# GROUNDWATER MANAGEMENT IN A CROSS BOUNDARY CASE: APPLICATION TO ISRAEL AND THE PALESTINIAN AUTHORITY

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To achieve temporal economic efficiency for groundwater in a geographic region such as the West Bank, we propose a management system that is a combination of a nonprofit regional utility with a representative governing body. Water prices would be determined by the utility to balance supply and demand and meet specific groundwater use limits. Revenue from water pricing would provide funds for investments to expand supply through water recycling and new technologies such as desalination. The desired levels of investment and security would be determined by a representative body of water users who would express willingness to pay for these public goods. Simulation modeling indicates that water prices could fall over time as investment and groundwater storage increase. While a water market could improve spatial allocation, it would not necessarily address sustainability or provide for investment.

**KEYWORDS**: aquifer, management, pricing, sustainability, utility, water,

## INTRODUCTION

The Mountain Aquifer which straddles Israeli and Palestinian lands can be viewed as a commons that provides benefits to users over time and over the geographic area of the West Bank. Pumping beyond the safe yield – the current situation – can destroy the aquifer for all users. For such groundwater externalities, some (Gisser and Sanchez, 1980; Hampton, 1990) have suggested privatization: determination of property rights followed by market solutions. Here, we argue for explicit management of the aquifer as a common property, based on a hydro-economic model, and recommend groundwater pricing as essential for appropriate management.

A common property resource has physical characteristics such that sustained use requires group, rather than individual, decisions about management. For example, for groundwater under scarcity conditions, if each user determined withdrawals according to individual maximum gain, then there would be destruction of the resource. In contrast, decision-making in a commons would determine as a group how much each user could withdraw to maintain the resource. Ostrom (1990) discusses successful examples of management in a commons. Local water management districts in the U.S provide examples of groundwater management (Kenney, 1997): local water districts manage water supplies for irrigation and domestic uses and fund local improvement projects through fees and taxes.

Price incentives can be a important tool for common property management. For water (as for other resource situations), economists recommend price incentives to promote efficient use (Rogers, 1993). Pricing groundwater in water-short areas could improve its allocation toward higher value uses, i.e. with an adequate price, groundwater would not be applied to low value field crops such as grains or cotton.

Price can be determined through a water market, but it can also be determined administratively, as in the case of water utility pricing. Although groundwater pricing has recently been advocated, political pressure has prevented its adoption except in rare cases.

**BACKGROUND: WEST BANK AND MOUNTAIN AQUIFER**

Cooperation is essential to improve the well-being of both Israelis and Palestinians utilizing water resources in the West Bank (US NAS et al, 1999). Cooperative agreements about water already exist: e.g. the Annex to the Israel-Jordan Peace Treaty for Water-related matters and the U.S.-Israel-Palestinian Trilateral agreement to promote cooperative efforts to increase the availability and more efficient use of water resources. But these agreements need to be implemented in the form of explicit management plans.

The Mountain Aquifer lies for the most part under the West Bank. It is the source of about 30% of the fresh water supply in Israel and is the most important source of fresh water for Palestinians in the West Bank (Isaac, 1998). The aquifer is recharged from rain; annual rainfall averages 600 mm per ha. The aquifer can be divided into three major

units: the Western basin with a 350 mcm safe yield, the Northeastern basin with a safe yield of 140 mcm, and the Eastern basin with an annual 125 mcm safe yield. Evidence of overexploitation is the decline in the water table of .3-.4 meters per year (Nassereddin, in Feitelson and Haddad, 1994)

Water use by Israelis and Palestinians exhibits great disparity. The total annual average recharge is 615 mcm per year; from this, Israel uses about 490 mcm while Palestinians use about 125 mcm per year (Isaac, 1998). Per capita use is 300cm per year in Israel versus 70cm in the West Bank. Further evidence of disparity is the types of crops grown by each side (Elmusa, 1996). Palestinians irrigate vegetables and fruits, whereas Israelis irrigate mainly field crops such as wheat and cotton; field crops have much lower value. The Palestinian irrigated area per person is about one-fourth that of Israel.

Any cooperative approach would require that this disparity be addressed. One aspect would be a guarantee for increased household water availability for Palestinians, for example guarantee level for household water use of 100 cm annually. Note that any level less than 500 cm per person is considered beyond the “water barrier” (Clarke, 1993, p.67).

Water pollution is a major concern with respect to contamination of the aquifer. Pollution sources include both chemical and industrial sources and raw sewage; many Palestinian villages lack basic treatment facilities. Improved treatment would both protect groundwater and provide an additional source of water. Currently, wastewater volume is about 45 mcm per year.

In peace accords, Palestinians and Israelis have agreed to manage common water resources jointly (Elmusa, 1996). The form that joint management would take is then the issue (Eckstein et al., 1994; Haddad and Feitelson, 1994; Committee on Sustainable Water Supplies for the Middle East, 1999). The work of Haddad and Feitelson emphasizes administrative needs for joint management, including monitoring, planning, enforcement, and other management activities. In their concept of joint management, independent governance bodies for Palestinians and Israelis would form a combined board and carry out needed activities through a secretariat.

However, their work does not address economic organization and institutions.

## ALTERNATIVE INSTITUTIONS FOR WATER PRICING

The water market approach for Middle East problems is of continuing interest (Fisher, 1995; Becker et al., 1996). Previous studies have investigated the implications of potential water market trading and valuation. Spatial optimization for the West Bank shows that an additional 100 mcm should be diverted to the Palestinians; modeling implies an equilibrium water price of about 40 cents/cm with a shadow price of about 80 cents/cm (Zeitouni et al., 1994). Similarly, Fisher (1995) found that: “the value of the water in dispute among the parties is not great. Using a liberal estimate, it is currently a maximum of $110 million per year and will rise to a maximum of less than $500 million per year by 2020. Such values are small compared with the economies involved....compared with the cost of military equipment.” (p. 386).

A water market could improve water allocation, but it would not provide for large scale investment needs of wastewater treatment and new technologies. Water quality and security are public goods that are not valued by a market.

West Bank water management could follow the pattern of a water utility. A water utility sets prices for water. A utility maintains a production and distribution system for a local service area, makes plans for future conditions, and finances investment through user revenues. A water utility does not own the water it manages. There is a contractual arrangement with citizens for whom water is managed.

Some have proposed that because of the political situation in the West Bank and the lack of trust among parties, water management should be carried out by a private utility. While there is much experience with successful privatization of water utilities, for example in France, there is no guarantee that a profit-oriented private utility would carry out needed large scale investments for water supply and improvements in pollution prevention.

This paper makes the argument that a nonprofit public utility is an appropriate type of organization to achieve temporal efficiency in water management. The basis is the comparison of decision-making

by a nonprofit utility with the conditions required to solve the inter-temporal planner problem for groundwater.

## THE INTER-TEMPORAL PLANNER PROBLEM

The planner problem – described by a hydro-economic model – concerns inter-temporal economic efficiency: the planner seeks optimal water withdrawal rates and investment rates such that no reallocation of withdrawal and investment would yield a higher level of welfare in every time period. In the language of optimal control theory, the control variables are groundwater withdrawal rates and investment in water supply technologies (recycling and new). The objective function is the total social value (discounted over time) resulting from withdrawal and investment decisions. State variables are water utilization, net consumption, a measure of water security, and water quality.

Constraints for the dynamic system are:
1) groundwater stock is determined by rain and withdrawals;
2) total demand for households and for production requirements is equal to total supply (withdrawal, surface water, recycled supply, and supply from new technologies);
3) net consumption is production minus costs of investment and variable cost of supply;
4) variable cost is specified in terms of withdrawal cost, recycling cost, new technology cost, and surface cost;
5) there is a minimum guarantee for per capita water use;
6) the storage level should not fall below the “safe” level.

Dynamic optimization provides a guideline for price-setting rules. The economic price of water is associated with achieving demand-supply balance. The shadow price of groundwater withdrawal is determined by value of future groundwater uses. Pricing rules are as follows:

1) Groundwater price should be the shadow price plus variable cost of withdrawal.

2) For each non-groundwater source, price should equal marginal cost (short term variable cost plus annual investment cost).

Thus, optimal allocation across supply sources should result in equality of marginal costs.

3) The same price should be placed on surface, ground, recycled, and new technology sources (ignoring quality differences).

**DECENTRALIZED ORGANIZATION FOR INTER-TEMPORAL ECONOMIC EFFICIENCY**

An organizational structure satisfying the inter-temporal optimization problem has consumers and producers operating in spot market and a public utility making inter-temporal decisions. (The organizational structure is called decentralized because information about households and producers is private.)

Water use decisions by households and producers would be made myopically each time period given appropriate water prices. Producers (agricultural and industrial) would choose water use each time period according to value of output relative to water prices. Households would determine water demand given the water price. Households would also pay fees to the utility for its maintenance of water security and water quality. Fees and prices could vary for different types of households. Because security and water quality are public goods, the sum of personalized prices would reflect the social value for each public good. Social values could be determined from expressions of household willingness to pay.

The public utility would make supply and investment decisions inter-temporally subject to hydrologic and rainfall conditions to meet demand each period. Each period, the utility would receive revenue not only for water supply but also for maintaining water security and water quality. The utility would set water prices to satisfy zero economic profit, subject to review by a regulatory body. Surface uses, groundwater withdrawal, recycling, and new sources would all have the same price. The public utility would also have to satisfy the household water guarantee.

The proof of the efficiency of this decentralized economic organization follows the paradigm of the First Theorem of Welfare Economics. Comparing first order conditions necessary for optimality in both the Planner and Decentralized problems, the efficiency

conditions for inter-temporal efficiency will be satisfied by the Decentralized problem. Feasibility of net consumption is implied by the zero profit condition. Thus, it is possible to find a feasible, efficient solution for groundwater management through the decentralized organization with a public utility, provided consumers and producers have the right prices. (Spot prices in the decentralized setting are related to the time values in I through the discount rate.)

## SOCIAL ORGANIZATION FOR COMMON PROPERTY MANAGEMENT

The needs of common property management of groundwater problems require more than an economic approach. First, because water security and water quality are public goods, their social values (or tradeoffs between private and public goods) must be determined. While measurement of willingness to pay can help to determine social values, social decisions (implying value tradeoffs) can also be made in a public arena. There is also a need to determine the appropriate discount rate, a matter of inter-generational equity. Issues of fairness also require social resolution. Thus, there is a role for social organization beyond the economic organization described above.

Perceived justice and equity are considered among the most important criteria for success of a group process (Mikula, 1980). Two characterizations are: rule fairness (or procedural justice) and outcome fairness (or distributive justice); Zajac, 1995. Since any procedure originally perceived as fair can lead to an outcome distribution that seems unfair, social organization should include procedures to adjust for any perceived fairness problems. For example, water rate-setting should be subject to review by water user representatives.

According to mediation theory, the perception of a common ground in framing a group process can be important for its success. A common ground exists whenever the participants in a decision-making process experience shared commitment to cope with problems or issues (Gray, 1989), such as sustainable water management. If group members place a value on a successful group outcome, they may be willing to relax pure self interest, and hence a group outcome is possible in spite of individual differences. Social psychologists have shown that when participants with different values can openly discuss

their diverse viewpoints in the decision process, they can become more committed to any decision eventually reached (Moscovici, 1994).

## CONCLUSIONS

The final status talks between the Israelis and Palestinians must settle questions of equitable allocation of water rights for resources common to both sides and joint management of these resources (Elmusa, 1996). Important questions to be resolved are, what does joint management mean and how close will the level of cooperation be? The hydro-geologic system for the Mountain Aquifer cannot be divided, and water contamination from any source would affect water supply for both Israelis and Palestinians. Thus, essential for groundwater sustainability is that eventually there be true cooperation between Israelis and Palestinians in management of the Mountain Aquifer.

This paper addresses what form economic organization should take, given the joint will to cooperate. The economic organization of a nonprofit water utility making investment and withdrawal decisions and applying appropriate pricing rules, together with domestic users and producers operating in a “spot” market, satisfies conditions for inter-temporal efficiency.

To economic organization must be added social structures to determine social values and adjudicate issues of fairness. Neither water markets nor private utilities would provide these requisite social management elements.

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