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Facing Water Scarcity in Jordan
Reuse, Demand Reduction, Energy, and Transboundary Approaches to Assure Future Water Supplies

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Abstract: *Jordan is extremely water-scarce with just 167 m³ per capita per year to meet domestic, industrial, agricultural, tourism, and environmental demands. The heavy exploitation of water resources has contributed to declines in the levels of aquifers and the Dead Sea. Rapid growth in demand, particularly for higher quality water for domestic, industrial, and tourism uses, is significantly increasing pressure on agricultural and environmental uses of water, both of which must continue to adapt to reduced volumes and lower quality water. The agricultural sector has begun to respond by improving irrigation efficiency and increasing the use of recycled water. Total demand for water still exceeds renewable supplies while inadequate treatment of sewage used for irrigation creates potential environmental and health risks and presents agricultural marketing challenges that undermine the competitiveness of exports. The adaptive capability of the natural environment may already be past sustainable limits with oasis wetlands having been most seriously affected. Development of new water resources is extremely expensive in Jordan with an average investment cost of US$4 to $5 per cubic meter. This paper examines four integrated water resources management (IWRM) approaches of relevance to Jordan: water reuse, demand management, energy-water linkages, and transboundary water management. While progress in Jordan has been made, the Ministry of Water and Irrigation continues to be concerned about the acute water scarcity the country faces as well as the need to continue working with concerned stakeholders to assure future water supplies.*

Keywords: *Integrated water resources management, water scarcity, water reuse, demand side management, transboundary water management, water policy.*

"Borrowing From the Future": The Depths of Jordan's Water Scarcity

The total renewable freshwater resources in Jordan are estimated to be 850 million cubic meters (MCM) annually including "rightful allocations" under the Peace Treaty with Israel (MWI, 1998c). Surface water, concentrated principally in the Jordan River Basin (Wadi Zarqa, Wadi Araba, Yarmouk River, etc.), totals 575 MCM, while renewable groundwater is estimated to be 275 MCM annually (MWI, 1998b). In aggregate terms, the annual per capita availability of *sustainable* water supply is 167 m^3 and is projected to decline below 150 m^3 per capita per year even assuming all feasible additional supplies are tapped (World Bank, 2001). This may be compared to 1,123 m^3 and 461 m^3 per capita per year in Egypt and Israel, respectively (Shannag and Al-Adwan, 2000), and is at the same level of the population-weighted average of 175 m^3 for Saudi Arabia, Kuwait, Oman, and the United Arab Emirates (Seckler et al., 1998), which epitomize absolute water scarcity. Other estimates of Jordan's water resource potential (CES Consulting and GTZ, 1996, cited in NRC, 1999; Shannag and Al-Adwan, 2000; Hussein, 2002; Al-Salihi and Himmo, 2003) vary somewhat with the 850 MCM availability figure cited above, but their implications do not. Numerous analysts have highlighted and discussed the chronic scarcity of Jordan's water resources (Salameh and Bannayan, 1993; Salameh, 2000).

Water demand outweighed sustainable supply by a factor of over 20 percent in 1997 (MWI, 1997a), with the deficit being met through groundwater overdraft, estimated as 216 MCM/year (JVA, 2000) or nearly 80 percent above natural groundwater recharge (Macoun and El-Naser, 1999). Aside from the impacts this has on human uses, as will be discussed, environmental quality has been affected. For example, the reduction of groundwater discharge to the Azraq wetlands has reduced the habitat for endemic species and migratory birds. The full exploitation of surface water also has strong environmental impacts. The combined water depletion in the Jordan River Basin has contributed to alarming declines in the levels of the Dead Sea (Salameh and El-Naser, 1999; 2000a; 2000b). The dominant water use in Jordan remains agriculture, which is estimated to consume between 73 and 77.5 percent of the nation's water (Nazzal et al., 2000; Shannag and Al-Adwan, 2000). However, urban and industrial demands for water are growing rapidly and will increasingly compete with agriculture for scarce water resources. Despite efforts to improve irrigation efficiency and encourage farmers to grow crops that consume less water, agricultural water demand has not decreased appreciably. As a result, total water demand is projected to continue to rise and with it the aggregate water deficit. The impacts on Jordan's aquifers are already being felt and will worsen. Static and dynamic water levels are falling and water quality is deteriorating through increased salinization.

A number of factors make Jordan's water resources balance unique. The 2000 population of 5.083 million is growing 2.87 percent annually (Population Reference Bureau, 2001), while the urban population is growing even more rapidly. Jordan's population has tripled in a very short period of time as a result of the Israeli-Arab conflict where hundreds of thousands of refugees, displaced persons, and returnees came to Jordan in 1948, 1967, and 1991, respectively. This situation has greatly strained the already limited water supplies. Economic growth is likely to increase the levels of both affluence and demand for water. Current per capita residential water supply levels are in the range of 60 to 100 liters per day, contrasted with the internationally accepted benchmark of 200 liters per capita per day to ensure adequate hygiene and public health. Particularly in the capital Amman, municipal water supply levels will increase rapidly in the near- to mid-term. As a result of rising urban demand for water, already low per capita supply levels, and population concentration in the cities, this sector will dominate an increasing share of the nation's water resources; with important consequences for other water demands (see Figure 1).

While the supply-demand imbalance in Jordan is not new, the current strategy of relying on aquifer overdraft to meet demand is not sustainable. In addition to the rising capital and energy costs of pumping groundwater, resource depletion and water quality degradation are threatening existing sources of supply. Creative solutions will have to be developed and applied. This paper addresses four approaches that may be applied, in an integrated fashion, to address water scarcity in Jordan: (1) water reuse; (2) reduction of water demand; (3) energy-water co-management; and (4) transboundary agreements. It needs to be recognized that the conventional sectoral approach to water management is unlikely to offer significant potential to resolve water scarcity. Further, irrigation or urban water supply, for example, can no longer be treated in isolation but must be viewed as integral components of Jordan's larger water management challenge. Dialogue and support from a range of stakeholders within Jordan is required. At the same time, consideration must be given to opportunities and constraints imposed from outside the water sector, particularly the availability, cost, and future trends in Jordan's energy supplies, as well as political and foreign policy issues associated with sharing water resources with Jordan's neighbors including Israel, Syria, the Palestinians, and Saudi Arabia.

This approach is characteristic of Integrated Water Resources Management (IWRM), which is being applied successfully in a range of local, national, and transnational contexts around the world. IWRM is a participatory planning and implementation process based on sound science, which brings together stakeholders to determine how to meet society's long-term needs for water and coastal re-

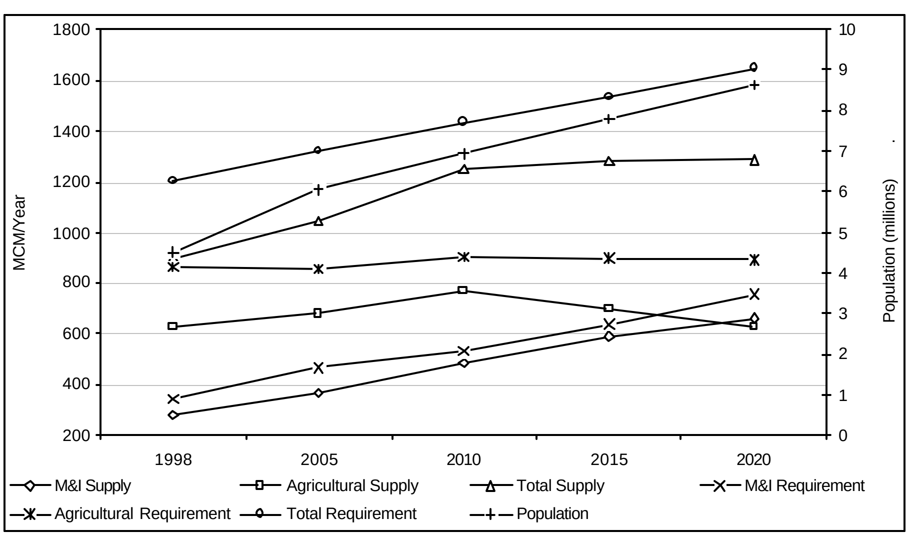

Figure 1. Projected supply and demand for water in Jordan. Source: World Bank, 2001.

sources while maintaining essential ecological services and economic benefits. Jordan's far-reaching Water Strategy (MWI, 1997a; 1997b; 1997c; MWI, 1998a; 1998b; 1998c) is based on these principles and provides a crucial policy underpinning to current and future efforts by the government and civil society to face the nation's considerable water management challenges.

Water Reuse

There is growing recognition at all levels in Jordan that water reuse is an important future resource and at present is the largest potential sustainable growth area for water use. We refer in this paper primarily to wastewater irrigation. The important and growing practice of household-level greywater separation and use has been documented by Faruqui and Jayyousi (2002). There is understandable concern over indiscriminate or unplanned water use, although the water and nutrient value embodied in urban effluent make this an increasingly appealing resource for farmers facing water scarcity. For example, numerous farmers along the Wadi Zarqa between the Khirbit As Samra wastewater treatment plant and the King Talal Reservoir value the wastewater sufficiently to pay pumping costs to lift it for irrigation. The As Samra plant has been treating wastewater to primary instead of full secondary level for reasons of treatment plant hydraulic overloading; however, the plant is currently being upgraded and will be generating effluent that meets Jordanian reuse standards by 2005. Additional examples of the reuse of treated urban effluent for irrigation in Jordan include Irbid (Shahalam et al., 1998) and Petra.

Nationwide, approximately 60 to 70 MCM of treated effluent is currently discharged to water bodies and subsequently reused for irrigation on an annual basis (El-Naser, 1997; McCornick, 2001). However, it is estimated that treated effluent availability will increase four-fold to 240 MCM/year within the next twenty years. If fully utilized through appropriate practices, water reuse could approach groundwater recharge in magnitude. Given that agricultural reuse of treated effluent with appropriate safeguards (discussed below) is an acceptable and growing practice, while potable reuse remains unacceptable from the risk management and public acceptability perspectives, it is conceivable that groundwater should be reserved exclusively to meet present and future urban water demands. A number of unavoidable agronomic, public health, economic, and hydrologic issues must be addressed, however, in order to pursue such a goal.

It has been noted that treated effluent in Jordan is significantly higher in total dissolved solids (TDS) and biochemical oxygen demand (BOD) as well as other contaminants than in water-abundant systems. This is due to low per capita water supply rates coupled with increased TDS in the supply water (average 580 ppm in 1998), with more or less constant wasteloads (MWI, 1998c; Al-Kharabsheh, 1999; Nazzal et al., 2000). For example, Khirbit As Samra effluent has approximately 1,200 ppm TDS, while Wadi Dulail TDS is as high as 5,000 ppm (P. McCornick, personal communication) which limits the range of crops that can be irrigated. Alfalfa is a common choice, given that it is tolerant of high TDS and because it is not consumed by humans; however, alfalfa is also deep rooted and water consumptive. Tree crops may be suitable for irrigation with treated effluent as the fruit does not come in contact with the water; however, apricots, peaches, and other stone fruit do not tolerate chloride levels well.

The public health imperatives, or perhaps more significantly the public perception of health risks, place important limits on agricultural reuse options for the range of issues associated with protozoan, bacterial, viral, and nematode parasites (McCornick et al., 2001). Of particular concern are the helminths (ascaris and trichuris), which have relatively long persistence and have a small infective dose. In general, viruses are considered to present minimal risk (WHO, 1989), although this risk decreases with the degree of treatment (Shuval, 1993). In addition to direct transmission of infectious diseases through wastewater, the ponds and canals used for its handling may serve as habitats for disease vectors, such as mosquitoes and snails. Public opinion on these issues tends to reflect very deeply held views. Experience from a range of Muslim countries including Jordan indicates that domestic wastewater is being reused in agriculture and many consumers are willing to purchase and eat wastewater-irrigated crops, provided they feel this is safe (Faruqui, 2001). At the same time, public awareness can be used as a strong galvanizing force to shape policy in favor of appropriate reuse practices (Bakir, 2000). Public education in mosques and churches could highlight the important issues of water demand management and identify the acceptability of wastewater reuse as long as public health is protected.

The economic and financial implications of a major program to reuse treated effluent for irrigation needs to be considered, particularly for the recovery of capital and operational costs. It is encouraging to note that the Water Authority of Jordan (WAJ) has succeeded in getting urban water consumers in Amman to pay a surcharge on their monthly water bill that goes for wastewater collection and treatment. While it has yet to be fully operationalized, this is a first step in the direction of the polluter-pays principle explicitly included in Jordan's wastewater management policy (MWI, 1998c). Given that agricultural reuse is the most feasible and low cost option for water reuse, the policy's recommendation to recover operation and maintenance (O&M) costs of delivery from end users might need modification for the practice to become more fully accepted. Nevertheless, the combined investment and O&M costs for collection, treatment, and delivery (in the range of $1/m^3) are significantly lower than the alternative of developing new supplies ($4-5/m^3), with the result that agricultural reuse is imperative.

The hydrological conditions prevailing in Jordan, however, may limit prolonged and indiscriminate irrigation with high TDS water. Several options exist ranging from adequate blending with freshwater to judicious irrigation of salt-tolerant crops with unblended effluent while taking due precaution to ensure sufficient leaching. Irrigation with unblended effluent will tend to build up soil salinity and leaching is crucial in order to maintain agricultural productivity and avert long-term, irreversible soil degradation (and with it, loss of agricultural productivity) caused by secondary salinization. Irrigating with water at TDS levels in excess of 1,200 ppm poses significant management challenges. The idea of creating an isolated 'wastewater irrigation district' must be carefully considered if unblended, high TDS effluent is to be used continuously over time. It is recommended that one or more freshwater irrigations be applied to meet the salt leaching requirement. This practice, even if it is successful in maintaining agricultural productivity, will contribute to the degradation of water quality in the underlying aquifers in the long run. It appears that these trends are occurring in the Jordan Valley, for example, where shallow groundwater has TDS in the range of 5,000 to 10,000 ppm. The salt balance implications for the upland aquifers are more severe, as these serve as the primary source of urban water supply to Amman.

Additional measures to enhance the utility of available recycled water by improving its quality include the reduction of contaminant source load, separate treatment of industrial effluent, and reduction in evaporation and salinization during wastewater treatment.

Demand Reduction/Management

Demand management entails reducing water abstraction, particularly of groundwater. Combined municipal and industrial supply levels are already critically low – as low as approximately 70 liters per person per day (MWI, 1998c) – suggesting that future water savings will need to come primarily from agriculture. Nevertheless, there is no doubt a potential for additional savings in urban water use, particularly for gardening and urban agriculture. Much attention has been paid to demand side management in urban water supply and further progress needs to be made; however, water presently lost through leakage that may be saved should be used to increase the per capita urban supply rates. As a result, we restrict our discussion here to reducing agricultural demand for water. We have discussed the potential and challenges of agricultural reuse of treated effluent as a substitute for groundwater and the shift to less water-intensive crops as means to reduce aggregate demand on scarce groundwater resources.

A major hurdle that must be faced in Jordan is the societal change required when moving to the higher levels of demand management, i.e., allocative efficiency, or improved water productivity through (re)allocation. Jordan has embarked on the *intrasectoral* component of allocative efficiency for agriculture. There is considerable interest and effort in Jordan on improving irrigation efficiency, primarily through the adoption of drip irrigation and related technologies to improve on-farm water management (JVA, 2000). Results indicate that farm-level water consumption under furrow irrigation can be reduced by 20 percent without compromising agricultural production. Two of the more complex aspects of agricultural intrasectoral allocation efficiency have yet to be addressed. Serious work is needed on restructuring market forces to encourage a move away from low value crops and toward high value crops. Allowing the movement of water from farmers operating at low water use efficiency to those with high water use efficiency is a subject of controversy. Both of these steps will increase the return per drop of water consumed.

The intersectoral component of allocative efficiency is much more stressful to the social fabric than are intrasectoral components, given that there are important social equity and poverty issues involved in addition to economic ones (Scott et al., 2001). Reallocation needs to be considered in the context of the specific country or society (Barker et al., 2000) and may not always be the most appropriate approach unless larger social, political, and economic factors warrant drastic measures. As water prices increase to market value, water tends to move from agriculture to industry. National programs that promote business development increase the rate at which water moves from agriculture to industry. Agriculture in Jordan is the largest water user, a significant employer, and is highly valued for reasons of agrarian identity, an emotionally charged subject in many societies. Land ownership and farming are culturally linked and breaking this mystique will not be easy.

Critical will be the ability to placate the powerful vested interests among water users presently benefiting from subsidized water or groundwater overabstraction, and the ability to create alternative livelihoods for people whose jobs may be at risk as a result of changes in water allocation. Success will require the use of an increasingly large number of socio-economic incentives as well as changes in institutions, water-laws, and regulations. Above all, it implies the involvement of people. The tensions, even conflicts, likely to occur as a result of the required changes are extremely difficult to predict (Ohlsson and Lundqvist, 2000). To reduce the severity of conflicts, the distinction between naturally available water and water supplied through a variety of service arrangements requiring investment, management, etc., must be made explicit and its significance explained to the Jordanian populace. Everyone needs to be aware of the issues and have input into the discussion on hard choices.

In order to correct the supply-demand imbalance and address the 216 MCM/year groundwater overdraft, other demand management measures must be considered, principally the phased and selective closure of wells through restricted permitting and buyouts (MWI, 2001). Based on the goal of reserving high quality groundwater for urban supply, agricultural wells drawing from the same aquifers as the Water Authority of Jordan's well fields for urban supply should be the first ones identified (M. Chebaane, MWI Water Resource Policy Support Project, personal communication). This will not be a trivial process, as livelihoods and lifestyles are at stake.

Despite concerted efforts to reduce aggregate agricultural water demand, it is likely that consumptive use will remain higher than available supply for the foreseeable future. During this transition, additional sources including brackish water, the mining of non-renewable groundwater resources, and desalination of brackish or saline groundwater, as for example in Hisban, may be relied upon (the extremely high cost of pumping desalinated sea water from Aqaba to demand sites in the Amman highlands make this option unattractive). Private farmers in the Jordan Valley are resorting to desalination of brackish water (up to 10,000 ppm TDS); however, it appears that their financial feasibility relies on forward linkage of graded and packed high-value produce exported directly to European supermarket shelves.

Energy-Water Co-management

Jordan is energy-poor and relies on fuel imports to sustain its economy. The financial and economic costs of energy consumption are high, to say nothing of political and foreign policy considerations. Energy costs for water abstraction, supply, treatment, and reuse are exceedingly high, driven by the spatial and temporal distribution of water sources and uses, and must explicitly be factored in to water management plans. This fact is accounted for in Jordan's Water Strategy through the recognition that "water and energy are twins" (MWI, 1997a).

It is estimated that up to one-quarter of Jordan's total electrical energy budget goes to supply water, i.e., a combination of the energy consumed by the Water Authority of Jordan for water and wastewater service provision, including groundwater pumping, lifting surface water from the Jordan Valley to urban centers in the highlands, treatment, distribution, and wastewater collection and treatment, as well as private groundwater pumping throughout Jordan. This does not include water management, treatment and recycling within industry. Water's share of the national energy budget will rise further when the Disi project comes on line, to pump and convey groundwater from the Disi aquifer (100 MCM/year of fossil groundwater) in the southeast to Amman via a US$600 million conveyor – currently one of the most critical issues in the water sector in Jordan. However, pumping additional water from the Jordan Valley to Amman will increase energy consumption even further.

As a result, measures to reduce aquifer overabstraction will have clear energy and economic benefits in addition to the water resources implications discussed above. A comment is in order here on using electrical power supply as a tool to reduce agricultural water demand through power rationing, limiting transformer size, etc. High capacity pumps for deep groundwater extraction are required throughout the highlands, where water levels are low and falling. Given the high cost that pumping represents as a fraction of agricultural inputs (currently in the range of 10 percent or greater), limiting electrical power will cause farmers to further resort to adaptive behavior including switching to diesel pump sets. Nevertheless, continuing to allow farmers to bear the high costs of groundwater abstraction will tend to reduce demand. The energy and water savings that could be realized through full cost pricing (Schiffler, 1998) of both resources give important grounds for linking their management in an overall demand management approach as discussed above.

In the highly abstracted Zarqa basin, future trends in groundwater levels will increasingly be influenced by abstraction on the Syrian side of the border, given that much of this highland aquifer's recharge comes from the north where rainfall and recharge rates are higher (although the bulk of recharge still occurs in Jordan). The two countries have started sharing data and information on water, energy or agricultural trends that will permit sounder planning of this shared resource.

Transboundary Water Resource Management

The Tigris, the Euphrates, the Orontes, the Jordan, and the Nile are the major river basins in the Middle East. Much has been written about them collectively and individually by politicians and scientists. A common denominator among them is the absence of comprehensive riparian agreements that regulate the rights and responsibilities of each riparian in water sharing, environmental protection, inefficient use, exchange of data, and the avoidance of inflicting appreciable harm upon co-riparians.

Riparians on the Jordan River system are Lebanon, Syria, Israel, Jordan, and the Palestinians. No multilateral agreement exists to regulate the use of the river waters. There is a bilateral agreement between Syria and Jordan to regulate and utilize the flow of the Yarmouk River, including discussions on the possible construction of the Wihdeh Dam, which would make irrigation and domestic water available to Jordan. The most recent agreement on the Yarmouk River between Jordan and Syria was signed in 1987, based on an earlier agreement between the two counties in 1954. More recently, a further bilateral agreement has been reached between Jordan and Israel on allocating the water of the Jordan and Yarmouk rivers as a result of the Peace agreement between the two countries signed in October 1994 (El-Naser, 1999).

The Jordan River rises from three main surface and groundwater sources: the southern slopes of Mount Hermon in Lebanon (Hasbani), Israel (Dan), and Syria (Banias).

The three streams join to form the Jordan River whose flow averages 650 MCM/year as it enters Lake Tiberias or the Upper Jordan. The total discharge of the Jordan River into the Dead Sea or the Lower Jordan, prior to the implementation of water development projects, was about 1,400 MCM/year. The river is joined after it exits the Lake by different streams and side wadis. Its major tributary is the Yarmouk, which rises in Syria and Jordan, flows westward towards the Jordan River, and in many of its reaches, forms the international boundary between Syria and Jordan. The basin suffers from considerable environmental degradation including the diversion of saline springs and fishpond effluents by the Israelis to the Lower Jordan; irrigation return flows from the agricultural activities and the disposal of sewage and treated wastewater from all riparian countries.

Jordan and Israel have defused tension by replacing confrontation with negotiation, as the two countries agreed to cooperate on the use and management of the Jordan and Yarmouk waters. The signed agreement between the two countries on water-related matters, however, is bilateral instead of a multilateral agreement that is needed on the use of water among the various countries. Other involved parties are encouraged to reach bilateral agreements on the remaining water resources of the basin before moving towards a unified management agreement. There is a need to reach agreement on the Upper Jordan River waters among Israel, Syria, Lebanon, and the Palestinians to further enhance cooperation on water issues, protect the environmental conditions of the watercourses and the groundwater aquifers. Israel and the Palestinians concluded on September 1995 the interim agreement on the West Bank and Gaza Strip, which covers water and wastewater issues. The agreement specifies commitments and responsibilities of both sides. However, the agreement did not talk about the Jordan River basin; it dealt with the allocation of some surface and groundwater resources and the management of existing supplies.

In 1996 in Norway, as an output of the multilateral working group on water resources of the Middle East Peace Process, Israel, Jordan, and the Palestinians signed a declaration of principles for cooperation among the core parties on water-related matters and new and additional waters. This instrument identifies common issues to be included in water resources legislation and management, mechanisms of cooperation on new and additional water resources, and proposed areas for possible cooperation.

Since the multilateral track of the Middle East Peace Process began in 1992, the Working Group on Water Resources (WGWR) has encouraged closer cooperation on water issues among the core parties of the region, namely: Jordan, Israel, and the Palestinians. The main objective of the multilateral peace talks is to support bilateral peace talks and to help bilateral negotiations through facilitating the process by providing data, know-how, and information on several matters of regional importance. The WGWR works under four agenda items, enhancement of data availability, water management practices including conservation, enhancing water supply, concepts of regional water management and cooperation.

The group has started projects under the agenda items in the fields of water databases, wastewater treatment and reuse, public awareness and conservation, rehabilitation of municipal water supply systems, future water supply and demand among the core parties, capacity building in the field of water and the establishment of a regional desalination research center in Oman. Unfortunately and due to the political situation and tension prevailing in the Middle East, the formal meetings of the WGWR are frozen. The WGWR could play a major role with the core parties in reaching comprehensive and multilateral agreements between all the involved parties, which will pave the road for unified management of the Jordan River Basin. Unified management of the river basin is very much needed. However, to reach that level of cooperation and collaboration among the riparian countries many prior steps are needed. Allocation issues should be resolved prior to any regional collaboration. Knowledge of the benefits of cooperation might enhance the process of reaching bilateral agreements. Standardization of water measurement methods, site measurements, data collection, processing, storage, and assessment is essential to initiate multilateral cooperation among the parties. Protocols for data exchange and technology transfer are important to achieve the overall objective of regional management of the basin.

Having established the above unified management starts with the evaluation of alternative investments, administrative measures, and human resources development. Such cooperation among various parties should be based on a strategy that gives the primary role to the private sector in economic activities with the public sector playing a lesser but more efficient supportive role. On the operational side, forecasting systems for drought conditions and pollutant levels should be established. The development of such systems will offer significant benefit to all involved parties. Shared knowledge of the technical specifications for the water conveyance systems and possibilities for their linkage would be very useful for future transboundary water transfers to alleviate water shortage in other locations within the basin.

Conclusions

Jordan faces chronic and severe water scarcity with a growing population, increasing urban and industrial demands for water, and limited options in the short-term for securing significant additional water resources through technological innovation or transboundary approaches. There appears to be considerably greater potential in pursuing an integrated water resources management (IWRM) approach, which links water supply and demand for various sectors with factors external to the water sector in a concerted effort to balance demand levels with sustainable supplies.

This paper provides an overview of four components of an IWRM approach and assesses these in relation to Jordan's Water Strategy. The key lies in Jordan's ability to reduce demand for water, which may most feasibly be achieved through a combination of energy and pricing mechanisms, and importantly, by substituting treated effluent for freshwater in agriculture, except to meet blending and leaching requirements. Regional water sharing agreements must be formalized in order for Jordan to take full advantage of its share of transboundary surface and groundwaters.

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References

Al-Kharabsheh, A. 1999. "Groundwater Quality Deterioration in Arid Areas: A Case Study of the Zerqa River Basin as Influenced by Khirbet Es-Samra Wastewater (Jordan)." *Journal of Arid Environments* 43, No. 3: 227–239.

Al-Salihi, A.H., and S.K. Himmo. 2003. "Control and Management of Jordan's Water Resources." *Water International* 28, No. 1: 1–10.

Bakir, P. Hotchkiss. 2000. "Establishing Mutual Trust – A Prerequisite to Public Partnership." In I. Chorus, U. Ringelband, G. Schlag and O. Schmoll, eds. *Water, Sanitation and Health: Resolving Conflicts between Drinking-Water Demands and Pressures from Society's Wastes.* London, England, United Kingdom: IWA Publishing.

Barker, R., C.A. Scott, C. de Fraiture, and U. Amarasinghe. 2000. "Global Water Shortages and the Challenge Facing Mexico." *International Journal of Water Resources Development* 16, No. 4: 525–542.

CES Consulting Engineers and GTZ. 1996. *Middle East Regional Study on Water Supply and Demand Development, Phase I, Regional Overview*. Sponsored by the Government of the Federal Republic of Germany for the Multilateral Working Group on Water Resources. Eschborn, Germany: Association for Technical Cooperation (GTZ).

El-Naser, H. 1997. "The Partition of Water Resources in the Jordan River Basin: History and Current Development." Paper submitted to the Conference on The Water in the Mediterranean Countries – Management Problems of a Scarce Resource. Naples, Italy.

Faruqui, N.I. 2001. "Islam and Water Management: Overview and Principles." In Naser I. Faruqui, Asit K. Biswas, and Murad J. Bino, eds. *Water Management in Islam.* Tokyo, Japan: The United Nations University Press and Ottawa, Canada: The International Development Research Centre.

Faruqui, N.I. and O. Jayyousi. 2002. "Greywater Reuse in Urban Agriculture for Poverty Alleviation: A Case Study in Jordan." *Water International* 27, No. 3: 387–394.

Hof, F.C. 2000. "The Water Dimension of Golan Heights Negotiations." In Hussein A. Amery and Aaron T. Wolf, ed). *Water in the Middle East.* Austin, Texas, USA: The University of Texas Press.

Hussein, I.A.J. 2002. "Water Planning in Jordan: Future Scenarios." *Water International* 27, No. 4: 468–475.

Jordan Valley Authority (JVA), The Hashemite Kingdom of Jordan. 2000. Paper on *Irrigated Agriculture in Jordan and the On-going Irrigation Advisory Service Pilot Program with the Jordan Valley Authority*. August 2000. Amman, Jordan

Macoun, A. and H. El-Naser. 1999. *Groundwater Resources Management in Jordan: Policy and Regulatory Issues*. World Bank Technical Paper No.456. Washington, D.C., USA: The World Bank.

McCornick, P. 2001. "Plan for Managing Water Reuse in the Amman-Zarqa Basin and Jordan Valley." Water Reuse Component Working Paper, Water Policy Support Project. Ministry of Water and Irrigation, Amman.

McCornick, P, Haddadin, Rashid and Sabella. 2001. Water Reuse in Wadi Zarqa and from Other Amman-Zarqa Sources. Water Reuse Corporation, Water Policy Support Project. Ministry of Irrigation, Amman.

Ministry of Water and Irrigation (MWI), The Hashemite Kingdom of Jordan. 1997a. *Jordan's Water Strategy*. April. Amman, Jordan: MWI.

—— 1997b. *Water Utility Policy. Policy Paper No. 1.* July. Amman, Jordan: MWI.

—— 1997c. *Water Sector Investment Program 1997-2011*. Amman, Jordan: MWI.

—— 1998a. *Irrigation Water Policy. Policy Paper No. 2*. February. Amman, Jordan: MWI.

—— 1998b. *Groundwater Management Policy. Policy Paper No. 3*. February. Amman, Jordan: MWI.

—— 1998c. *Wastewater Management Policy. Policy Paper No. 4*. June. Amman, Jordan: MWI.

—— 2001. *Study of Groundwater Use and Users in Northeastern Amman-Zarqa Basin Highlands*. Amman, Jordan: Water Resource Policy Support, Groundwater Management Component, MWI/USAID/ARD.

National Research Council (NRC) Committee on Sustainable Water Supplies for the Middle East. 1999. *Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan*. Washington, D.C., USA: National Academy Press.

Nazzal, Y.K., M.Mansour, M. Al Najjar, and P. McCornick. 2000. Wastewater Reuse Law and Standards in the Kingdom of Jordan. Ministry of Water and Irrigation. March. Amman, Jordan: Ministry of Water and Irrigation.

Ohlsson, L. and J. Lundqvist. 2000. "The Turning of a Screw: Social Adaptation to Water Scarcity." Part 3 of Falkenmark et al., eds. *New Dimensions in Water Security.* Rome, Italy: FAO, AGLW.

Population Reference Bureau. 2001. http://www.prb.org/

Salameh, E. 2000. "Redefining the Water Poverty Index." *Water International* 25, No. 3: 469-473.

Salameh, E. and H. Bannayan. 1993. *Water Resources of Jordan: Present Status and Future Potentials*. Amman, Jordan: Friedrich Ebert Stiftung.

Salameh, E. and H. El-Naser. 1999. "Does the Actual Drop in the Dead Sea Level Reflect the Development of Water Sources within its Drainage Basin?" *Acta Hydochim. Hydobiol.* 27, No. 1: 5–11.

2000a. "Changes in the Dead Sea Level and their Impacts on the Surrounding Groundwater Bodies." *Acta Hydochim. Hydobiol*. 28, No. 1: 24–33.

2000b. "The Interface Configuration of the Fresh-/Dead Seawater - Theory and Measurements." *Acta Hydochim. Hydobiol.* 28, No. 6: 323–328.

Schiffler, M. 1998. *The Economics of Groundwater Management in Arid Countries: Theory, International Experience and a Case Study of Jordan*. London, England, United Kingdom: Frank Cass.

Seckler, D., U. Amarasinghe, D. Molden, R. de Silva, and R. Barker. 1998. *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues*. Research Report 19. Colombo, Sri Lanka: International Water Management Institute.

Scott, C.A., P. Silva-Ochoa, V. Florencio-Cruz, and P. Wester. 2001. "Competition for Water in the Lerma-Chapala Basin." In A. Hansen and M. van Afferden, eds. *The Lerma-Chapala Watershed: Evaluation and Management.* Dordrecht: Kluwer Academic/Plenum Publishers.

Shahalam, A., B.M. Abu Zahra, and A. Jaradat. 1998. "Wastewater Irrigation Effect on Soil, Crop and Environment: A Pilot Scale Study at Irbid, Jordan." *Water, Air, and Soil Pollution* 106: 425–445.

Shannag, E. and Y. Al-Adwan. 2000. "Evaluating Water Balances in Jordan." In David B. Brooks and Ozay Mehmet, eds. *Water Balances in the Eastern Mediterranean*. Ottawa, Canada: International Development Research Centre.

Shuval, H.I. 1993. "Investigation of Typhoid Fever and Cholera Transmission by Raw Wastewater Irrigation Santiago, Chile." *Water Science and Technology* 27. Nos. 3/4: 167–174.

World Bank. 1997. T*he Hashemite Kingdom of Jordan - Water Sector Review. Rural Development, Water and Environment Department, Middle East and North Africa Region*. Washington, D..C., USA: The World Bank.

World Bank. 2001. *The Hashemite Kingdom of Jordan - Water Sector Review Update. Report No. 21946-JO. Rural Development, Water and Environment Department, Middle East and North Africa Region*. Washington, D.C., USA: The World Bank.

World Health Organization (WHO). 1989. *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.* Geneva, Switzerland: World Health Organization.