. This farmer was sent to appear before a military court on October 10th 1987, and was sentenced to one year imprisonment and five years probation, and was fined $800. This same farmer applied many times for permission to increase the allowed discharge from his well, his requests were always rejected.

Major obstacles facing Palestinians regarding irrigation water.

1. Prohibition of digging wells for irrigation water.
2. The Israeli water administration through its military officers, refuse the transfer of funds for the purpose of purchasing new drilling equipment, tools etc..for the sinking and maintenance of wells.
3. The Israeli Mekorot Water Company, using modern equipment, has sunk deep wells reaching deeper underground water in close proximity to Palestinian wells, thus causing these Palestinian wells to dry up. A case in point is a well dug by Mekorot at Beit Dajan, where three existing Arab wells have subsequently dried up. The continuous pumping of large volumes of water has had a severe impact on the pumping of the Arab wells.
4. The occupation authorities prevented Palestinian from using many wells, ponds, and channels owned by absentee Palestinians (forced to leave their lands in 1967).
5. The Israeli policy of land confiscation by military order.
6. Destruction of irrigation channels in the Jordan Valley area during military exercises.
7. The occupation authorities' policy of confiscating land for the purpose of building new roads was deliberately aimed at fertile agricultural areas. A case in point is the planned

road number 57, which if implemented, will destroy the Faraah Irrigation Project. This project irrigates 16,000 dunums - the total volume of water involved is estimated at 15 million cubic meters.

These major obstacles have caused the following:

a. Farmers now tend to partially plant their land only once a year because of water restrictions.
b. Therefore, large areas of agricultural lands are not being used.
c. Water has become more expensive, while crops have become cheaper. This has caused many farmers to abandon agricultural work, thus satisfying the aims of Israeli policies by forcing people to leave their land either to work as cheap labour in Israeli agricultural and industrial sectors, or forcing many of them to voluntarily leave their homeland, meanwhile making it easy for the Israelis' to implement their plans for confiscating more Arab lands.

Table 2 shows the allotted water volume for irrigation purposes for the year 1992.

Table 2

Area	Water (m3) for irrigation	m3/Dunum allowed for irrigation	NIS/ m3	No. of Dunums irrigated	Location
Anabta	150,000	100	0.64	1,500	W.Bank
Atail	269,000	134.50	0.40	2,000	W.Bank
Baqa.G	650,000	325	0.78	2,000	G.Line
Qalansawa	171,000	228	0.72	750	G.Line
Kfar Hiss		1800	0.25		Israel
Kfar Olesh		500	0.45		Israel

WATER FOR INDUSTRIAL PURPOSES.

There is little demand for water use in industry in the OPT. It is used only in small factories and workshops such as brick factories, stone cutters, and soft drink factories. In Israel however, more than 122 Cu.m of water are used annually for industrial purposes. This amount exceeds the total available for all uses in the OPT.

A summary of the Israeli and Palestinian water situation.

ISRAELI	PALESTINIAN
1. Have modern water wells.	1. Have old, primitive wells.
2. Water pumped continuously and in large volumes.	2. Low productive capacity.
3. Wells pump from deep underground water.	3. Wells pump from shallow depths.
	4. None available.
4. Israel has annual budget for developing water resources.	5. Restrictions enforced on their limited consumption.
5. Settlers and Israelis in general are allowed almost inlimted water consumption.	6. Most of the drinking water is from cisterns or springs.

6. Drinking water in accordance with specifications of international health organizations.
7. 98 houses in Beirtofia consume 1.5 million m3 of water per year for agriculture.
8. The population of Kfar Olesh is 300. They have drinking water all day long.
9. High water consumption by the Israeli user - 490m3 per person per year.

7. 1200 houses in Atteel allowed to use only 269,000 m3/year for agriculture.
8. At nearby Balaa, there are 10,000 people who don't have piped drinking water, they depend on cisterns and springs.
9. Very low consumption, about 40m3/year for one person.

THE TOWN OF ANABTA.

Location: Lies on the main road between Nablus and Tulkarm. It is 200 meters above sea level.
Population: Approximately 7,000.
Area: 15,445 dunums. 1,700 dunums are considered part of its regional border. The remainder, by Israeli occupation authorities order, are not. A licence is not given for any building outside this 1,700 dunums.
Rainfall: The average rainfall in Anabta is around 560mm per year, and humidity is 57% during the summer months.

Anabta Municipality.

The municipality of Anabta was founded in 1954. It has the following departments.

1. Accounting Department.
2. Health Department.
3. Engineering Department.
4. Levying Department.
5. Water and Electricity Department.
6. Public Works Department.

Anabta Municipality owns three Artesian wells. The first well is 150m deep. Its productive capacity is 30 Cu.m/hour. It was dug in 1948. The second well is 270m deep, and its productive capacity is 70 Cu.m/hour. It was dug in 1960. The third well is 270m deep, and is no longer operational as its pumps and pipes are damaged and cannot be replaced for the reasons mentioned in this paper.

The municipality supplies the residents with water from the second well through the network, the rest is pumped to the municipality's own tank - (its capacity is 300 Cu.m). The first well used to pump 30 Cu.m/hour, but it has been out of order for many years because a turbine fell into the well. The municipality tried hard to get the approval of the military governor in order to provide maintenance for these wells, after many lengthy attempts, the municipality got the permission.

The municipality then asked the water department in Ramallah (responsible for water wells in the West Bank) to help in the maintenance, their initial reply was that there were no drilling machines or lifting equipment to remove the turbine. However, the department offered an old rig (circa. 1940) in order to pull the turbine - of course, this was an impossible task.

The water department in the municipality.

This is a small department which carries out simple maintenance work on the water network, and the laying of water pipelines for the benefit of new customers. This department faces many problems, some of which are:

1. The non-availability of suitable machinery to assist the department in its work. This has led to pipe defects not being detected, hence huge amounts of water leak out from the system.
2. The shortage of employees and workers in these departments, making work very slow, causing delays in maintenance works.
3. The piped water network is over 30 years old, parts of the network need replacing in many places, and maintenance in many others. The municipality cannot afford to do either, therefore 43% of available water for drinking is lost due to leakages.

In addition to this, Anabta shares some other problems with neighboring villages which are administratively linked to Anabta. Many have applied for drinking water supplies. These villages cannot afford the financial cost of implementing such projects, i.e. - water tanks, a new network, water pumps. In addition to this, there are great difficulties which the municipality faces with the military authorities.

For example, not having the permission for the repair of two other wells in the town. If permission was granted and financial support is available, two more wells could be put back into operation and some of these villages could have the water they need.

SUGGESTIONS AND RECOMMENDATIONS.

1. The establishment of a national water authority in the OPT to ensure Palestinian water rights.
2. Digging deep water wells and working on the maintenance of old ones.
3. Installation of new turbines and new pumps to give a higher productive power.
4. Sending technicians and engineers for training programmes on the maintenance of wells and pumps.

Joint Declaration by Professor Moshe Ma'oz (Truman Institute of the Advancement of Peace of the Hebrew University of Jerusalem) and Dr. Sari Nosseibeh (Head of the Jerusalem Center for Strategic Studies, MAQDES)

At the Conclusion of the First Israeli-Palestinian International Academic Conference on Water

Zurich, Switzerland
December 10-13, 1992

Water is a fundamental resource for human survival. While the issue of water is being discussed by Israelis and Palestinians in the ongoing bilateral and multilateral negotiations, academics and researchers have a role to play in promoting understanding and in resolving water resources problems. In order to discuss these issues, Israeli, Palestinian, and other international water scientists met in Zurich for four days of wide ranging and open discussions. At the conclusion of these productive exchanges, we feel that we have taken an important step forward in building bridges of mutual understanding and confidence. Among the many issues discussed were questions of the equitable distribution of shared water resources, water rights, new sources of supply and techniques for improving the efficiency of the existing system, the history and relevance of international water law, methods of water management, and water marketing. While disagreements remain, we were able to identify areas of management and consensus.

As members of the international scientific community, we urge that all disputes over water resources be resolved peacefully. We also urge that actions be taken to identify appropriate methods of new supply and effective techniques for improving the efficiency of current distribution and use, especially in the Gaza Strip, where water problems are extremely urgent. In addition, we acknowledge the importance of free and open sharing of scientific data. One of the first steps that should be taken is the complete sharing of water resources data of the region. To facilitate access to these data, we intend to establish a joint clearinghouse, with a third party of recognized international professional standing.

We recommend further cooperative efforts among academic researchers, scientists, and other specialists. The academic community has a vitally important role to play in conducting water resources research and studies and identifying solutions. We urge all scientists interested in these issues to continue the productive discussions begun here.

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