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17 September 1992

Dr. John Kolars
P.O. Box 4133
Ann Arbor, Michigan

Dear Dr. Kolars,

Enclosed is the report I mentioned to you in our recent telephone conversation, entitled *Water-sharing Regimes in Israel and the Occupied Territories -- A Technical Analysis*. This is the first in a series of studies focusing on the problem of common water resources for future progress in the bilateral Israeli-Palestinian peace process. In the paper, I describe one possible methodology for determining a "fair and reasonable" division of the waters of the three transboundary aquifers shared between Israel and the West Bank. My intent is to establish a normative standard for an equitable water-sharing regime against which to measure progress in the Israeli-Palestinian bilateral negotiations as they pertain to water.

The second report in this series (which I am currently researching) will bring this analysis "back to earth", examining the extent to which the Israeli and Palestinian leaderships (and their respective domestic constituencies) are disposed toward acceptance of the norms, principles, rules and procedures of an equitable water-sharing regime such as that described in the enclosed report.

I should emphasize that this report is only the first step in a "work-in-progress." Consequently, any comments, suggestions, criticisms, or observations you may have, either related to this or the follow-on study, would be greatly appreciated.

Thank-you for taking the time to review this work.

Sincerely yours,

[redacted]

James W. Moore
(613) 992-4532

Canada

[redacted]

DEPARTMENT OF NATIONAL DEFENCE
CANADA

OPERATIONAL RESEARCH AND ANALYSIS ESTABLISHMENT

PROJECT REPORT 609

WATER-SHARING REGIMES IN ISRAEL AND THE OCCUPIED TERRITORIES -- A TECHNICAL ANALYSIS

by

James W. Moore, Ph.D.

August 1992

OTTAWA, CANADA

National Defence Défense nationale

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OTTAWA, CANADA AUGUST 1992

ABSTRACT

This study outlines an approach for equitably apportioning the transboundary groundwaters shared between Israel and the Palestinians of the occupied territories.

RESUME

Ce rapport propose une approche en vue d'une division équitable des eaux souterraines transfrontalières partagées entre Israël et les Palestiniens des territoires occupés.

EXECUTIVE SUMMARY

1. An important, if not the central, issue in any final resolution of the Israeli-Palestinian dispute will be the ultimate disposition of the shared transboundary groundwaters -- Yarqon-Tanninim, Northern, and Nablus-Jenin aquifers -- straddling the Green Line separating pre-1967 Israel from the West Bank. To this end, negotiators will be called upon to conclude a fair and reasonable allocation regime dividing the combined water potential of these aquifers (545 million cubic meters [MCM] per year) between Israel and the Palestinians in the territories. This paper outlines a multidisciplinary approach -- drawing upon such diverse fields as demography, hydrology, international law, and others -- that may prove useful in efforts to construct such a regime. This approach includes five major steps:

(1) forecast aggregate domestic, industrial, and agricultural demand for water for Israel and Palestinians in the occupied territories;
(2) estimate the water potential of renewable fresh water resources, including those situated wholly within Israel or the territories, as well as shared boundary groundwaters;
(3) identify principles from international law for the equitable division of shared groundwater resources, and derive equity standards against which to measure alternative allocation regimes;
(4) evaluate alternative regimes to determine which is "best" from an equity standpoint; and,
(5) calculate the total water supply available to Israel and Palestinians in the territories and assess the demand/supply balance for each.

The approach is described using illustrative data for the year 2000. Particular attention is given in this exercise to identifying the assumptions underlying each stage of the analysis.

2. Derived from the preceding methodologies, a notional allocation regime and demand/supply balance for the year 2000 is presented in the final stage of the analysis. Though this exercise is not intended to provide definitive conclusions regarding the potential structure and demand/supply impact of a practical allocation regime, the results of the analysis are

suggestive. Within the parameters of the problem as defined here, this investigation demonstrates that, even with an equitable division of shared waters, the available supply of renewable fresh water resources still falls well short of that required to satisfy the socio-economic development needs of Israel and an independent Palestine. Though redressing the current imbalance in use of the shared aquifers, the implementation of an equitable water-sharing regime will not, in and of itself, resolve the perennial water shortage problem confronting either Israel or Palestine, thus requiring further coordination and cooperation between the two in such areas as seawater desalination, wastewater recycling, crop substitution, and market pricing in order to enhance supply and curtail demand.

3. The importance of this exercise, however, is the description of methodologies by which an equitable water-sharing regime can be devised. While, admittedly, not the "final word" on the matter, this exercise, at a minimum, identifies those areas -- demographic, hydrological, legal, etc. -- in which more detailed analysis is needed to move from a notional water-sharing regime such as the one described here to a functioning allocation regime.

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WATER-SHARING REGIMES IN ISRAEL AND THE OCCUPIED TERRITORIES -- A TECHNICAL ANALYSIS

I. INTRODUCTION

1. 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 within the next nine months 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 an equitable regime for allocating transboundary groundwater resources between the two communities.

2. What follows is a description of a multidisciplinary approach which could assist negotiators as they attempt to construct such an allocation regime. This approach includes five major steps:

- forecast aggregate domestic, industrial, and agricultural demand for water for Israel and Palestinians in the occupied territories;
- estimate the water potential of renewable fresh water resources, including those situated wholly within Israel or the territories, as well as shared transboundary groundwaters;

■ identify principles from international law for the equitable division of shared groundwater resources, and derive equity standards against which to measure alternative allocation regimes;

■ evaluate alternative regimes to determine which is "best" from an equity standpoint; and,

■ calculate the total water supply available to Israel and the Palestinians in the territories and assess the demand/supply balance for each.

Using illustrative data projected for the year 2000, each step in this approach will be described in detail, with particular attention to the assumptions underlying the analysis.

3. 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. It is hoped, however, that a detailed examination of the requirements for each step in this approach will shed some light upon the kinds of demographic, hydrological, economic, legal and other information that will be needed when this problem is addressed in earnest in later stages of the peace process. A second aim of this exercise is to introduce certain methodologies which may assist negotiators and their technical advisers in developing and evaluating alternative supply/demand scenarios and allocation regimes. 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.

4. Before proceeding, one assumption fundamental to the analysis must be identified: in this exercise, it is assumed that negotiations on the final status of the territories will lead to the creation of an independent Palestinian state along side Israel (the two-state solution).[1] This outcome is by no means assured, nor is it universally accepted as the ideal solution. The two-state scenario is assumed here so that the problem can be framed in terms of the two parties directly concerned with the sharing of these transboundary groundwaters -- Israel and

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[1] The framework of a two-state solution has been described in Mark Heller and Sari Nusseibeh, *No Trumpets, No Drums: A Two-State Settlement of the Israeli-Palestinian Conflict* (New York: Hill and Wang, 1991); as will become evident, some of the assumptions used in the following analysis are based on the two-state framework presented in the book.

the Palestinians in the West Bank (and, indirectly, the Gaza Strip)[2] -- being equal and sovereign in the eyes of international law. The selection of this scenario should not be seen as an attempt to prejudge the outcome of the negotiations, or to advocate a particular resolution to the conflict; that is beyond the scope of this paper. The two-state scenario is assumed here in the belief that the need for cooperation in, and coordination of, the use of these shared groundwaters -- and, hence, the need for an equitable allocation regime -- is greatest in those circumstances in which neither community is constrained (in either an international-legal or power-political sense) from exploiting (or over-exploiting) these resources in response to their particular socio-economic needs.

5. A detailed presentation of the approach follows. It begins with the assumptions and methodologies used to forecast aggregate domestic, industrial, and agricultural demand for water for Israel and Palestine in the year 2000.

II. THE DEMAND FOR WATER

POPULATION PROJECTIONS

6. Before the demand for water can be approximated, it is necessary to estimate the size of the Israeli and Palestinian populations for the forecast year (2000). The population estimates used in this analysis are summarized in Table One[3]:

Table One. Projected Population in Israel and Palestine (Year 2000)

Scenario	Israel	West Bank	Gaza Strip
1. No Final Settlement	7,040,400	1,329,700	921,100
2. Independent Palestinian State	7,040,400	1,736,600	1,124,900

[2] This is discussed in greater detail in Para.32.

[3] See the **APPENDIX**, Tables A-1 to A-3, for detailed calculation of these projections.

7. Two scenarios are considered (these will be used for comparative purposes in the latter stages of the analysis):

- *No Final Settlement* -- Israel and the Palestinians are unable to agree on the final status of the territories, and Israel retains ultimate control over the territories and their inhabitants.
- *Independent Palestinian State* -- Israel and the Palestinians conclude an interim agreement on Palestinian autonomy in the territories, to begin as of end-1993; a five-year transition period runs from end-1993 to end-1998 during which negotiations proceed on a final settlement); and, a two-state solution along the lines described in Heller and Nusseibeh (1991) is implemented as of start-1999.

The estimates in these scenarios are based upon the following assumptions, described below.

8. Population projections to the year 2000 are made for four communities within Mandatory Palestine: the Jewish population in Israel (including East Jerusalem and the occupied territories); the non-Jewish population in Israel-proper (Muslim, Christian, and other); the West Bank Palestinian population; and the Gaza Strip Palestinian population.

9. Projections are generated using a **modified geometric growth model** in which the population for a given community is assumed to increase or decrease at the same rate per unit time, and in which net migration is included as a separate term:

$$P_n = P_0 (1 + r)^n + M_1 (1 + r)^{n-1} + \ldots + M_{n-1} (1 + r) + M_n$$

where n = number of years;

P_n = final population;

P_0 = initial population;

r = rate of population change;

M_i = net migration in period i, $i = 1,\ldots,n$.

10. Certain assumptions, listed in Table Two, concerning growth rates and migration balances for the respective communities are used in the analysis:

Table Two. Population Projections -- Assumptions

Community	Growth Rate (Percent growth per annum)	Net Migration
Jews	1.396	1991 170,521 1992-2000 120,000 per year
Non-Jewish Israeli	2.960	zero
West Bank Palestinian	3.446	*No Final Settlement* zero *Independent Palestinian State* 1990-1998 zero 1999-2000 200,000 per year
Gaza Strip Palestinian	3.811	*No Final Settlement* zero *Independent Palestinian State* 1990-1998 zero 1999-2000 100,000 per year

11. The growth rate for each community represents the "best-fit" rates calculated from the last eight years of available population data. The "best-fit" rates were derived in the following manner. An initial value for r -- the rate of population growth -- was selected, and predicted population values for the years 1983 to 1990 for the Jewish and non-Jewish Israeli

communities, and 1982 to 1989 for the West Bank and Gaza Palestinian communities, were calculated:

$$\hat{P}_n = \hat{P}_{n-1}(1 + r) + M_n \quad \text{for } n = 1, \ldots, 8$$

where $\hat{P}_n$ = Predicted population value for the n th period;

$\hat{P}_{n-1}$ = Predicted population value for the preceding period;

r = Rate of population growth;

M_n = Net migration balance for the n th period.

The predicted values were then subtracted from actual population figures for the respective communities over the eight-year intervals, and the differences squared and summed. An iterative process was used to determine the growth rate which minimized the sum of the squared errors. This rate represented the "best fit" of the model to the actual population data, with the sum of the squared errors serving as a measure of the "goodness" of the fit.[4]

12. The "best-fit" rate is assumed to be the growth rate for the community as a whole. This presupposes that the rates for immigrant and veteran sub-communities within the Jewish, West Bank Palestinian, and Gaza Strip Palestinian communities are the same. In fact, the natural growth rates of the two sub-communities -- and the component fertility, birth, and death rates summarized in each -- may be different for a variety of cultural and socio-economic reasons. Should this data become available, differential growth rates for veteran and immigrant populations within a given community can be incorporated in the modified geometric growth model.

13. In terms of migration assumptions, it is assumed that net migration for the Jewish community in the two scenarios is 170,521 for 1991[5], and 120,000 per year for the years

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[4] For a detailed discussion of this and other demographic assumptions and calculations, see James W. Moore, "Aliya and the Demographic Balance in Israel and the Occupied Territories," *NPSIA Working Paper* [forthcoming] (Ottawa: Norman Paterson School of International Affairs, 1992).

[5] Foreign Broadcast and Information Service, *Daily Report -- Near East and South Asia* (hereafter *FBIS-NES*), 8 January 1992, p.33.

1992 to 2000 inclusive. The latter assumes that one million Soviet Jews will emigrate to Israel over the decade, though at a slower rate than originally anticipated when the latest *aliya* wave began (due largely to uncertainty among potential immigrants over employment, housing, etc. in Israel). The assumed extent of *aliya* is based upon information from the Israeli Ministry of Foreign Affairs indicating that approximately one million invitations to emigrate to Israel were sent to Jews living in the then Soviet Union in 1990 and 1991. While admitting that not all these people are likely to emigrate, the Israeli government believes the estimate of one million immigrants "reflects the **potential** [emphasis added] for *Aliyah*."[6] This estimate is used since it is reasonable to assume that, as negotiations over the division of shared water resources proceed, Israel will base its appraisal of future water demand on "high" forecasts of potential Jewish immigration.

14. A zero annual migration balance is assumed for the non-Jewish Israeli population in each scenario (this is consistent with assumptions used in Israel's Central Bureau of Statistics pre-*aliya* population projections).[7] In terms of the second scenario -- an Independent Palestinian State -- this implicitly assumes that there will not be a massive "return" of Palestinian refugees to their homes within the pre-1967 boundaries of Israel as originally stipulated under United Nations General Assembly Resolution 194 III. This seems a reasonable assumption since Israel is unlikely to accept implementation of the return components of the resolution since this would effectively lead to the "de-Judaization" of the country.[8] It is possible that some refugees may be readmitted in special circumstances; it is also possible, however, that some Palestinians currently resident in Israel may choose to emigrate to the new independent Palestinian state. Thus, for the purposes of this analysis, it is assumed that this cross-migration cancels itself out, and that the net migration balance for the non-Jewish Israeli population remains zero.

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[6] Israel, Consulate General of Israel, *Soviet Jewry News*, No.739 (New York: Consulate General of Israel, 1991), p.1.

[7] Israel, Central Bureau of Statistics, *Monthly Bulletin of Statistics - Supplement* 38 (April 1987): 17.

[8] Heller and Nusseibeh, *No Trumpets, No Drums*, p.95.

15. Concerning net migration for the West Bank and Gaza Strip Palestinian communities, the first scenario -- *No Final Settlement* -- assumes that Israel, retaining ultimate control over the territories, will not permit large-scale emigration from the Palestinian *diaspora* to the West Bank and Gaza Strip, resulting in a zero annual net migration balance (this is in keeping with Central Bureau of Statistics pre-*aliya* population projections[9]). In the second scenario -- *Independent Palestinian State* -- it is assumed that Israeli-imposed restrictions on Palestinian immigration remain in effect during the five-year transition period from end-1993 to end-1998, but that immigration becomes the prerogative of the Palestinian state upon independence. Under these circumstances, Nusseibeh assumes that 750,000 to 1,500,000 *diaspora* Palestinians will return to the fledgling Palestinian state over a three-to-five year period.[10] In this analysis, it is assumed that 300,000 Palestinians will return to the territories in each of five years, beginning in the first year of independence (1999); this is consistent with the higher estimate of returnees from Nusseibeh.[11] Two-thirds of these returnees (200,000) are assumed to settle in the West Bank, while the remainder (100,000) settle in the Gaza Strip. Given the severe crowding and extremely high natural growth rate in Gaza, it is reasonable to assume that Palestinian authorities will try to encourage the majority of returnees to settle in the relatively more spacious West Bank region of an independent Palestinian state. Nevertheless, some degree of emigration to the Gaza Strip, for family reunification, etc., is likely to occur.

DOMESTIC, INDUSTRIAL, AND AGRICULTURAL WATER CONSUMPTION

16. The forecast demand for water for Israel and Palestine in each scenario is presented in Tables Three and Four:

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[9] Israel, Central Bureau of Statistics, *Monthly Bulletin of Statistics --Supplement* 38 (April 1987): 17.

[10] Heller and Nusseibeh, *No Trumpets, No Drums*, p.166.

[11] The rationale for adopting the higher estimate for Palestinian immigration is similar to that discussed in the case of Soviet Jewish immigration (see Para.13 above).

Table Three. Water Demand for Israel and Palestine for the Year 2000 - *No Final Settlement*

Region	Population ('000)	Per Capita Domestic (cu.m/yr)	Total Domestic (MCM)	Total Industrial (MCM)	Total Agricultural (MCM)	Total Demand (MCM)
Israel	7,040.4	104.4	735.0	129.4	1,180.0	2,044.4
West Bank	1,329.7	50.0	66.5	3.0	80.0	149.5
Gaza Strip	921.1	50.0	46.1	3.0	60.0	109.0

Table Four. Water Demand for Israel and Palestine for the Year 2000 - *Independent Palestinian State*

Region	Population ('000)	Per Capita Domestic (cu.m/yr)	Total Domestic (MCM)	Total Industrial (MCM)	Total Agricultural (MCM)	Total Demand (MCM)
Israel	7,040.4	104.4	735.0	129.4	1,180.0	2,044.4
West Bank	1,736.6	80.0	138.9	33.0	305.0	476.0
Gaza Strip	1,124.9	80.0	90.0	33.0	-	123.0

Israel

17. The forecast demand for water in Israel is assumed to remain the same regardless of the scenario. Aggregate per capita domestic water consumption for the 1991 base year (100.6 cu.m/year) is assumed to be equal to the average annual per capita domestic consumption for the years 1980/81 to 1990 (a ten-year period).[12] This estimate is an aggregate figure for the country as a whole; in reality, per capita consumption varies with urban/rural locale, ethnic community, etc. Per capita domestic consumption is assumed to grow at a rate of .37% per year over the forecast period (the average annual growth rate in per capita consumption for

[12] Historic water consumption data is found in the **APPENDIX**, Tables A-4 and A-5; Table A-6 presents the detailed calculations for projected Israeli domestic and industrial water consumption to the year 2000.

the years 1980/81 to 1990). Thus, per capita domestic consumption in Israel for the forecast year (2000) is estimated to be 104.4 cu.m/yr. Total domestic consumption for the year 2000 is simply the product of projected total population in Israel multiplied by per capita domestic consumption.

18. Projected total industrial consumption in Israel for the 1991 base year (107.5 MCM) is assumed to be equal to the average annual total industrial consumption for the years 1980/81 to 1990, and to grow at a rate of 1.87% per year over the forecast period (the average annual growth rate for the years 1980/81 to 1990). Thus, total industrial demand for the year 2000 is 129.4 MCM.[13]

19. Projected total agricultural consumption for the year 2000 (1,180 MCM) is taken from *The Master Plan for Water Management and Agricultural Planning*, submitted to Israel's Water Commissioner by the Israel Water Authority Company in November 1988.[14] This estimate assumes that Israel invests an average of $90 million per year in water management from 1988 to the year 2000; if only $30 million per year are invested, the volume of water available for agriculture in the year 2000 will fall to 980 MCM.

Palestine

20. In the first scenario -- *No Final Settlement* -- it is assumed that, in the absence of an agreement on the final status of the territories, Israel retains control of water resources in the West Bank and Gaza Strip; consequently, Palestinian water consumption is restricted to levels set under current Israeli water management plans. Under these circumstances, Palestinian per capita domestic consumption for the year 2000 is projected to be 50 cu.m/year, and total domestic consumption 66.5 MCM in the West Bank and 46.1 MCM in the Gaza Strip. Total

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[13] In this analysis, the demand for water in Israel's industrial and agricultural sectors is assumed to grow at a pace consistent with historic trends. However, these estimates will not reflect the increase in demand for industrial and agricultural products -- and, hence, the demand for water in these two sectors -- as Israel's population swells under this latest *aliya* wave. To capture this indirect effect upon industrial and agricultural demand for water, a more detailed economic analysis than is possible here would be required.

[14] Israel, State Comptroller, *Report on Water Management in Israel* (Jerusalem: Israel State Comptroller, 1990), Ch.7 "The Master Plan for Water Management and Agricultural Planning."

industrial consumption is estimated to be 3 MCM in each region, and total agricultural consumption 80 MCM and 60 MCM in the West Bank and Gaza Strip, respectively.[15]

21. In the second scenario -- *Independent Palestinian State* -- it is assumed that Palestinian authorities will set the levels of water consumption consistent with the state's socio-economic development plans. Under this scenario, projected Palestinian per capita domestic consumption for the year 2000 is 80 cu.m/year with total domestic consumption of 138.9 MCM in the West Bank and 90 MCM in the Gaza Strip; total industrial consumption of 33 MCM in each region; and, total agricultural consumption of 305 MCM in the West Bank.[16]

III. THE SUPPLY OF WATER

RENEWABLE GROUNDWATER AND SURFACE WATER RESOURCES

22. Aggregate estimates of renewable groundwater and surface water resources in Israel and the occupied territories are presented in Table Five[17]:

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[15] Tahal Consulting Engineers, Ltd., "Israel Water Sector Review: Past Achievements, Current Problems and Future Options," by J. Schwartz, pp.10-8 to 10-9. Paper presented to *The World Bank International Workshop on Comprehensive Water Resources Management Policies*, Washington, D.C., 24-28 June 1991. No estimate is given for total industrial consumption in the West Bank for the year 2000; therefore, it is assumed to be comparable to that in the Gaza Strip (3 MCM).

[16] George T. Abed, "The Economic Viability of a Palestinian State," *Journal of Palestine Studies* 19 (Winter 1990): 26. Abed does not provide an estimate for total industrial consumption in the Gaza Strip; therefore, it is assumed that industrial consumption is comparable to that in the West Bank (33 MCM). No estimate for agricultural consumption in the Gaza Strip is given; according to Abed, continued high population growth and overcrowding will strain already overused groundwater resources to such an extent that agriculture will have to be seriously curtailed or eliminated altogether [p.9].

[17] For detailed estimates of fresh water resources in Israel and the territories, see **APPENDIX**, Table A-7.

Table Five. Fresh Water Resources in Israel and the Occupied Territories

Source	Israel (MCM)	Transboundary (MCM)	West Bank and Gaza Strip (MCM)
Groundwater	573	545	165
Surface Water	650		
Other	235		
Total	1,458	545	165

23. There is no one universally-accepted set of hydrological data for Israel and the territories. The estimates used here are not definitive; however, they are broadly consistent with most estimates as reported in the open literature and, so, sufficient for demonstration purposes in this analysis. Nevertheless, collection of an accurate hydrological data base for Israel and the territories, and the region as a whole, is one of first critical tasks for the multilateral negotiations on Middle East water.

24. These estimates represent the *water potential of the catchment area*, defined as the...

> ...maximum quantity of water which on a perennial average can be extracted from it [the catchment area] and supplied every year without damaging it. In the long term, potential equals the quantity of water added to the catchment area on a perennial average via natural refilling by rainfall, minus the inevitable losses [e.g. groundwater flow from the coastal catchment area to the Mediterranean sea, or water from the mountain catchment area overflowing at the Tarqon springs].[18]

The potential of a catchment area can be used as an "index of the quantity that can be extracted from it, *provided that an operating stock exists in the catchment area* [emphasis added]."[19] The operating stock is defined as "the volume of water existing above the level

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[18] Israel, State Comptroller, *Report on Water Management in Israel*, Ch.4 "Israel's Water Resources."

[19] Ibid.

of the red line [or minimum groundwater table] in a catchment area at any given time."[20] This reserve is drawn upon during hot and dry years when natural replenishment of the catchment area by rain falls below the perennial average. In subsequent years, some portion of a catchment area's water potential must be dedicated to restoring the operational stock. Therefore, in any given year, the volume of water available for immediate consumption from a catchment area may be less than its water potential.[21]

25. In this analysis, surface water resources of the Jordan Basin are assigned to Israel in accordance with existing utilization. However, an acceptable water-sharing regime allocating the waters of the basin among its five riparians -- Israel, Lebanon, Syria, Jordan, and Palestine -- has yet to be devised. It is beyond the scope of this paper to examine the reallocation of Jordan basin waters; this will be done in a subsequent study. Thus, the water potential of the Jordan basin is allocated according to existing utilization patterns, i.e., 650 MCM/year to Israel and no usable water to Palestine (the waters of the Jordan River below Lake Kinneret are too saline for use). In a comprehensive regional water-sharing regime, some volume of the basin's water potential would undoubtedly be allocated to the downstream riparian Palestine. This volume of water could be made available by increasing the outflow of water from Lake Kinneret to the lower Jordan River, or, more probably, given salinity problems in the lower Jordan, through artificial recharge of the mountain catchment area from the waters of Lake Kinneret, or through off-setting arrangements in which a volume of water equivalent to that assigned to Palestine from the Jordan Basin is extracted from transboundary groundwater aquifers.

26. Though not explicitly addressed in this analysis, any division of waters must also take into account considerations of water quality as well as the quantitative water potential of

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[20] Ibid., Appendix 1. "Definition of Hydrological Terms."

[21] The Israeli State Comptroller's report stated that, as a result of overpumping and prolonged drought, there was no operating stock in the three major catchment areas of the National Water System -- Lake Kinneret, the mountain catchment area, and the coastal catchment area [Israel, State Comptroller, *Report on Water Management in Israel*, Ch.1 "Coordination of Findings"]. It is unclear whether heavy precipitation during winter 1991/1992 was sufficient to restore the operating stock in these catchment areas to optimal levels.

catchment areas. The proportion of high-salinity water (i.e. greater than 400 mg/l chlorides) in the overall water balance is increasing. Full exploitation of aquifers, and pollution from fertilizers and other human activities, is increasing the mineral and contaminant content in groundwater resources; moreover, recycled wastewater accounts for an increasing proportion of the water budget. Thus, in relative and absolute terms, the volume of fresh water available for domestic use and irrigation of salt-sensitive crops, e.g. avocados, Jaffa oranges, flowers, strawberries, is decreasing. A practical water allocation regime must, therefore, apportion shared groundwaters on the basis of quality as well as quantity.

EQUITABLE ALLOCATION OF TRANSBOUNDARY WATERS UNDER INTERNATIONAL LAW

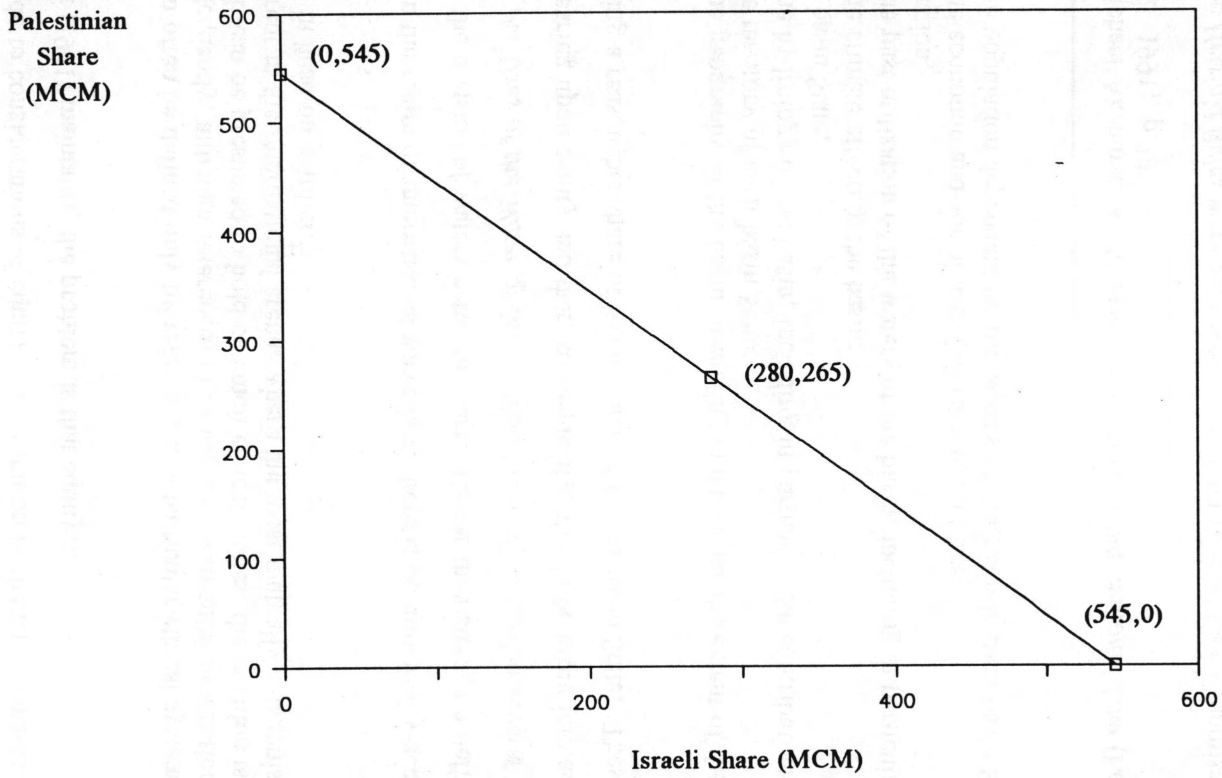
27. Those surface and groundwater resources wholly located within the boundaries of Israel and Palestine are allocated for each state's exclusive use. However, the shared groundwaters straddling the Israeli-Palestinian border -- i.e., the Yarqon-Tanninim Aquifer, the Northern Aquifer, and the Nablus-Jenin Aquifer with a combined water potential of 545 MCM/year -- must be equitably apportioned between the two states.

28. What is a fair division of waters? There are a host of possible allocation regimes from which to choose. Assuming only integral values are used, the set of all possible allocation regimes is defined as

$$R = \{R_1(0,545),\ R_2(1,544),\ R_3(2,543),\ldots R_{545}(544,1),\ R_{546}(545,0)\}$$

where the the Israeli share is listed first and the Palestinian share second in parentheses, and the sum of the two shares equals 545 (the combined water potential of the three aquifers); these are depicted in Figure One. All possible allocation regimes in which the full water potential of the shared aquifers is apportioned between Israel and Palestine are represented along the diagonal line in the Figure. For example, $R_{281}(280,265)$ denotes the regime in which Israel and Palestine are allotted 280 MCM and 265 MCM, respectively, from the transboundary aquifers.

Figure One. Allocation Regimes



29. However, which of these myriad combinations constitutes an *equitable* allocation regime? 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 (1991) 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.[22]

30. In the realm of international water law, there is no universally-accepted definition of equity in the division of waters between users. Rather than attempt a definition, the *Helsinki Rules on the Uses of the Water of International Rivers*[23] identified several factors thought to have a bearing upon equity and that, consequently, should be taken into account when determining a reasonable share of basin waters for each basin State. These factors include:

> (a) the geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;
> (b) the hydrology of the basin, including in particular the contribution of water by each basin State;
> (c) the climate affecting the basin;
> (d) the past utilization of the waters of the basin, including in particular existing utilization;
> (e) the economic and social needs of each basin State;
> (f) the population dependent on the waters of the basin in each basin State;

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[22] Michael Akehurst, *A Modern Introduction to International Law* (London: HarperCollins Academic, 1991), p.39.

[23] The *Helsinki Rules* were approved by the International Law Commission in full conference at Helsinki, Finland, in August 1966. These nonbinding rules...

> ...were designed to serve where the States concerned ("basin States") had *not* [author's emphasis] achieved agreement or a binding customary regime...They also provide a point of departure, or guidelines, for those who are charged with negotiating agreements and may be relied upon as "residual rules" to govern matters not dealt with by particular agreements or local custom [Robert D. Hayton, "The Law of International Aquifers," *Natural Resources Journal* 22 (January 1982): 73].

(g) the comparative costs of alternative means of satisfying the economic and social needs of each basin State;
(h) the availability of other resources;
(i) the avoidance of unnecessary waste in the utilization of waters of the basin;
(j) the practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses; and,
(k) the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.[24]

Under the *Helsinki Rules*, there is no one factor upon which an allocation regime should be based; indeed, the Helsinki approach specifies that weighted consideration must be given to all relevant 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.[25]

The difficulty lies in translating these legal provisions into a practical allocation regime; the process by which this can be done is described below.

31. The factors identified in the Helsinki approach must first be operationalized. Alternative allocation regimes, each based upon a specific operational definition of these factors taken *in isolation*, are derived -- these represent the *equity standards* used in the subsequent analysis. Four alternative equity standards are presented in Table Six:

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[24] Robert D. Hayton and Albert E. Utton, "Transboundary Groundwaters: the Bellagio Draft Treaty," *Natural Resources Journal* 29 (Summer 1989): 700-701.

[25] Ibid., p.701.

Table Six. Alternative Equity Standards

State	Alternative A [Existing Utilization] (MCM)	Alternative B [Recharge Area] (MCM)	Alternative C [Natural Flow] (MCM)	Alternative D [Population] (MCM)
Israeli Share	450	27	341	387
Palestinian Share	95	518	204	158

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 (b)]; and, projected population for the year 2000 [factor (f)]. 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.

32. The four factors from which the equity standards are derived were operationalized as follows:

■ *Existing Utilization (EU)*

The water potential of the transboundary aquifers is allocated between Israel and Palestine according to current (circa 1991) utilization rates. The following utilization rates are assumed (Israel/Palestine): Yarqon-Tanninim Aquifer (.94/.06); Northern Aquifer (.85/.15); Nablus-Jenin Aquifer (.21/.79).[26]

[26] Utilization rates for the Yarqon-Tanninim and Northern aquifers are taken from Tahal Consulting Engineers, Ltd., *Israel Water Sector Review: Past Achievements, Current Problems and Future Options*, p.3-5. Based on these utilization rates, Israel draws 435 MCM/year from these two aquifers. Kolars (1992) indicates that Israel extracts a combined amount of 450 MCM/year from the three transboundary aquifers [Kolars, "Water Resources of the Middle East," p.113]. This suggests that 15 MCM/year comes from the Nablus-Jenin Aquifer (21 per cent of its 70 MCM/year water potential). Consequently, the utilization rate for this aquifer is assumed to be (.21/.79) for Israel and Palestine, respectively.

■ *Recharge Area (RA)*

The water potential of the aquifers is apportioned according to the extent of the recharge area lying within Israel and Palestine respectively. Naff (1991) 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.[27]

■ *Natural Flow (NF)*

According to Kolars (1992), 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."[28]

■ *Population (Pop)*

An Israeli population of 7,040,400 and a population of 2,861,400 for an independent Palestinian state are assumed[29], representing 71% and 29% of the total population in Mandatory Palestine, respectively. The population estimate for Palestine includes both the West Bank and Gaza Strip. According to the Helsinki approach, shared water resources should be allocated on the basis of "the population *dependent* [emphasis added] on the waters of the basin [or catchment area in the case of groundwater] in each basin State."[30] Currently, residents of the Gaza Strip 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 Palestine to Gaza may have to be considered as an alternative to satisfy projected demand in that area. This could be done directly via connecting

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[27] Thomas Naff, "The Jordan Basin: Political, Economic, and Institutional Issues," p.3. Paper presented to the *World Bank International Workshop on Comprehensive Water Resources Management Policies*, Washington, D.C. 24-28 June 1991.

[28] Kolars, "Water Resources of the Middle East," p.114.

[29] See Table One.

[30] Hayton and Utton, "Transboundary Groundwaters: The Bellagio Draft Treaty," p.701.

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 an extension of the National Water Carrier and withdraws an equivalent amount from the Palestinian share of the transboundary groundwaters).

33. Measured against *all* four equity standards[31], there is no manifestly "best" division of waters; the standards do not converge on one particular allocation regime. The task, then, is to identify that regime which does the "least violence" to the four equity factors taken together. In other words, is it possible to distinguish an optimal allocation regime which, while not necessarily the best when measured against each equity factor in isolation, is the *least worst* of all regimes when all factors are taken into account?

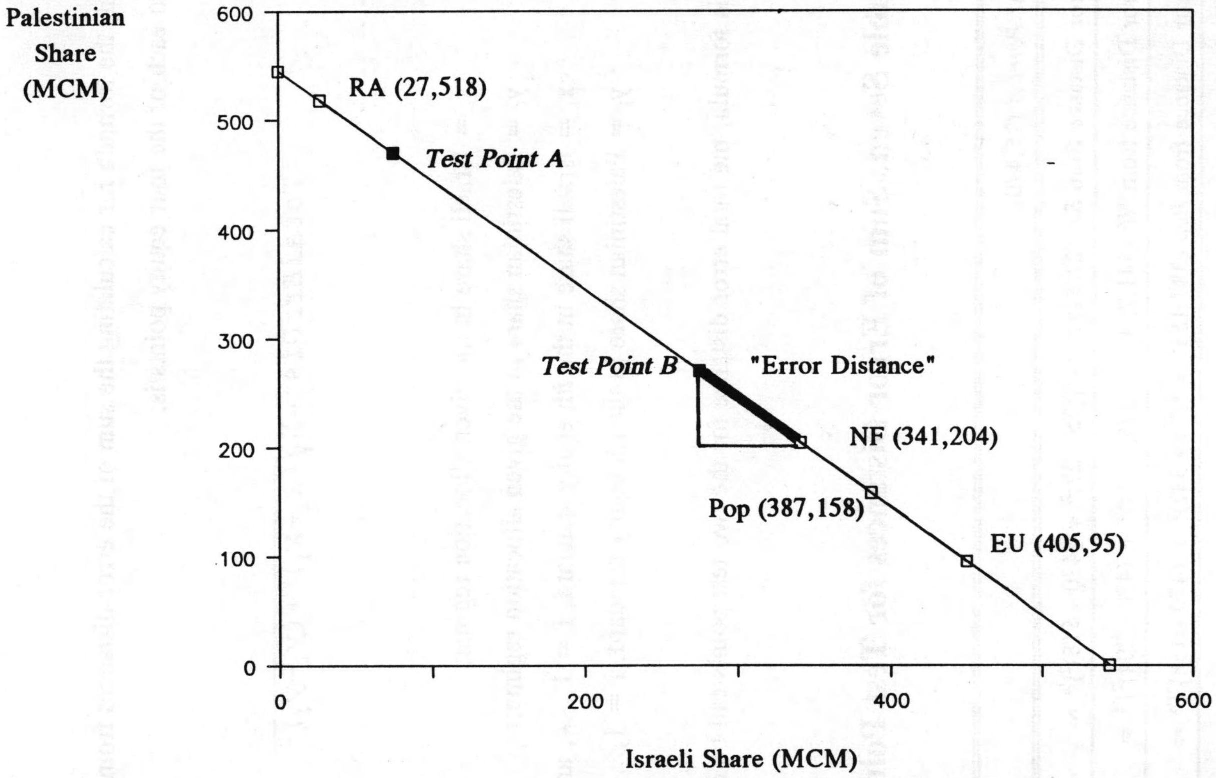
34. To explore this possibility further, assume two hypothetical allocation regimes: *Test Point A* (75,470) and *Test Point B* (275,270) positioned relative to the four equity points in Figure Two. Upon reflection, it seems unlikely that an allocation regime located at either extreme of the diagonal, such as *Test Point A,* would represent an optimal regime. Though the shares of water allocated to Israel and Palestine in this regime compare favourably with those of the equity point in its immediate vicinity -- *RA* (27,518) -- they fare poorly when compared with those of the other three points further down the line. Intuitively, then, the optimal regime 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 regime:

The optimal allocation regime 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* (275, 270). In the Figure, the "Error Distance" between *Test Point B* and the *Natural Flow* (341,204) equity point is highlighted. This distance is calculated as:

[31] It is assumed that all four equity factors are given equal weight.

Figure Two. Error Distance



Key.

RA - Recharge Area

NF - Natural Flow

Pop - Population

EU - Existing Utilization

$$ErrDist = \sqrt{(275-341)^2+(270-204)^2} = 93.34$$

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:

$$TotalErrDist = \Sigma\sqrt{(x_t-x_i)^2+(y_t-y_i)^2}$$

where,

x_t = Israeli share in the given allocation regime;

y_t = Palestinian share in the given allocation regime;

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 Seven):

Table Seven. Sum of Error Distances for Test Points A and B

Test Point A (75,470)	
Error Distance from *RA* (27,518) = $[(75 - 27)^2 + (470 - 518)^2]^{1/2}$ =	67.88
Error Distance from *NF* (341,204) = $[(75 - 341)^2 + (470 - 204)^2]^{1/2}$ =	376.18
Error Distance from *Pop* (387,158) = $[(75 - 387)^2 + (470 - 158)^2]^{1/2}$ =	441.23
Error Distance from *EU* (450,95) = $[(75 - 450)^2 + (470 - 95)^2]^{1/2}$ =	530.33
Sum	1,415.62

Table Seven (cont.). Sum of Error Distances for Test Points A and B

Test Point B (275,270)		
Error Distance from *RA* (27,518)	$= [(275 - 27)^2 + (270 - 518)^2]^{1/2} =$	350.72
Error Distance from *NF* (341,204)	$= [(275 - 341)^2 + (270 - 204)^2]^{1/2} =$	93.34
Error Distance from *Pop* (387,158)	$= [(275 - 387)^2 + (270 - 158)^2]^{1/2} =$	158.39
Error Distance from *EU* (450,95)	$= [(275 - 450)^2 + (270 - 95)^2]^{1/2} =$	247.49
	Sum	849.94

As expected, *Test Point B* (275,270) emerges as the preferred allocation regime -- the sum of the error distances to each equity point are less for it than for *Test Point A*.

35. Returning to the general problem, a search program was written to determine which regime from the set of possible allocation regimes, ***R***, satisfies the stated criterion.[32] The search revealed that, rather than one optimal solution, there is, in fact, a range of equally good allocation regimes extending from $R_{343}(342, 203)$ to $R_{387}(386, 159)$ in which the summation of the error distances to the four equity points is minimized; in Figure Two, this range is located along the line between the two equity points *NF*(341,204) and *Pop*(387,158). In other words, from an equity standpoint, the forty-five allocation regimes within this range are equally preferred, given the optimality criterion as defined above. This represents the *bargaining space* within which a negotiated allocation regime should be located (assuming the parameters of the problem as defined in this analysis).

A NOTIONAL ALLOCATION REGIME AND THE SUPPLY OF WATER IN ISRAEL AND PALESTINE

36. For illustrative purposes, assume that Israeli and Palestinian negotiators agree to allocation regime $R_{365}(364,181)$ (the midpoint along the range of equally preferred regimes);

[32] The computer search program is found in the **APPENDIX**, Table A-8.

that is, Israel relinquishes 86 MCM/year currently consumed from transboundary groundwaters, and an equivalent amount is allotted to the independent Palestinian state. Including those freshwater resources wholly located within the boundaries of Israel and Palestine respectively, the total water potential available to each in the year 2000 under the *Independent Palestinian State* scenario is 1,822 MCM/year and 341 MCM/year for Israel and Palestine, respectively; a breakdown by source is summarized in Table Eight and compared with the notional water potential for the year 2000 under the *No Final Settlement* scenario[33]:

Table Eight. Water Supply in Israel and Palestine -- *No Final Settlement* and *Independent Palestinian State* Scenarios[34] (MCM)

	Israel		West Bank		Gaza Strip	
Source	N.F.S.	I.P.S.	N.F.S.	I.P.S.	N.F.S.	I.P.S.
Groundwater (Exclusive Resources)	573	573	100	100	65	65
Groundwater (Transboundary Resources)	450	364	95	181		
Surface Water	650	650				
Floodwater/Recycled Water	235	235				
Total	1,908	1,822	195	281	65	65

Key.
N.F.S. -- No Final Settlement
I.P.S. -- Independent Palestinian State

[33] For simplicity, the latter scenario assumes that utilization patterns circa 1991 are maintained to the year 2000.

[34] For a detailed breakdown by source, see **APPENDIX**, Tables A-9 to A-10.

IV. THE DEMAND/SUPPLY BALANCE

37. Drawing upon the calculations from Sections II and III above, the demand and supply balance under the *No Final Settlement* and *Independent Palestinian State* scenarios can be approximated (Table Nine):

Table Nine. Demand/Supply Balance -- *No Final Settlement* and *Independent Palestinian State* Scenarios

Region	No Final Settlement		Independent Palestinian State	
	Total Demand (MCM)	Total Supply (MCM)	Total Demand (MCM)	Total Supply (MCM)
Israel	2,044.4	1,908.0	2,044.4	1,822.0
West Bank	149.5	195.0	476.0	281.0
Gaza Strip	109.0	65.0	123.0	65.0

38. In the *No Final Settlement* scenario, Israel experiences a 136.4 MCM/year shortfall in the year 2000. Current Israeli water management legislation assigns priority of consumption to household needs and utilities, industry, and, finally, agriculture; the supply of water available for agriculture in a given year, then, is simply the total planned extraction less the quantities designated for domestic and industrial consumption.[35] In this instance, projected domestic and industrial demand is 864.4 MCM/year. Therefore, 1,043.6 MCM/year are available for the agricultural sector, representing 88% of total agricultural consumption projected for the year 2000 in *The Master Plan for Water Management and Agricultural Planning* (1988).

39. Concerning the territories, the West Bank enjoys a 45.5 MCM/year water surplus under the *No Final Settlement* scenario. However, this is an artificial surplus; Palestinian

[35] Israel, State Comptroller, *Report on Water Management in Israel*, Ch.5 "Water Allocation and Consumption for Various Purposes."

demand for water in these circumstances does not reflect the socio-economic development needs of the populace, but rather reflects restrictions on water use imposed by the Israeli administration, e.g. the 80 MCM/year ceiling on water for agriculture in the West Bank.

40. Despite the existence of a restrictive water management regime imposed from without, the Gaza Strip experiences a serious water deficit of 44 MCM/year. This reflects both the continued role of agriculture as the principal consumer of water in the economy, as well as the growth of domestic demand as a result of continued high population growth. Renewable freshwater supplies in the area cannot satisfy the increase in demand, resulting in a deficit temporarily (and precariously) satisfied through the continuing over-exploitation of the Gaza coastal aquifer.

41. In the *Independent Palestinian State* scenario, Israel's water deficit rises to 222.4 MCM/year. Although the demand for water remains unchanged, total supply is reduced as some of the transboundary groundwater currently extracted by Israel is reallocated to an independent Palestine under the allocation regime described above. Once again, given the priority assigned to domestic and industrial consumption, the reduction in supply is absorbed by the agricultural sector -- only 957.6 MCM/year are available for this sector (81% of total agricultural consumption projected for the year 2000 in *The Master Plan*).

42. The West Bank region of Palestine suffers a water deficit of 195 MCM/year. Although total supply has increased through the reallocation of groundwaters shared with Israel, the return of hundreds of thousands of refugees from the *Diaspora* and the extensive socio-economic development programs envisioned for the fledgling state result in a situation where demand outstrips the adjusted supply.

43. Similarly in the Gaza Strip region of Palestine, the water balance deteriorates to a 58 MCM/year deficit. Assuming the complete elimination of agriculture from the economy of the region, the increased demand for water arising from natural population growth and immigration, as well as from the industrialization programs needed to provide alternative economic growth and employment in the absence of a local agricultural sector, places even greater strain upon over-extended local water supplies.

44. As a general observation, it is readily apparent that neither Israel nor the West Bank and Gaza Strip (whether Israeli-administered or independent) can, in either scenario, easily satisfy their socio-economic development needs given the limited availability of local renewable fresh water supplies.[36] The creation of an equitable allocation regime for the shared water resources of Israel and Palestine, though essential for redressing the imbalance in current utilization patterns of these transboundary aquifers, does not in and of itself "solve" the water problem for either community.

V. CONCLUSION

45. The preceding represents an approximation of an equitable water-sharing regime for the transboundary groundwaters of Israel and Palestine. The intent here was not to provide a definitive "solution" to the water-sharing problem. Rather, the aim of the exercise was to highlight some of the critical elements that must be taken into consideration as a practical water-sharing regime develops over the course of negotiations. These elements include the following:

Demand

46. Detailed demographic projections for the Israeli Jewish, Israeli non-Jewish, and Palestinian communities are needed to forecast domestic water demand and, indirectly, industrial and agricultural demand (through the demand for industrial and agricultural goods and services). Of particular importance for this exercise is the net migration component. In a post-occupation scenario, the short-term driving force behind both Israeli and Palestinian population growth will be the in-gathering of people from the Jewish and Palestinian *diasporas*. The extent and tempo of the return to Israel and an independent Palestine will critically influence the relative and absolute population balance in Mandatory Palestine and, hence, the anticipated demand for water.

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[36] It is beyond the scope of this paper to assess in detail the impact of such demand/supply imbalances on Israeli and Palestinian societies and the socio-economic restructuring they are likely to entail; this will be examined in a subsequent study.

Supply

47. The absence of publicly-available detailed and reliable hydrogeological data for Israel, the West Bank, and Gaza Strip is the most serious and immediate obstacle to progress on developing an equitable water-sharing regime. The estimates used in this analysis, drawn largely from secondary sources, are in no sense definitive, and, as with other attempts to evaluate the water potential of the area, will no doubt invite criticism. Before discussion of a practical water-sharing regime can proceed, technical experts must compile a detailed hydrological data base, recording such vital statistics as the extent of catchment areas, natural recharge rates, etc. Nor is it sufficient to focus solely on the quantitative dimension of water supply. Serious problems affecting water quality -- salination, infiltration of contaminants, etc. -- will limit the availability of higher-quality water to satisfy the socio-economic needs of Israel and the Palestinians in the coming years. Reliable data on the qualitative dimension of the water supply is likewise essential.

48. The definition of an equitable allocation regime for the shared transboundary aquifers must also be linked to the broader question of regional water-sharing regimes, in particular, to water-sharing arrangements relating to the Jordan River basin. In the preceding analysis, the potential impact of such regional arrangements was ignored in order to focus more fully on the immediate issue of the transboundary aquifers. However, as stated in the *Helsinki Rules*, the equitable division of shared water resources depends, in part, upon the availability of alternative supplies. In this respect, an equitable settlement of conflicting claims to the waters of the Jordan River among the basin states -- Lebanon, Syria, Israel, Jordan, and Palestine -- will have a critical impact upon the availability of alternative sources and, hence, upon the importance of the transboundary groundwaters in the overall water budget of both Israel and Palestine.

49. Further regarding alternative supplies, consideration must also be given to other options such as desalination, floodwater capture, wastewater recycling, etc. In this analysis, it was assumed, for simplicity, that the volume of floodwater and recycled wastewater available in Israel in the forecast year (2000) was equivalent to that available for the year 1991. In reality, the progress of recycling and desalination technologies and a shift to market-pricing for water will render greater volumes of low-quality water available for certain

domestic, industrial, and agricultural purposes. Once again, since the availability of other supplies affects the relative importance of transboundary groundwater in the total water budget of Israel and Palestine, forecasts of water potential from these alternative sources, based upon assessments of technological feasibility and economic viability, are integral to the development of an equitable water-sharing regime.

Equity Standards

50. In terms of the equity principles upon which the division of waters is based, four factors were operationally defined in this exercise; clearly, this set of factors was not exhaustive. It remains, therefore, to define and operationalize such other factors as are deemed relevant to this particular water-sharing problem.

51. A word of caution on the question of weighting, however. The *Helsinki Rules* specified that each equity factor should be weighted in accordance with its importance relative to all other factors. 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, 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.

A Dynamic Process

52. Finally, the development of an equitable water-sharing regime must be seen as a dynamic process. Although the regime was defined in this exercise in terms of one forecast year, it should not be assumed that, once defined, the volume of water allotted to each state remains fixed. The regime must be dynamic in order to adapt to changing conditions. For example, the water potential of the aquifers may change over time, both in terms of the quantity that may be safely extracted and its quality. Moreover, actual extractions will fluctuate each year 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, over time, 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 regime to fluid hydrological, demographic and other conditions.

53. The development of an equitable distribution regime for the transboundary groundwaters of Israel and Palestine is a complex undertaking. It will call upon the particular talents of demographers, economists, hydrologists, international lawyers, and others to ensure that a fair and reasonable allocation regime is constructed.

APPENDIX

Pages

Table A-1. Projected Population in Israel (1991-2000)

	Jewish Population in Israel				Non-Jewish Population in Israel				Total Israeli Population at end of period ('000)
Year	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	
Actual									
1983	3,349.6	1.01487	13.1	3,412.5	684.1	1.03040	1.2	706.1	4,118.6
1984	3,412.5	1.01453	9.6	3,471.7	706.1	1.02988	0.7	727.9	4,199.6
1985	3,471.7	1.01446	(4.7)	3,517.2	727.9	1.02899	0.0	749.0	4,266.2
1986	3,517.2	1.01390	(4.7)	3,561.4	749.0	1.02804	(0.1)	769.9	4,331.3
1987	3,561.4	1.01323	4.4	3,612.9	769.9	1.02909	1.3	793.6	4,406.5
1988	3,612.9	1.01306	(1.1)	3,659.0	793.6	1.02999	0.4	817.8	4,476.8
1989	3,659.0	1.01285	11.1	3,717.1	817.8	1.03069	(0.4)	842.5	4,559.6
1990	3,717.1	1.01294	181.4	3,946.6	842.5	1.03145	6.1	875.1	4,821.7
Projected									
1991	3,946.6	1.01396	170.5	4,172.2	875.1	1.0296	0.0	901.0	5,073.2
1992	4,172.2	1.01396	120.0	4,350.4	901.0	1.0296	0.0	927.7	5,278.1
1993	4,350.4	1.01396	120.0	4,531.2	927.7	1.0296	0.0	955.1	5,486.3
1994	4,531.2	1.01396	120.0	4,714.4	955.1	1.0296	0.0	983.4	5,697.8
1995	4,714.4	1.01396	120.0	4,900.2	983.4	1.0296	0.0	1,012.5	5,912.8
1996	4,900.2	1.01396	120.0	5,088.6	1,012.5	1.0296	0.0	1,042.5	6,131.1
1997	5,088.6	1.01396	120.0	5,279.7	1,042.5	1.0296	0.0	1,073.3	6,353.0
1998	5,279.7	1.01396	120.0	5,473.4	1,073.3	1.0296	0.0	1,105.1	6,578.5
1999	5,473.4	1.01396	120.0	5,669.8	1,105.1	1.0296	0.0	1,137.8	6,807.6
2000	5,669.8	1.01396	120.0	5,868.9	1,137.8	1.0296	0.0	1,171.5	7,040.4

Source:
1983-1990 population data -- Israel, Central Bureau of Statistics, Statistical Abstract of Israel 1991, p.44.

Table A-2. Projected Population in the Occupied Territories (1990-2000) -- No Final Settlement

	West Bank Palestinian Population				Gaza Strip Palestinian Population				Total Palestinian Population
Year	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	Population in the Occupied Territories at end of period ('000)
Actual									
1982	732.7	1.03344	(7.9)	749.3	469.6	1.02300	(3.1)	477.3	1,226.6
1983	749.3	1.03363	(2.7)	771.8	477.3	1.03813	(1.0)	494.5	1,266.3
1984	771.8	1.03550	(5.8)	793.4	494.5	1.04085	(4.8)	509.9	1,303.3
1985	793.4	1.03416	(5.0)	815.5	509.9	1.03922	(2.9)	527.0	1,342.5
1986	815.5	1.03348	(5.1)	837.7	527.0	1.04099	(3.6)	545.0	1,382.7
1987	837.7	1.03545	0.7	868.1	545.0	1.04385	(3.3)	565.6	1,433.7
1988	868.1	1.03548	(3.5)	895.4	565.6	1.04526	(2.7)	588.5	1,483.9
1989	895.4	1.03764	(13.1)	916.0	588.5	1.04877	(6.8)	610.4	1,526.4
Projected									
1990	916.0	1.03446	0.0	947.6	610.4	1.03811	0.0	633.7	1,581.2
1991	947.6	1.03446	0.0	980.2	633.7	1.03811	0.0	657.8	1,638.0
1992	980.2	1.03446	0.0	1,014.0	657.8	1.03811	0.0	682.9	1,696.9
1993	1,014.0	1.03446	0.0	1,048.9	682.9	1.03811	0.0	708.9	1,757.8
1994	1,048.9	1.03446	0.0	1,085.1	708.9	1.03811	0.0	735.9	1,821.0
1995	1,085.1	1.03446	0.0	1,122.5	735.9	1.03811	0.0	764.0	1,886.4
1996	1,122.5	1.03446	0.0	1,161.2	764.0	1.03811	0.0	793.1	1,954.2
1997	1,161.2	1.03446	0.0	1,201.2	793.1	1.03811	0.0	823.3	2,024.5
1998	1,201.2	1.03446	0.0	1,242.6	823.3	1.03811	0.0	854.7	2,097.2
1999	1,242.6	1.03446	0.0	1,285.4	854.7	1.03811	0.0	887.3	2,172.6
2000	1,285.4	1.03446	0.0	1,329.7	887.3	1.03811	0.0	921.1	2,250.7

Source:
1982-1989 population data -- Israel, Central Bureau of Statistics, Statistical Abstract of Israel 1991, p.710.

Table A-3. Projected Population in the Occupied Territories (1990-2000) --
Independent Palestinian State

	West Bank Palestinian Population				Gaza Strip Palestinian Population				Total Palestinian Population in the Occupied Territories at end of period ('000)
Year	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	Population at beginning of period ('000)	Growth Rate	Migration Balance ('000)	Population at end of period ('000)	
Actual									
1982	732.7	1.03344	(7.9)	749.3	469.6	1.02300	(3.1)	477.3	1,226.6
1983	749.3	1.03363	(2.7)	771.8	477.3	1.03813	(1.0)	494.5	1,266.3
1984	771.8	1.03550	(5.8)	793.4	494.5	1.04085	(4.8)	509.9	1,303.3
1985	793.4	1.03416	(5.0)	815.5	509.9	1.03922	(2.9)	527.0	1,342.5
1986	815.5	1.03348	(5.1)	837.7	527.0	1.04099	(3.6)	545.0	1,382.7
1987	837.7	1.03545	0.7	868.1	545.0	1.04385	(3.3)	565.6	1,433.7
1988	868.1	1.03548	(3.5)	895.4	565.6	1.04526	(2.7)	588.5	1,483.9
1989	895.4	1.03764	(13.1)	916.0	588.5	1.04877	(6.8)	610.4	1,526.4
Projected									
1990	916.0	1.03446	0.0	947.6	610.4	1.03811	0.0	633.7	1,581.2
1991	947.6	1.03446	0.0	980.2	633.7	1.03811	0.0	657.8	1,638.0
1992	980.2	1.03446	0.0	1,014.0	657.8	1.03811	0.0	682.9	1,696.9
1993	1,014.0	1.03446	0.0	1,048.9	682.9	1.03811	0.0	708.9	1,757.8
1994	1,048.9	1.03446	0.0	1,085.1	708.9	1.03811	0.0	735.9	1,821.0
1995	1,085.1	1.03446	0.0	1,122.5	735.9	1.03811	0.0	764.0	1,886.4
1996	1,122.5	1.03446	0.0	1,161.2	764.0	1.03811	0.0	793.1	1,954.2
1997	1,161.2	1.03446	0.0	1,201.2	793.1	1.03811	0.0	823.3	2,024.5
1998	1,201.2	1.03446	0.0	1,242.6	823.3	1.03811	0.0	854.7	2,097.2
1999	1,242.6	1.03446	200.0	1,485.4	854.7	1.03811	100.0	987.3	2,472.6
2000	1,485.4	1.03446	200.0	1,736.6	987.3	1.03811	100.0	1,124.9	2,861.4

Source:
1982-1989 population data -- Israel, Central Bureau of Statistics, Statistical Abstract of Israel 1991, p.710.

Table A-4. Water Consumption in Israel

Budget Year (Apr-Apr)	Jewish Population ('000)	Non-Jewish Population ('000)	Total Population ('000)	Domestic (MCM)	Industry (MCM)	Agriculture (MCM)	Total Consumption (MCM)
1971/1972	2,662.0	458.6	3,120.6	268	87	1,210	1,565
1972/1973	2,752.7	472.3	3,225.0	286	93	1,297	1,676
1973/1974	2,845.0	493.2	3,338.2	288	97	1,180	1,565
1974/1975	2,906.9	514.7	3,421.6	294	95	1,208	1,597
1975/1976	2,959.4	533.8	3,493.2	305	95	1,328	1,728
1976/1977	3,020.4	555.0	3,575.4	308	91	1,271	1,670
1977/1978	3,077.3	575.9	3,653.2	348	94	1,231	1,673
1978/1979	3,141.2	596.4	3,737.6	367	96	1,327	1,790
1979/1980	3,218.4	617.8	3,836.2	375	90	1,235	1,700
1980/1981	3,282.7	639.0	3,921.7	367	100	1,212	1,679
1981/1982	3,320.3	657.5	3,977.8	385	103	1,282	1,770
1982/1983	3,373.2	690.4	4,063.6	401	103	1,255	1,759
1983/1984	3,412.5	706.1	4,118.6	419	103	1,356	1,878
1984/1985	3,471.7	727.9	4,199.6	422	109	1,389	1,920
1985/1986	3,517.2	749.0	4,266.2	450	103	1,434	1,987
1986/1987	3,561.4	769.9	4,331.3	424	111	1,025	1,560
1987/1988	3,612.9	793.6	4,406.5	447	123	1,179	1,749
1989	3,717.1	842.5	4,559.6	501	114	1,236	1,851
1990	3,946.7	875.1	4,821.7	482	106	1,162	1,750
Total			74,067.6	7,137	1,913	23,817	32,867

Note.

1. For first seventeen cases, data recorded for budget year (April-April). For final two cases, data recorded for calendar year. Therefore, data for period April-December 1988 NOT included in Table.

2. For first seventeen cases, population data corresponds to end of first year indicated, e.g.for 1971/1972, population at end of 1971 calendar year. For final two cases, population data for end of calendar year.

Source:

Israel, Central Bureau of Statistics, Statistical Abstract of Israel 1991.

Table A-5. Domestic and Industrial Water Consumption in Israel

Year	Per Capita Domestic (cubic meters)	Growth Rate	Industrial (MCM)	Growth Rate
1971/1972	85.9		87	
1972/1973	88.7	0.03	93	0.07
1973/1974	86.3	-0.03	97	0.04
1974/1975	85.9	-0.00	95	-0.02
1975/1976	87.3	0.02	95	0.00
1976/1977	86.1	-0.01	91	-0.04
1977/1978	95.3	0.11	94	0.03
1978/1979	98.2	0.03	96	0.02
1979/1980	97.8	-0.00	90	-0.06
1980/1981	93.6	-0.04	100	0.11
1981/1982	96.8	0.03	103	0.03
1982/1983	98.7	0.02	103	0.00
1983/1984	101.7	0.03	103	0.00
1984/1985	100.5	-0.01	109	0.06
1985/1986	105.5	0.05	103	-0.06
1986/1987	97.9	-0.07	111	0.08
1987/1988	101.4	0.04	123	0.11
1989	109.9	0.08	114	-0.07
1990	100.0	-0.09	106	-0.07

Table A-6. Projected Israeli Domestic and Industrial Water Consumption (1991–2000)

Year	Population at end of period ('000)	Per capita domestic consumption at beginning of period (cu.m/yr)	Growth rate	Per capita domestic consumption at end of period (cu.m/yr)	Total domestic consumption (MCM)	Total industrial consumption at beginning of period (MCM)	Growth rate	Total industrial consumption at end of period (MCM)
Projected								
1991	5,073.2	100.6	1.0037	101.0	512.3	107.5	1.0187	109.5
1992	5,278.1	101.0	1.0037	101.3	534.9	109.5	1.0187	111.6
1993	5,486.3	101.3	1.0037	101.7	558.1	111.6	1.0187	113.6
1994	5,697.8	101.7	1.0037	102.1	581.7	113.6	1.0187	115.8
1995	5,912.8	102.1	1.0037	102.5	605.9	115.8	1.0187	117.9
1996	6,131.1	102.5	1.0037	102.9	630.6	117.9	1.0187	120.1
1997	6,353.0	102.9	1.0037	103.2	655.8	120.1	1.0187	122.4
1998	6,578.5	103.2	1.0037	103.6	681.6	122.4	1.0187	124.7
1999	6,807.6	103.6	1.0037	104.0	708.0	124.7	1.0187	127.0
2000	7,040.4	104.0	1.0037	104.4	734.9	127.0	1.0187	129.4

Note.

1. Forecast assumes per capita domestic consumption of 100.6 cu.m/yr for the 1991 base year (average annual per capita domestic consumption for the years 1980/81 to 1990). A growth rate of .0037/yr over the forecast period is also assumed (average annual growth rate for the years 1980/81 to 1990).

2. Forecast assumes total industrial consumption of 107.5 MCM for the 1991 base year (average annual total industrial consumption for the years 1980/81 to 1990). A growth rate of .0187/yr over the forecast period is also assumed (average annual growth rate for the years 1980/81 to 1990).

Table A-7. Groundwater and Surfacewater Resources in Israel and the Occupied Territories

Source	Israel			Transboundary			West Bank and Gaza Strip		
	Fresh	Brackish	Irrigation	Fresh	Brackish	Irrigation	Fresh	Brackish	Irrigation
Groundwater									
Coastal Aquifer	300								
Western Galilee Aquifers	155								
Eastern Galilee Aquifers	15	10							
Carmel Basin	53	15							
Arava Aquifers	9	16							
Yarqon–Tanninim Aquifer				300	40				
Northern Aquifer				135					
Nablus–Jenin Aquifer				70					
Eastern Basins							100		
Gaza Coastal Basin							20	45	
Total	532	41		505	40		120	45	

Note.
Fresh Water -- 400 mg/l chlorides or less
Brackish Water -- greater than 400 mg/l chlorides
Irrigation Water -- flood and recycled water

Table A-7 (cont.). Groundwater and Surfacewater Resources in Israel and the Occupied Territories

Source	Israel			Transboundary			West Bank and Gaza Strip		
	Fresh	Brackish	Irrigation	Fresh	Brackish	Irrigation	Fresh	Brackish	Irrigation
Surfacewater									
Jordan Basin									
Lake Kinneret	580								
Yarmouk River	70								
Total	650								
Other									
Floodwater			40						
Reclaimed Wastewater			195						
Total			235						

Sources:

John Kolars, "Water Resources in the Middle East," Canadian Journal of Development Studies (Special Issue, 1992), p.113.

Tahal Consulting Engineers, "Israel Water Sector Review: Past Achievements, Current Problems and Future Options," by J. Schwartz, pp.2-1 to 2-10. Paper presented to the World Bank International Workshop on Comprehensive Water Resources Management Policies, Washington, D.C., 24-28 June 1991.

Table A-8. Computer Search Program

```
10 REM ENTER ISRAELI SHARE FROM EQUITY STANDARDS
20 FOR A=1 TO 4
30 READ ISR(A)
40 NEXT A
50 DATA 450,27,341,387
60 REM ENTER PALESTINIAN SHARE FROM EQUITY STANDARDS
70 FOR B=1 TO 4
80 READ PAL(B)
90 NEXT B
100 DATA 95,518,204,158
110 REM SUM OF DISTANCE
120 LET C=1.7E+38
130 FOR D=0 TO 545 STEP 1
140 E=545-D
150 F=((D-ISR(1))^2+(E-PAL(1))^2)
160 G=((D-ISR(2))^2+(E-PAL(2))^2)
170 H=((D-ISR(3))^2+(E-PAL(3))^2)
180 I=((D-ISR(4))^2+(E-PAL(4))^2)
190 Z=SQR(F)
200 Y=SQR(G)
210 X=SQR(H)
220 W=SQR(I)
230 N=Z+Y+X+W
240 REM DETERMINE MINIMUM OF SUMMED DISTANCES
250 IF N>C THEN GOTO 300
260 PRINT D,E,N
270 ISRALL=D
280 PALALL=E
290 C=N
300 NEXT D
310 PRINT "ISRAEL ALLOCATION";ISRALL
320 PRINT "PALESTINE ALLOCATION";PALALL
330 PRINT "SUM OF DISTANCES";C
```

Table A-9. Allocation of Ground and Surface Water Resources in Israel and the Occupied Territories -- No Final Settlement

Source	Israel	West Bank	Gaza Strip
Groundwater			
Coastal Aquifer	300		
Western Galilee Aquifers	155		
Eastern Galilee Aquifers	25		
Carmel Basin	68		
Arava Aquifers	25		
Yarqon-Tanninim Aquifer	320	20	
Northern Aquifer	115	20	
Nablus-Jenin Aquifer	15	55	
Eastern Basins		100	
Gaza Coastal Basin			65
Surfacewater			
Jordan Basin			
Lake Kinneret	580		
Yarmouk River	70		
Other			
Floodwater	40		
Reclaimed Wastewater	195		
Total	1,908	195	65

Table A-10. Allocation of Ground and Surface Water Resources in Israel and the Occupied Territories -- Independent Palestinian State

Source	Israel	West Bank	Gaza Strip
Groundwater			
Coastal Aquifer	300		
Western Galilee Aquifers	155		
Eastern Galilee Aquifers	25		
Carmel Basin	68		
Arava Aquifers	25		
Yarqon-Tanninim Aquifer			
Northern Aquifer	364	181	
Nablus-Jenin Aquifer			
Eastern Basins		100	
Gaza Coastal Basin			65
Surfacewater			
Jordan Basin			
Lake Kinneret	580		
Yarmouk River	70		
Other			
Floodwater	40		
Reclaimed Wastewater	195		
Total	1,822	281	65

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Water-sharing Regimes in Israel and the Occupied Territories - A Technical Analysis

4. AUTHORS (Last name, first name, middle initial)

Moore, James W.

5. DATE OF PUBLICATION (month and year of publication of document) August 1992	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 46	6b. NO. OF REFS (total cited in document) 53

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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