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The Economics of Water in Jordan

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Water is essential for life, but it is scarce in many parts of the world, particularly in arid and semiarid regions. Even in some water-blessed countries, the uneven spatial distribution of water resources leads to water stress in some areas. Water is scarce in Jordan, and dealing with such scarcity is thus a major policy issue.

The state holds the water of Jordan in trust for its residents. The policy in this regard has been reflected in laws that stipulate that water is a "state property." In this sense, water belongs to every member of the society, giving each the right to it, but at the same time, it is the property of no one. The state, through the Ministry of Water and Irrigation (MWI), regulates water use and attempts to ensure that use by some does not negatively impact the resource or cause appreciable harm to others. The question is how this can be accomplished optimally.

The basic concerns of economic analysis are the allocation of scarce resources and the relation of the value of those resources to their scarcity and allocation. The fact that water is essential for human life makes water and its allocation critical, but that does not exempt it from the applicability of the principles of economics. There are differences, even open clashes, worldwide between those who would treat water as a private economic commodity and those who insist that it is a good with a critical social dimension. The proponents of the first notion advocate the transfer of water to private hands, whereas the proponents of the second defend keeping water within the realm of the public sector.

The standard answer given by economists to the question of how best to allocate a natural resource is that this should be done through private markets.[1] That answer is often correct, but only if certain conditions hold.

- The market for the resource must be competitive, with many small buyers and sellers.
- All social costs and benefits involved in the use of the resource must be private ones, so that they are reflected in the profit-and-loss decisions of firms and the economic choices of consumers.
- The rate at which future costs and benefits are discounted by society must also coincide with the private discount rate.

At least the first two of these conditions, and quite possibly the third, do not hold for water, and definitely not for water in Jordan. The country has only one water owner—the state—and the water infrastructure involves large investments, making an arrangement with many small sellers difficult to construct. Further, even if one could devise a scheme for placing water rights in the hands of many small sellers, there would remain good reasons not to do so.

The principal reason is given in the second condition above. Not all social costs and benefits associated with water use are private ones. On the cost side, for example, the extraction of water from an aquifer will lower the level of the water table, increasing the costs of extraction at other wells. Further, private water extractors will not consider the possibility that their actions, together with those of other private extractors, will result in overpumping, thus damaging the aquifer for later use and possibly ruining it altogether. Similarly, private water users will not fully take into account the effect their individual use has on the environment.

On the benefit side, private markets will not provide water for positive environmental purposes. For example, in Chile, where a system of private water markets has been introduced, the habitat of flamingos has been endangered. In the water systems of the Jordan–Israel–Palestine region, private water markets would fail to offset the effects of the falling level of the Dead Sea or even to take such effects into account at all.

Looking at it from a different perspective, society has an interest in seeing that all its citizens—even those who might not be able to afford water at free-market prices—have an adequate amount of water.

Beyond all this, the fact that many countries, including Jordan, provide water to farmers at subsidized prices implies that the governments involved consider water in the hands of farmers to have a greater value than the farmers' willingness to pay. Such a view may be because of environmental effects—the desirability of green open spaces, for example; the fact that the loss of agricultural employment would cause social unrest; or political issues. Whatever the reason, neither the MWI nor the economic analyst can ignore such considerations.

It should be noted, however, that at least these last two matters might be handled in the context of a free competitive market for water. Poor people could receive cash subsidies, and farmers could receive subsidies for farm output rather than a lower price for water. In the latter case, the efficiency of the choice of agricultural inputs would not be harmed; in the former, the choice of consumption goods would be made by the consumers.

Finally, as to the third condition, the state may well have more concern for the welfare of future citizens than do private buyers and sellers.

Free markets in water are thus not a good solution to the water management problem. Governmental involvement is essential. But the question now becomes that of how such involvement should be optimally designed. We discuss this at the end of the chapter, after a description of governmental water management and the water situation in Jordan.

Private-Public Partnership

As part of the economic restructuring program that Jordan has been implementing since 1990, the government has pursued a new policy of managing water supply and sanitation. Supported by loans from the World Bank, the government has awarded management contracts for the provision of municipal water and wastewater services and management of systems maintenance. In particular, a management contract has been awarded to a private firm to manage the water and wastewater systems of the Greater Amman area, and more are planned for other regions in the country. Under this arrangement, the contractor is required to take under its own management responsibility the staff of the Water Authority of Jordan (WAJ) that had been in charge of operation and maintenance of the subject area, and it has the right, after a specified number of months, to return to the WAJ any employees that it sees as unfit for the job.

In an attempt to attract private sector participation in project financing, the government has also considered the idea of build-operate-transfer (BOT) in the development of water resources.[2] Through such approaches, the government hopes to achieve several goals: expanding the coverage and improving the quality of service, generating resources to finance future investments, increasing economic efficiency, reducing government fiscal burdens, and introducing technological advances.

Partnership between the private and public sectors regarding water and wastewater has thus emerged as a promising way to improve the performance of public water and wastewater utilities, expand the coverage and improve the quality of service, increase operating efficiency, provide alternative mechanisms of financing investment in infrastructure, and reduce the burden on government budgets. It is unrealistic, however, to expect the private sector to overcome the inertia of government's institutional and operational inefficiencies and to make up for all shortages in investment. Privatization of the water resources has never been on the table.

The success of the private-public partnership depends on the regulation role that government plays. Protection of the public against monopoly, overpricing of services, and deterioration of service is mandatory to win the support and confidence of consumers. On the other hand, a private concern will not function adequately to meet the desired goals if government intervenes frequently in its operations under the guise of regulation, nor will it work for a loss or little profit. Thus government regulations have to address the concerns of the investor, the contractor, and the public. It is expected that private sector participation will lead to improved service quality and expanded coverage. To keep costs to consumers within limits of affordability, the government has to control water tariffs and contribute enough funds toward capital investments to make water charges affordable.

Many of the initial successes have resulted from relatively simple management improvements that did not require large investments or sophisticated technologies. Private firms have shown a remarkable capacity to improve the operation of existing infrastructure within a short time. For example, under the management contract for the Greater Amman region, performance efficiency of manpower has improved, collection rates have increased, and unaccounted-for water decreased from 54% to 48%. This is not to give the impression that management by the private sector has done magic, but the results testify to the superiority of private sector handling of water and wastewater operations, known to require prompt responses to maintenance requests, supply of needed inputs, and mobility in staff and equipment. Under government (WAJ) management, rules such as those regulating procurement, raises for efficient staff, and working overtime do not promote improvements in performance efficiency. Additionally, the management contract is being funded by a loan from the World Bank, whereas the previous management by the WAJ suffered from chronic budget deficits that handicapped performance.

The success of structural reforms in the water sector depends on sustained, determined political commitment to implement them; the support of supplementary reforms in regulatory regimes; a realistic and efficient tariff structure; and a clear policy on subsidy and its mechanisms to provide quality service to the poor. Effective regulation is a necessary, but not sufficient, condition. It is the cornerstone of sustainable private sector participation. But the creation of a regulatory framework does not by itself guarantee effective regulation; rather, implementation of such regulations is what makes the difference. Government has to allocate financial and human resources to guarantee honest implementation through supervision, monitoring, and active follow-up. It continues to lead in contacts and negotiations with donor agencies, borrow funds for investments, and guarantee repayment of foreign loans extended to its departments. The MWI, with its constituent entities, has been in charge of water administration and management since its establishment in 1988. In 1997, the MWI finalized an investment program with the year 2010 as its horizon. The investment program gets amended as years pass by and the situation changes.

We discuss later the methods through which infrastructure projects can be evaluated and the water system optimally managed.

The Population–Water Resources Relationship

With Jordan's population continuing to rise, the gap between water supply and demand at current prices will rise accordingly.[3] By the year 2020, if current trends continue, the per capita share of free freshwater potential (surface water 838 mcm and groundwater 266 mcm) available for all purposes will fall from the current 196 m^3 per person in 2004 (5.63 million persons) to only 127 m^3 per person (8.65 million persons), putting Jordan in the category of countries with an absolute water shortage. Soil water (866 mcm), used only for agricultural purposes, would, if conserved, add around 100 m^3/cap, making the total per capita availability about 227 m^3 in 2020.

Government's attempts to deal with the scarcity problem have focused not only on supply management, including rationing of water service, but also on demand management measures and the adoption of a public information policy. Nongovernmental organizations (NGOs) also were mobilized in the informational campaign in an attempt to increase public awareness and participation. Despite all measures, the coming scarcity problem will remain a major challenge facing water managers and the country at large. It will be more intense if the planned projects are not implemented in time. So far, government has secured only 42% of planned investment for water and wastewater projects. Delays in implementation of the projects are possible for reasons of finance or other unforeseen factors. A fallback solution obviously will be at the expense of irrigated agriculture. It is recognized that it is easier to move goods around than it is to move water (Allan 1991). Food imports will have to compensate for any loss of irrigation water. It takes 1,000 tons of water, for example, to produce 1 ton of wheat. It is easier to move 1 ton of grain from Nebraska to Jordan than it is to move 1,000 tons of water to meet the water shortage in the country.

Because of the inability of the WAJ to supply municipal water on demand to its entire service area, which is the whole Kingdom of Jordan, water rationing in many parts of the country has become the practice. Industrial, commercial, and tourism establishments are charged higher prices for their water consumption than are average consumers (the tariff specifies the equivalent of US\$1.41/m^3 to hotels and industries). These factors helped develop a trucking business for water abstracted from private wells, thus prompting overabstraction to take advantage of market demand, especially in summer. However, the government policy, currently being strictly implemented, charges high prices for every cubic meter abstracted from groundwater in excess of the permissible annual abstraction rate.

A key policy question in designing urban water policy and institutional reforms is that of the appropriate structure of water charges to ensure long-term sustainability of service. Water pricing touches on equity and the willingness of the consumer to pay (including the consumer's ability to pay). As such, it becomes a politically sensitive issue, and government will not surrender this matter to private firms managing water and wastewater services. In order to determine optimal pricing policies, estimates of demand and supply functions for water have yet to be made. Studies are needed to focus on understanding the nature of household demand for water and should attempt to express it in household demand functions. Specifically, the household sources of water supply should be characterized along with quality of water service, cost of water, and levels of water charges in relation to household income, and policy-related implications should be based on cross-section household survey data. Unfortunately, such household data have not been collected in Jordan. The effort to develop demand functions requires careful planning based on long-term data availability and equity in water allocation and use, taking into consideration various water rights, priority for reasonable domestic use, socioeconomic development imperative, and needs of agriculture, industry, tourism, services, and the environment. No such studies have ever been made for Jordan.

We discuss later in this chapter how water prices should be efficiently set.

The Dilemma of Unaccounted-for Water

About 97% of the WAJ service area (the entire country) is covered by piped water networks, a high percentage indeed. However, in terms of measures of efficiency—percentage of nonrevenue water, hours of water availability, and number of personnel per 1,000 connections—Jordan has a poor record. On average, the WAJ provides water for a duration of only about 8 to 18 hours per week. Manpower deployment efficiency is impaired by overemployment, as evidenced by the number of personnel per 1,000 connections, and financial operation has always been below the break-even level.

The most dramatic evidence of WAJ management inefficiency is the high percentage of nonrevenue water (NRW) or water that is not accounted for because of illegal connections, leakages, human errors in meter readings and processing, and other reasons. Nearly 50% of water produced by the WAJ is not billed or not accounted for.

This contrasts unfavorably with the situation in other countries. For example, NRW is only 8% in Singapore, one of the lowest rates worldwide, and about 30% in Bangkok, which is about the average among developing countries. The WAJ's efforts to reduce the high percentage of NRW have focused on the replacement of networks to minimize leakage and, it is hoped, illegal connections. Investment in this regard has been undertaken by the WAJ, assisted by concessionary loans from friendly donors. This program has brought recent modest reductions in NRW percentages.

Until these results began to be obtained, the additional water brought to the towns and villages of Jordan by heavy capital investments did not increase revenue. However, restructuring of the municipal water tariff, made effective in 1997, did bring in more revenue. In effect, law-abiding consumers have had to carry the burden of the WAJ's inefficiency, because they have been paying for the unaccounted-for water, whose loss occurred through no fault of their own. It is felt that more equity should be reflected in the water tariff, with the WAJ carrying the burden of its inefficiency.

The Irrigation Water Tariff

Water is a constraint on agricultural expansion in arid and semiarid countries, and Jordan is no exception. Renewable freshwater availability in the kingdom, including soil water that supports rain-fed agriculture, is on the order of 337 m^3/cap/y (2004), compared with an average of 1,700 m^3/cap/y needed to meet the municipal, industrial, and agricultural requirements (Haddadin 2003) meant to make agricultural exports offset agricultural imports.[4] Nonetheless, the charges for municipal, industrial, and agricultural water have been subsidized for decades.

Under current water policy directives, agriculture occupies third place in priority of allocation of new water, after municipal and industrial requirements, and first place in allocation of treated wastewater. Although less than 25% of arable land is irrigated, agriculture consumed about 63% of all available blue water in 2002.

In 1989, the irrigation water tariff in government-operated projects in the Jordan Valley did not cover the operating and maintenance costs, let alone the water's scarcity value. At that time, the incentive to adopt advanced on-farm irrigation systems was prompted more by increased agricultural yields and the expansion of irrigated land area than by the water charges. In 1995, the price was adjusted upward by more than double, and a block tariff was introduced. The revenues from water sales, when collected in total, do not come close to covering the costs of operation and maintenance.[5]

After upward adjustment of water tariffs for both agriculture and domestic use, and because of water stress, the efficiency of water use has increased. For example, irrigation efficiency in the Jordan Valley reached 70% in 2000, compared with 57% in 1994. The restructuring of water pricing has helped increase this efficiency. In order to ease transition to market pricing of water, the increase of water price to agriculture has been scheduled over a number of years. The

average price to agricultural users rose from about US$0.0052/$m^3$ in 1989 to US$0.031/$m^3$ in 1995 and about US$0.04/$m^3$ in 2000 (JVA 2005).

The Extent of Treasury Subsidies to Water and Wastewater Services

Jordan's Treasury remains heavily indebted despite debt forgiveness, rescheduling, and government buyback of debt. The ratio of total debt to gross domestic product (GDP) stood at 105% in 2000 (although it had declined drastically from its 1991 level of 180%). External debt amounted to 84% of GDP that year. The ratio of debt service payments to exports of goods and services (liquidity ratio) also fell to 15% in 1999. However, debt-rescheduling agreements have left Jordan with an inflexible debt service profile that persists over the medium term. The WAJ fails to receive revenue for about half the water it supplies (best practice is considered to be less than 15%), and cost recovery is low because of losses and low water prices. This necessitates large government subsidies to the WAJ, exceeding 1% of GDP.

Costs and Revenues of Irrigation Water in the Jordan Valley

The Jordan Valley Authority (JVA) is responsible for economic and social development in the valley. In the 1990s, the JVA recovered an average of 65% of its operating and maintenance expenditure, but only about 30% of its total annual costs, including depreciation (details of annual cost and expenditure are shown in Table 6-3 below). In terms of costs and revenues per cubic meter, operating and maintenance (O&M) costs averaged US$0.023 and capital costs US$0.027, totaling US$0.050/m^3, while the revenue averaged US$0.015/$m^3$, or about 30% of the actual total cost, leaving about 70% of the cost, or US$0.035/$m^3$, subsidized by the Treasury.[6]

Cost recovery, funding, and commercialization issues have recently come to the fore. Maintaining and improving service levels, and introducing institutional changes to carry them out, have intensified the JVA's need for flexible and sophisticated analytical and policy tools for utility management and financial planning. Further adjustment of the irrigation water tariff in light of diminishing agricultural returns would seriously jeopardize the sustainability of irrigated agriculture in the country. Jordan's entry into international agreements with the European Union and its ascension to membership in the World Trade Organization, coupled with the liberal import policies associated with the economic-restructuring programs, have burdened indigenous agricultural production. Additionally, the traditional markets of Jordanian agricultural exports in the Levant have been restricted by political rivalries and competition from other producers. Unless farm income is improved through better marketing

TABLE 6-1. Current Irrigation Water Tariff in the Jordan Valley

Water delivered (m³/month)	*Tariff (US$/m³)*
0–2,500	$0.01
2,501–3,500	$0.02
3,501–4,500	$0.03
More than 4,500	$0.05

Source: JVA 1995.

TABLE 6-2. Tariff to Recover Operating and Maintenance Costs

Usage level (m³/month)	*Tariff (US$/m³)*
0–1,000	$0.01
1,001–2,000	$0.02
2,001–3,000	$0.03
≥ 3,001	$0.05

Source: JVA 1997.

outlets, any increase in agricultural cost of production will increase the debt burdens of Jordan Valley farmers. For the purpose of serving the Jordanian farmer, the government is looking into the establishment of a specialized company with private sector participation to expand outlets and improve competitiveness. The current JVA irrigation tariff system has been in place since 1995 and makes no seasonal, geographic, or water quality distinctions. It is structured in four usage block charges, as shown in Table 6-1.[7]

A tariff structure to recover the costs of operation and maintenance is shown in Table 6-2.

The cost of water is relatively high in Jordan because of its limited availability. Water for municipal and industrial (M&I) uses is either abstracted from deep bore holes in the Highlands or pumped from the Jordan Valley in the form of surface water to Amman and groundwater to Irbid. The average estimated cost of M&I supplies delivered to the consumer is US$1.12/m³, compared with an average revenue of US$0.637/m³ in 1993–2002. This necessitated a subsidy of US$0.478/m³.

Groundwater used by farmers in the Highlands, financed exclusively by the beneficiary, is not subject to any charges, save when the beneficiary abstracts from a well more water than allotted (150,000 m³/y), in which case the beneficiary has to pay for each cubic meter of the overabstracted quantity (the charges are shown in Tables 6-4 and 6-5).

It is important to note that such costs do not include the scarcity rent of the water itself—the opportunity costs of not achieving the benefits that the water would bring in other uses. An efficient system of pricing would systematically reflect such rents, as is discussed in a later section.

TABLE 6-3. Annual Costs and Revenues of Irrigation Water in the Jordan Valley

	Irrigation water quantity (mcm)	*Annual O&M cost (US$ million)*	*Capital cost (US$ million)*	*Total cost (US$ million)*	*Revenue (US$ million)*	*Deficit/ subsidy (US$ million)*
1990–1992	264.3	5.8	5.5	11.3	1.0	−10.3
1993–1995	252.6	4.8	6.1	10.8	3.9	−7.0
1996–2000	234.3	6.1	8.2	14.2	5.5	−8.7
Average	250.4	5.5	6.6	12.1	3.5	−8.6

Source: JVA 2005.

Ignoring scarcity rents (which should not be done) and looking only at direct costs, the total cost of consumed irrigation water consists of the sum of O&M plus capital costs. A study made for the JVA by a U.S.-based consultant and funded by Agency for International Development (AID) regional funds indicates that the annual growth rate of investments in the irrigation sector throughout the last decade of the twentieth century was estimated at 4.83% (Forward 1998). Total costs, broken down into capital costs and O&M costs for different periods, are shown in Table 6-3. Volumes of water supplied are also shown, as are the direct subsidies that irrigation water received.

In contrast to the situation in the Jordan Valley, agriculture in the Highlands is sustained primarily by water from groundwater wells. Most of the licenses (two-thirds) of these wells define maximum abstraction quantities, and water meters are installed on almost all the wells, except that half of the meters have been deliberately or accidentally put out of order. There has been growing concern about overabstraction, and only recently did the Ministry of Water and Irrigation mobilize political support to legislate for groundwater control (see Chapter 2). By that legislation, the charges to be levied for overabstraction are shown in Tables 6-4 and 6-5.

The charges for overabstraction undoubtedly affect the feasibility of agricultural water use when they exceed a certain ceiling set by a blend of free abstraction and the charges for overabstraction. Note that the "free" quantity does not mean no cost to the well operator; it just means that the government does not charge for that quantity. The operator does pay for the entire operating and maintenance costs and for the depreciation of equipment. The well owner or operator will adjust the area farmed in light of the direct cost of production increased by the charges for overabstraction.[8]

Costs and Revenues Associated with Water and Wastewater Services

During the 1990s, the low level of water tariffs made it impossible for the MWI to come closer to the long-term objective of the Urban Water and Sanitation

TABLE 6-4. Charges for Overpumping Water for Licensed Wells

Water pumped (m^3/y)	Charges (per m^3)
0 to 150,000	Free
151 to 200,000	25 fils (US$0.035)
More than 200,000	60 fils (US$0.085)

Source: WAJ 2004.

TABLE 6-5. Charges for Overpumping Water for Nonlicensed Wells

Water pumped (m^3/y)	Charges (per m^3)
0 to 100,000	25 fils (US$0.035)
101,000 to 150,000	30 fils (US$0.042)
151,000 to 200,000	35 fils (US$0.050)
More than 200,000	70 fils (US$0.098)

Source: WAJ 2004.

sector to finance its operating expenses and capital investments from its own revenue stream. In fact, the WAJ operations have generated annual deficits in excess of US$50 million in 1990 and, in the process, have reduced the WAJ's net worth from US$175 million in 1990 to zero in 1995. The WAJ's inability to generate sufficient surplus to finance its investment program resulted in its incurring large debt obligations. By 1998, the WAJ's cumulative debt obligations amounted to about 10% of the year's GDP. This prompted the government to provide significant direct assistance (of nearly US$706 million by the year 1999–2000) to bail out the WAJ from its debt burden. However, debt relief is not the only resource that the government has been providing to the WAJ. Others have included capital investments and transfers to cover operating shortfalls that averaged US$70 million annually from 1997 to 1999. The income of the WAJ in 1990–1999 is presented in Table 6-6.

Table 6-7 shows indicators of the WAJ's performance efficiency in 1993–2002.

Legally, the WAJ is an autonomous corporate body with financial and administrative independence. Its budget is not part of the government's own budget, but the government is its backer and guarantor. A huge cost will accrue to society of covering the annual losses, recapitalizing the WAJ, and paying off its long-term debts. The WAJ's annual deficit alone exceeds 1.2% of GDP.

Consumers' Ability to Pay for Municipal Water

The poor, who consume 20 m³ or less of municipal water per quarter per connection, were accorded due consideration in designing the municipal water tariff. According to the World Bank, poverty in the country increased from 3% in 1987 to 12% in 1997. Many Jordanian analysts, using various poverty surveys, estimate poverty to about double the rate reported by the bank's missions.

TABLE 6-6. WAJ Historical Financial Performance (US$ thousand)

	1990	1992	1995	1997	1998	1999
A. Income before depreciation (operating revenues less operating expenses)	–5,065	–7,250	–10,373	–4,039	14,562	21,949
B. Net operating income (A less annual depreciation)	–26,786	–38,792	–51,972	–54,942	–36,525	–35,707
C. Net income (B less annual interest expenses)	–50,767	–59,848	–83,021	–79,320	–64,405	–67,850
Working ratio (operating expenses/ operating revenues)	1.17	1.19	1.19	1.06	0.84	0.76
Operating ratio (operating expenses including depreciation/operating revenues)	1.89	1.99	1.93	1.79	1.39	1.39

Source: WAJ 2004.

In 1997, under pressure from lending institutions, the government adjusted the tariff upward, increasing the rate for the lowest consumption block from US$0.28/m³ to US$0.49/m³ on average. Table 6-8 shows the average charge per cubic meter from the various blocks of tariff.

Table 6-9 shows the percentage of total household expenses, exclusive of wastewater collection charges, that water expense represents.

As wastewater charges are approximately 50% of the water bill alone, the average expense for water and wastewater together was on the order of 1.34% of total household expenses in 2003. This expense, however, does not reflect the total real cost of water service. The total operational expenses in 1999, for example, amounted to US$34.82 per capita, while the collection rate from consumers amounted to US$20.69. The average subsidy thus amounted to US$14.13 per capita. Compared with per capita GDP in that year (US$1,412), the cost of water and wastewater service, excluding capital cost, amounted to about 2.5% of the GDP, of which the consumer paid 1.46% and the government contributed the rest.

It is estimated that the average consumer can afford to pay about 2% of income for water and wastewater services. This means that the current tariff could be adjusted slightly upward to recover a higher percentage of the operational cost of water and wastewater services. To recover the entire annual cost, per capita, incomes would have to double—and probably keep increasing in the future as water costs increase. For full cost recovery, Jordan is in a race with time to achieve higher rates of economic growth and assure a balanced pattern of income distribution. Until then, water and wastewater services will continue to

TABLE 6-7. Performance Indicators of WAJ, 1993–2002

Item	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Number of employees	6,714	6,900	7,330	7,570	7,414	7,460	7,762	7,869	7,709	8,006
Total employee salaries (US$ million)	19.99	21.38	23.33	25.79	26.76	27.36	27.80	29.86	33.26	30.88
Average monthly salary per employee (US$)	249	258	266	284	301	305	298	316	360	322
Quantities of water billed (mcm)	92.41	97.82	104.07	108.03	108.76	105.62	109.24	112.91	117.59	124.93
Total water return (US$ million)	33.35	38.06	42.47	45.44	50.93	69.31	66.20	79.55	79.21	79.57
Sewage water return (US$ million)	14.76	15.96	17.36	16.17	18.78	23.78	24.18	24.76	31.58	28.74
Total return (US$ million)	48.11	54.02	59.83	61.62	69.70	93.09	90.38	104.31	110.79	108.32
Employment cost (US$/m³)	$0.22	$0.22	$0.22	$0.24	$0.25	$0.26	$0.25	$0.26	$0.28	$0.25
Average water return (US$/m³)	$0.36	$0.39	$0.41	$0.42	$0.47	$0.66	$0.61	$0.70	$0.67	$0.64
Average sewage water return (US$/m³)	$0.16	$0.16	$0.17	$0.15	$0.17	$0.22	$0.22	$0.22	$0.27	$0.23
Average total water return (US$/m³)	$0.52	$0.55	$0.57	$0.57	$0.64	$0.88	$0.83	$0.92	$0.94	$0.87
Total water connections (thousands)	532	548	569	595	621	650	672	696	773	726
Total sewage water connections (thousands)	265	278	290	307	325	360	376	391	415	444
Total beneficiaries (thousands)	797	826	859	901	947	1,010	1,048	1,087	1,188	1,170
Connections per employee	118.7	119.7	117.2	119.1	127.7	135.4	135.0	138.2	154.1	146.2
Quantities of water pumped (mcm)	165	175	234	234	237	239	239	235	239	245
Quantities of nonrevenue water (mcm)	72	77	130	126	128	134	129	123	121	120
Percent of nonrevenue water	43.90	44.20	55.46	53.83	54.14	55.85	54.21	52.04	50.80	49.07
Population (millions)	3.993	4.1394	4.291	4.444	4.60	4.7557	4.90	5.039	5.182	5.329
Per capita billed water (m³/y)	23.1	23.6	24.3	24.3	23.6	22.2	22.3	22.4	22.7	23.4
Per capita pumped water (m³/y)	41.3	42.4	54.4	52.7	51.6	50.3	48.7	46.7	46.1	46.0
Per capita billed water (L/day)	63.4	64.7	66.4	66.6	64.8	60.8	61.1	61.4	62.2	64.2
Per capita pumped water (L/day)	113.0	116.0	149.2	144.2	141.3	137.8	133.4	128.0	126.4	126.1

Source: WAJ 2004.

TABLE 6-8. Development of Average Municipal Water Charges, 1980–2003 (US$/m³)

Water block (m³)	*Block midpoint (m³)*	*1980–1985*	*1986–1988*	*1988–1990*	*1990–1996*	*1997–1999*	*1999–2001*	*2001–2003*
0–20	10	0.30	0.28	0.28	0.28	0.41	0.41	0.49
21–40	30	0.32	0.27	0.24	0.24	0.24	0.24	0.31
41–70	55	0.44	0.40	0.38	0.38	0.41	0.68	0.72
71–100	90	0.58	0.55	0.54	0.58	0.62	1.10	1.12
101–150	125	0.72	0.71	0.69	0.78	0.82	1.37	1.38
151–250	200	0.81	0.83	0.83	0.95	1.03	1.75	1.77

Source: WAJ 2004.

be subsidized. Any elimination of the subsidy will be at the expense of other obligations by households, and this would prejudice the standard of living and the quality of life.

Table 6-9 indicates that, with subsidies to water and wastewater upheld, there is room for increased charges from the beneficiaries. The percentage of expenses assigned to water and wastewater can be increased to 2%, as compared with the percentages indicated in the table. The government may find itself forced to adjust the water tariff upward to account for the increase in fuel prices enforced in 2005 and 2006.

Farmers' Ability to Pay for Overabstraction

We now turn to the question of the cost of groundwater abstraction and its affordability. This cost varies with location, crop, and technology. In open-field vegetable farms in the Highland areas, the estimated water requirement for one dunum (du), corresponding to an application rate of 4 mm/day/du during eight months of cropping, is 1,000 m³/du/y.[9] The allotment given to each well under the new Groundwater Bylaw of 2002, 150,000 m³, is sufficient for the irrigation of 150 du without incurring additional charges. If a farmer wanted to increase the planted area by, say, 75 du, his decision requires the payment of US$3,884 to the WAJ for the overabstracted amount. The additional cost raises the total cost of water, estimated at an average of US$0.22/m³, by 8% to US$0.23/m³. The increase eats up an average of 40% to 30% of the net profit that such a farmer would expect from this classical farm in a year of depressed prices, or 10% to 7% of the net profit in a good year, depending on the cropping pattern. The adverse economic impacts of charges for overabstraction increase with the size of the farm. However, the present policy of charging for overabstraction may reduce, but is not likely to eliminate, overpumping from aquifers. At current charges, farmers can afford the modest increase in the cost of production.

TABLE 6-9. Development of Household Water and Wastewater Annual Expenses

Year	*Water expense as % of total household expenses*			*Wastewater expense as % of total household expenses*			*Household water and wastewater expense as % of total household expenses*		
	Jordan	*Rural*	*Urban*	*Jordan*	*Rural*	*Urban*	*Jordan*	*Rural*	*Urban*
1980	1.06	1.30	0.94	0.53	0.65	0.47	1.59	1.95	1.41
1987	0.76	0.56	0.82	0.38	0.28	0.41	1.14	0.84	1.23
1992	0.59	0.51	0.61	0.30	0.25	0.31	0.89	0.76	0.92
1997	0.73	0.84	0.71	0.37	0.42	0.36	1.10	1.26	1.07
2003	0.89	0.62	0.98	0.45	0.31	0.49	1.34	0.93	1.47

Source: WAJ 2004.

Water consumption per unit land area differs with the environmental conditions of the farm. In the Badia region, for example, for an average farm of 150 du with 60 greenhouses, a case investigated by the authors, the total consumption of water reaches 180,000 m^3 per growing season, or an average of 1,250 m^3/du/season. This makes the cost of water US\$0.23/m^3 for the farmer. In the Mediterranean environment region in the neighborhood of Amman, on the other hand, the cost to the farmer is on the order of US\$0.56/m^3, where a dunum requires an average of 725 m^3 per growing season. In terms of cost per dunum, the comparison becomes US\$290 in the Badia to US\$410 around Amman, energy and land costs included. The saving in the cost of water per dunum in the Badia more than offsets the reduction in agricultural yield per dunum compared with the more moderate environment of the Mediterranean region around Amman. Following the enforcement of the Groundwater Bylaw, farmers will have to pay a charge of US\$1,059 for overabstraction beyond the allowable limit of 150,000 m^3. Divided by the area of 150,000 du, the extra cost is US\$7/du, or an overall increment of water cost of US\$0.006/ m^3. Such an increase in the water price represents 3% of the net profit that accrues from owned farms and 14% from rented farms. The most probable response to the charges for overabstraction will be to increase water use efficiency, adopt automated systems of irrigation to reduce labor cost, and increase the yield per unit flow. Farming will become more intensive, and overabstraction will continue in the Badia.

The most important adjustment will have to be made by vegetable farmers. Indeed, to keep their farms profitable, farmers—users of wells—are decreasing the quantity of water they pump and reducing the area they crop. In the Governorate of Mafraq, for example, vegetable farms cover about 44% of cropped land (or 29,000 du), of which about 70% are operated by tenant farmers (approximately 20,000 du). If these farmers continue to use the quantities of water per dunum to which they have been accustomed, they will have to reduce their cropped area by one-third to stay within the free-water zone. If they improve water use efficiency to apply only 750 m^3/du instead of the usual 1,000 m^3/du, they still will have to decrease the cropped area by 11%. The production of vegetables could be improved by advanced farming methods, so total production may not even decrease. Although farming in the Mediterranean climate may be expensive because of land rental prices, the charge for overabstraction could make a difference in profitability. The structure of overabstraction charges may not prove successful in achieving the desired objectives in all cases, however.

Water Demand Management

Pricing is one of the most important measures for demand management to reach an efficient, sustainable, and socially acceptable use of scarce water resources. Water service can be sustained only if its cost is met; failing that, the quality of service will deteriorate. Cost recovery must be done either through water or water-associated pricing or through governmental subsidies reflecting the view that water has societal benefits that exceed private benefits. In particular, a policy that intends to provide water for free implies the need for subsidies from other segments of society to the water-providing agency. A water-for-free policy along with a run-down distribution system can often result in the powerful and rich getting water cheaply through self-financed pipe systems while poor people buy water at excessive rates or drink unsafe water (Liu et al. 2003).

A free-water policy also has other problems. Longtime subsidization distorts people's perception of water as a scarce and therefore valuable resource. Low water prices thus are likely to engender excessive use and waste of water, worsening an already tenuous situation. The most effective instrument to break this vicious cycle is to allow for water prices that recover the cost of water supply and enable financial sustainability.

We discuss efficient water pricing more generally in a later section. Here we note two points. First, as explained earlier, free-market pricing of water will generally not be socially optimal. And second, although the capital costs of water infrastructure must be met, it is generally not efficient to do this in the water tariff itself (even assuming that there is not to be a subsidy). This latter point requires some further discussion.[10]

Suppose first that a particular large piece of infrastructure has been built and will not be used to capacity for some time. For simplicity, assume that its operating and maintenance costs are zero. Then it cannot be optimal to increase the tariff for water use in an attempt to recover the capital costs of the infrastructure. To do so would be to reduce water consumption, even though it costs nothing to use the already built infrastructure. This would unnecessarily lower the benefits that can be brought by the water system while leaving costs unchanged. Of course, if operating and maintenance costs are not zero, then charging for them in the water price makes sense. Capital costs, however, should be charged for *in the water price itself*, provided that the increased usage taxes the capacity of the system.

That is not to say that capital costs should not be recovered. Rather, they should be recovered in a way that does not alter incentives for water use at the margin. This can be done through a system of connection charges, taxation, or other ways not directly affecting water usage.

Social considerations play a major role in the pricing of household water (a major component of the municipal water sector) and are also relevant in the industrial and agricultural water sectors. There are, however, substantial differences between requirements for household water and that used elsewhere. Agricultural production can often use water of lower quality than that used by households, such as recycled, brackish, or untreated surface water. In addition, the elasticity of water demand—the response to changes in water prices—is higher in agriculture than in basic domestic water demand. Another significant difference is that water supply to households, industry, and services must be extremely reliable, whereas the reliance of the agricultural sector on a dependable supply of water may not be as important, especially when water is to be used for low-cash crops. As a result, agriculture, although the main water-consuming sector, tends to be the one that offers the largest potential for adapting water requirements to changes in the water availability.

Jordan's agriculture is subject to considerable uncertainty as to water supply, but it also shows great flexibility because of the possible choices among a large variety of crops that can be grown in the same area. This flexibility is due to annual field crops, such as wheat and maize, which can be grown by using different amounts and qualities of water during different growing seasons. Planning methods to deal with such issues have been developed and used, but the sensitivity of agriculture to water remains an important issue for many countries in formulating water policies (Amir and Fisher 1999).

Affecting Agricultural Water Use through Price Policies

The government can use policy instruments to affect water usage. The two principal instruments are price incentives and quantity constraints.

Salman et al. (2001) evaluated the responsiveness of agricultural water demand to prices for water of different qualities—surface, brackish, recycled, and groundwater—in the Jordan Valley and the Highlands. The applied linear programming model allowed also for a subsequent estimation of water price elasticity. Results for the valley show that when the price of surface water rises (for example, from US\$0.20/m^3 to US\$0.25/m^3), a reduction in the irrigated area occurs (from 23,513 ha to 22,052 ha). This is because some crops, such as alfalfa, leave the optimal solution, as they are no longer profitable compared with the other crops. The quantity of surface water demanded is reduced by 13 mcm/y.[11] On the other hand, the use of other water types, mainly recycled, increases by 6 mcm/y, partially compensating for the decline in surface-water usage.

Table 6-10 shows the price elasticities—the percentage change in water quantity demanded because of a percentage change in water price—for each water type and for all water types together. The elasticities in the "All water" rows are with respect to the price of the given water type just above.

The demand curve for surface water in the Jordan Valley that is implied by the optimizing model is shown in Figure 6-1.[12]

The own-price elasticity of surface-water demand was about –0.04 at the actual surface-water price of US\$0.049/m^3. This is a very low elasticity showing that, starting at that price, an increase of 1% in the price of surface water will decrease the quantity of surface water demanded by only 0.04%. This,

TABLE 6-10. Price Elasticities for Irrigation Water of Different Qualities in the Jordan Valley

Type of irrigation water	*Price elasticity at actual price*	*Price elasticity at midpoint*
Surface	–0.0414	–0.9068
All water	–0.0269	–0.4229
Brackish	–0.2930	–1.0052
All water	–0.0101	–0.0344
Recycled	–0.4272	–1.2117
All water	–0.0632	–0.0712

Source: Salman et al. 2001.

however, is almost entirely due to the fact that the actual price is so low that a 1% increase adds only about US$0.0005/m³ to the price, hardly affecting demand. By contrast, at the midpoint of the range of surface prices considered (US$0.575/m³), the own-price elasticity of surface water demand is about –0.91. This means that, starting at that price, an increase of 1% in the price of surface water (corresponding to about US$0.058) will decrease the quantity of surface water demanded by about 0.91%, so that demand is slightly inelastic. Because the demand curve is approximately linear, what matters is its slope. An increase of US$0.01/m³ reduces surface-water demand by about 1.4 mcm/y.

Still using the optimizing model, one can regress the total water quantity demanded on surface-water price, holding the prices for brackish and recycled

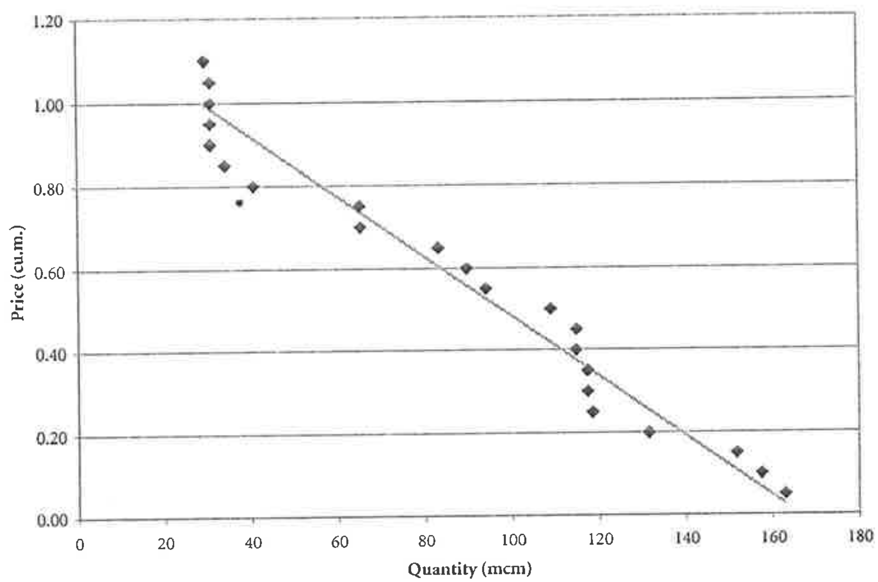

FIGURE 6-1. Surface Water Demand Curve in the Jordan Valley

TABLE 6-11. Water Quantities, Total Net Returns per Hectare, and Maximum Water Prices for Different Farm Types in the Jordan Valley

	Farm types				
	Vegetables				
	Plastic houses	*Drip irrigation*	*Surface irrigation*	*Citrus*	*Fruits*
Water quantity (m³/ha)	3,730	3,690	2,340	9,560	17,440
Average total net income (US$/ha)	2,458	777	565	4,520	8,785
Water expenses (US$/ha)	79	78	50	203	369
Maximum price of water (US$/m³)	0.68	0.23	0.26	0.49	0.52

Note: Figures, especially water prices, have been updated to 2003.

water constant. The overall water demand elasticity is –0.027 at the actual surface-water price of US$0.049/m³ but –0.42 at the midpoint price of US$0.575/m³ for surface water. Again, the demand curve (not shown) is linear, and total water demand decreases by about 1.3 mcm/y when surface-water price increases by US$0.01/m³.

The effect on overall water demand of increasing prices of brackish and recycled water is an elasticity of –0.01 with respect to the recycled-water price and –0.06 with respect to the brackish-water price at the actual prices. Even at the midpoints of the ranges studied, the elasticity is also small, being –0.07 with respect to the recycled-water price and –0.03 with respect to the brackish-water price.

In evaluating and discussing water demand management, it is worthwhile considering the water use and profitability of the different farm types. Salman (1994) presented and discussed the quantities of water allocated to each farm type and the corresponding profitability. The quantity of irrigation water used varies from one farm type to another according to the prevailing cropping pattern. The specialized plastic-house farms required 4,130 m³/ha of irrigation water, considerably lower quantities than did farms with fruit trees (17,440 m³/ha) and citrus (9,560 m³/ha). Farms that cultivated bananas and other fruits used an even higher rate of water per hectare. The affordability of the excessive use of this scarce production factor was mainly attributed to the low water price at that time (World Bank 1989), at up to US$0.009/m³; it has risen since then to US$0.0211/m³.

Table 6-11 shows the high variation of water consumption among the different farm types, as well as the maximum water price that each type would be able to pay. At this price, net revenues equal zero, provided that prices of other inputs remain constant. Although the specialized citrus and fruit farms had higher returns per unit area, they earned lower returns for the water used when compared with the specialized plastic-house farms. Maximum water prices were up to US$0.68/m³ for plastic-house farms, whereas prices did not exceed US$0.49/m³ for specialized citrus farms and US$0.52/m³ for fruit farms.

A general increase in water price would therefore overproportionally affect cultivation of vegetables, fruits, and citrus in the open field and support the tendency to change toward production in plastic houses. Expected consequences would include a loss in the variety of cultivated crops and an increased requirement for investments by farmers. That increased requirement might also engender further negative secondary effects, as small-scale family enterprises, which constitute the majority of farms in the Jordan Valley, might not be able to cope with the increased financial demands (Wolff and Nabulsi 2003). Benefit pricing, the coupling of water prices to the type of cultivation, has the potential for alleviating the consequences of the required adaptation of the current water prices to the real value of water as a scarce resource. Recent research indicates that, if this is seen as a desirable policy, water prices should be higher for fruit trees such as banana, apple, and citrus than for vegetables (Wolff and Nabulsi 2003).

Farmers' Response to Adjustments in Irrigation Water Tariffs

The Agricultural Sector Adjustment Loan (ASAL), extended to the Jordanian government by the World Bank, was first suggested in 1990, when the government was consulting with the International Monetary Fund on measures to help alleviate its economic and fiscal crises. The ASAL, in the amount of US$80 million, was approved in 1995, along with a US$7 million technical assistance loan. The objective was to promote efficient use of water resources through managing demand, deregulating markets, restructuring institutions, and improving planning and investment in the sector. Irrigation tariffs were raised by 150%, from US$0.008/m³ to US$0.021/m³ in 1997. Price controls for food, including fruits and vegetables, were abandoned; producer subsidies for wheat, barley, and tomatoes were lifted; and the land-lease market in the Jordan Valley was deregulated, allowing longer-term leases of land than the 10-year ceiling previously set.

Although agricultural exports grew by 11% per annum from 1995 to 1998 under the prevailing cropping pattern, it was expected that the ASAL would result in a shift from water-intensive crops to low-water-use crops. The results on the ground proved to be modest, however. Water meters installed on groundwater wells led to better knowledge of abstraction quantities, but they did not improve water conservation or income from water sales. Farmers were willing to pay more for water at a time when they were being squeezed by the decrease in subsidies.

The JVA raised the water tariff twice and in 1995 adopted an increasing block tariff structure designed to yield an average tariff of US$0.021/m³. Between 1995 and 2000, the average tariff was US$0.016/m³ based on billings and only US$0.012/m³ based on collections. But after 1997, the effective tariff declined by 10% as the JVA mitigated the adverse impacts of water shortages on farm incomes by forgiving or rescheduling collection as a form of financial relief. The tariff was levied on the total water flow per month in cubic meters per farm of 3.5 ha, in accordance with the schedule shown in Table 6-1.

It was anticipated that increased water tariffs would reduce agricultural water use, but this did not happen. Water allocation to farms has been made by the JVA on the basis of water availability and demand patterns, with quotas calculated for seasonal and perennial crops at times of shortage. Irrigation water shortages occur in lean years or when the Yarmouk River flow recedes in average and good years as a result of Syrian abstraction from springs and wells, as well as dams Syria had built in the catchment.

The first priority for water allocation under conditions of shortage is perennial crops, with the share per dunum scaled down to bridge the demand–supply gap. The justification for this allocation priority is the perceived need to protect the capital investment made in developing fruit tree orchards.

Next in priority come seasonal crops, with shares per dunum scaled down as well. The largest water shortage occurs in the dry months, but the supply increases in the winter months (November–April), when climatic conditions in Syria end the summer crops and their need for springwater, and precipitation in the lower catchment downstream of the Syrian dams contributes handsomely to the flow of the Yarmouk. Farmers of seasonal crops, facing the quota system for water allocation, opt to plant part of their crops during the early planting season in the Jordan Valley (August–September), expanding to the full area in November. Fruit trees normally are more profitable and owned by better-off farmers (owner–operators), whereas seasonal crops generally are planted by tenant farmers, and part of the profit goes to the owners. The quota system raises questions of equity, but these have been overruled by the economic considerations.

When the ASAL (World Bank 2003) validity was extended in 1993, a decrease in the planting of high-water-demand crops in favor of low-water-demand crops was projected, but the results on the ground were to the contrary. Bananas increased from 1,598 ha in 1994 to 2,060 ha in 2000. The irrigated area in the Highlands, dependent on groundwater that the ASAL meant to preserve by reducing overabstraction, increased instead, from 31,000 ha in 1996 to 42,000 ha in the year 2000, and most of the 11,000 ha expansion was in tree crops (8,900 ha), which consume more water per unit area of land.

It is not difficult to understand why this happened (Amir and Fisher 2000). The government was using two policy instruments at the same time: prices and quantity allocations.

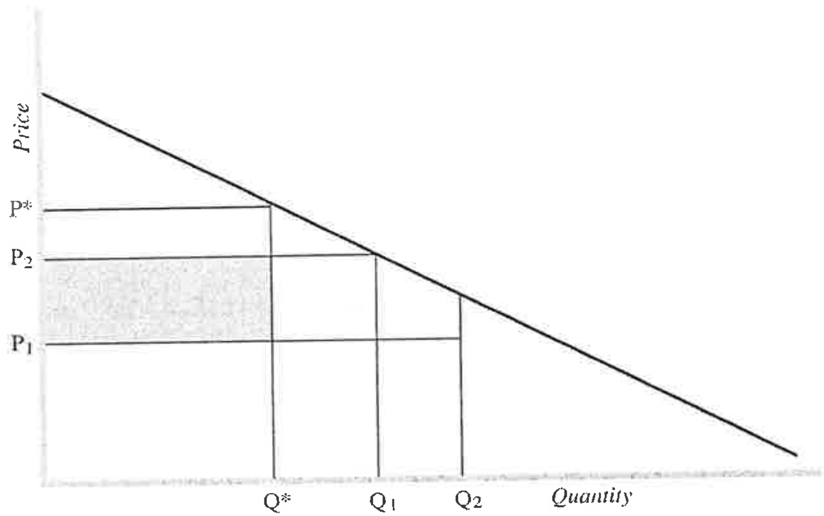

FIGURE 6-2. A Schematic Demand Curve for Above-Quota Water Quantities

Consider Figure 6-2. Here, Q* is the amount of water allocated to the farm, the quota. P1 and P2 are the low and high prices, respectively, and Q1 and Q2 are the corresponding amounts of water that would be demanded if there were no quotas. Note that these are both greater than Q*, indicating that the quota is a binding constraint on water use. In this circumstance, it is clear that raising the price from P1 to P2 has no effect on water usage. Instead, its only effect is to increase the payments made by the farmer for his allocated quota by (P2 – P1)Q*, the area of the shaded rectangle in the figure. In other words, if the government's allocation policy was effective, then its price policy was not.

Optimal Water Management and Policy: The WAS Model

We now return to the issues considered at the outset of this chapter. We explained there that a free-market system for water management will not work. This is partly because water markets are unlikely to be competitive and largely because social benefits and costs from water do not coincide with private benefits and costs, but include other things as well. In this context, how should governmental intervention be guided?

The answer lies in a systematic study of the values placed on water and, most of all, the resulting value of water itself in different locations and at different times. In effect, this means building an economic model that reproduces the advantages of free markets while taking full account of those matters that free markets will not handle well.

Such a model has been built for Jordan by the Water Economics Project.[13] Here is a brief description of how this Water Allocation System (WAS) operates.[14] It uses the following inputs:

1. The country or region to be studied is divided into districts. Ideally, these should be as small as possible, but data typically exist by governmental entities, governorates in Jordan.
2. Within each district, data are collected on naturally occurring water supplies. These data include the location of sources, the annual renewable amount of each, and the cost per cubic meter of extraction and treatment.
3. For each district, demand curves are specified for each of three water-user types: households, industry, and agriculture. Such demand curves depend on factors that vary over time, such as population size, incomes, and agricultural prices; this corresponds to the fact that the WAS model is to be run for projected data for several future years.[15]
4. Infrastructure—conveyance lines, desalination plants, water treatment plants—is specified. This can be either existing infrastructure or possible future projects. In each case, operating costs and capacities are needed.[16]

After these data have been entered, WAS maximizes the net benefits that the country or region obtains from water subject to a large number of constraints:

1. The first set of constraints consists of the capacity limits on the infrastructure.
2. The second set consists of restricting water extraction from any source to that source's annual renewable flow; this can involve constraints across districts, if different districts can use the same underlying water source.
3. The third set consists of constraints on water use or prices placed by the user of the model, as explained below.
4. Finally, further constraints state for each type of water and each district that the amount of water used in the district cannot exceed the sum of the water extracted there plus the water imported into the district less the water exported from the district.

Although the constraints in the first three sets can be varied by the user, the constraints in the fourth cannot. Thus, for example, the user can permit over-pumping of a particular water source or specify a particularly wet or dry year; he or she may also inquire as to the effect of changes in infrastructure capacity. But the user cannot change the physical facts embodied in the water constraints themselves.

We come then to the question of what is being maximized, of what is meant by net benefits from water. In the case of purely private benefits, this can be described as total gross benefits less costs. Total gross benefits consist of the amount that water users would be willing to pay for the quantity of water they receive. It is not hard to show that this can be measured by the area under the consumers' demand curves as water quantities go from zero to the amount actually supplied. Costs mean the total costs (excluding capital costs) of water supply and also an environmental charge where appropriate.[17]

The handling of the social benefits and costs that are not simply private benefits and costs can be thought of in two ways. The first of these is direct. Suppose, for example, that farmers are to receive a subsidy of US$0.10/m^3. This is a statement that water in the hands of farmers is worth US$0.10/m^3 more to society than it is to the farmers themselves. One can handle this by raising the agricultural demand curve for water by US$0.10, and then using the area under the altered curve to measure benefits. Unfortunately, for more complicated price policies, such as block rates, or for nonprice issues, such an approach is difficult to implement.

The second approach is easier. This amounts to permitting the user to impose constraints that directly reflect general policies. For example, the user can require that farmers receive water at a price US$0.10 lower than do other water users or according to a set block-rate schedule. Among other things, he or she also can set aside water for environmental purposes (or any other purpose), restrict the usage of treated wastewater, and require that certain groups of consumers obtain some minimum amount of water.[18] WAS then maximizes the objective function subject to these constraints that reflect public values and policy.

Now, as is generally true when something is being maximized subject to constraints, the optimal solution is accompanied by a system of shadow prices. Each shadow price is associated with a particular constraint, and each shows the amount by which systemwide net benefits from water would increase were the corresponding constraint relaxed by one unit. For example, the shadow price associated with a particular conveyance line capacity describes the systemwide change in net benefits that would be achieved were that capacity one unit larger.

But the most interesting shadow prices in the WAS solution are those corresponding to the water constraints themselves, the fourth set listed above. The shadow price of the water constraint in a given district shows the systemwide addition to benefits that would be achieved given (costlessly) one more cubic meter of water per year in that district. *These shadow prices are the true values of water in the different districts,* given the policy-imposed constraints involved and the rest of the input data used. Further, the shadow price of water at a source in situ is the scarcity rent of water from that source—the amount the country or region should be willing to pay to obtain an additional cubic meter of water from that source. The shadow price at any location that uses water from that source consists of the scarcity rent plus the per-cubic-meter costs of extraction, treatment, and conveyance to the user.[19]

If only private benefits and costs were involved, the water shadow prices would be the same as those arrived at by a free, competitive market. Note that they are not simply the marginal costs of extraction, treatment, and conveyance, but include a charge for scarcity value. Without additional government policies, such shadow prices would be the prices to charge to induce the efficient flows that would maximize the net benefits from water.

When the government has set price policies regarding water, the shadow prices will not be the ones seen by water consumers. In that case, they can be thought of as costs that the government is implicitly paying before reselling water to consumers at stated prices.

But shadow prices remain very useful even when the government decides that other prices should be charged. For example, the shadow price of water in a given district indicates the amount that it would be worth spending to obtain additional water there. This can be used to evaluate imports, new natural water sources, or desalination facilities. This brings us to the use of WAS to evaluate proposed infrastructure projects.

Evaluating Infrastructure to Avert a Water Crisis in Amman

Here we will concentrate on predictions for the year 2020 and the water problems in Amman. In this connection, we analyze a series of infrastructure projects that all have been undertaken, planned, or contemplated by the government. The discussion that follows is drawn from Chapter 7 of Fisher et al. 2005.

Figure 6-3 shows shadow prices for 2020 for the different governorates, assuming, contrary to fact, no changes in infrastructure after 1995 and no subsidization of water for agriculture. (Without the latter assumption, the water crisis in Amman would be at least as severe as depicted.)

These shadow prices show water crises in at least Amman, Zarqa, and Ajloun, with the shadow prices in Amman and Zarqa exceeding US$30/m^3. Such shadow prices for water are clearly unacceptable as actual prices and, with neighboring districts at much lower shadow prices, indicate a strong need for infrastructure improvements.

In Amman, the main infrastructure problem plainly involves getting water to the capital. In 1995, a conveyance pipeline carried 45 mcm/y of water from Balqa to Amman at an operating cost of US$0.22/m^3. Were no further infrastructure to be built, the shadow price in Amman would exceed US$30/m^3 by 2020, yet the shadow price in Balqa, in the Jordan Valley, would be only about US$0.16/m^3, and shadow prices elsewhere in the valley would be lower still. Plainly, the capacity of that pipeline will not be sufficient by 2020. Hence, either the pipeline must be expanded or other ways found to supply the capital.

Note that this is a problem not of water ownership, but of infrastructure. The shadow price of water ownership remains relatively low in the Jordan Valley despite the enormous shadow price in Amman. Because it is always the case in

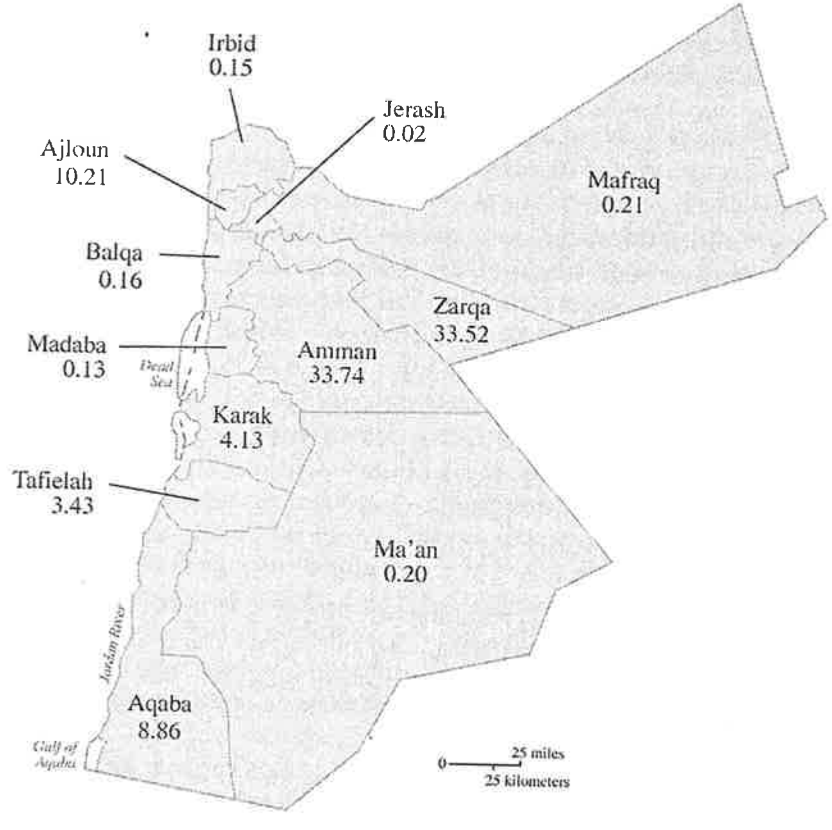

FIGURE 6-3. Baseline Shadow Prices in 2020 (US$)

the optimum solution of the model that, for conveyance from A to B, $p_B = p_A + t_{AB} = \lambda_{con}$ (where p_B denotes the shadow price at B; p_A, the shadow price at A; t_{AB}, the operating cost of conveyance per cubic meter between the two points; and λ_{Con}, the shadow price of conveyance capacity), the shadow price of the capacity constraint on the Balqa–Amman pipeline must be US$33.36/m^3 of annual capacity shown in Figure 6-3. This is the rate at which systemwide benefits would increase per cubic meter of additional conveyance capacity.

Here is an illuminating illustration. In 1994, when the Water Economics Project was in its infancy, Dr. Munther Haddadin, the editor of this volume and a later major participant in the project, was exposed to the proposed methods for the first time. He asked a rhetorical question: "If the two of us were lost in the desert east of Amman, what then would be the value of a bottle of water?" The answer is that the value of water in the desert would be very high indeed, but the value of water in the Jordan River would not change as a result. In such

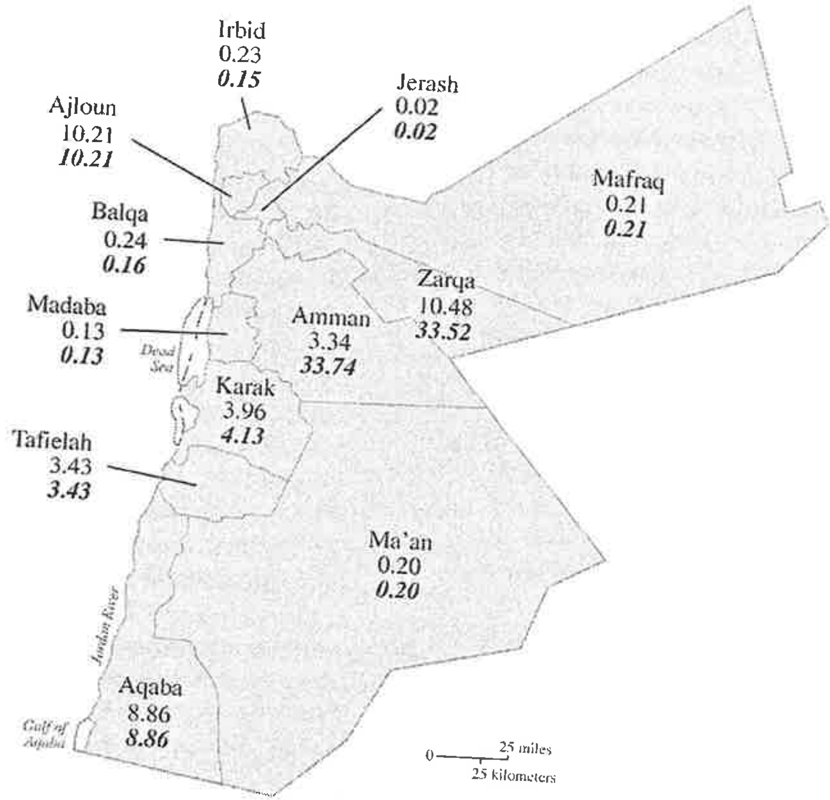

FIGURE 6-4. Shadow Prices in 2020 with (Upper Figures) and without (Lower Figures) Pipeline from Balqa to Amman Expanded to 90 mcm/y and Zarqa Ma'een Project Completed (US$)

a case, what is involved is a shortage of infrastructure to convey the water from the river to the desert, not a shortage of ownership of the resources.

Not surprisingly, therefore, the Jordanian government is expanding the Deir Alla–Amman pipeline from 45 to 90 mcm/y. In addition, the Zarqa Ma'een project would bring 35 mcm/y of desalinated brackish water from the Balqa district at a cost of US$0.47/m^3; it starts operation in 2006.[20] Beginning with these changes in infrastructure, we see the immediate impact on Amman in terms of shadow prices, which drop from US$3.58 to US$0.47—the cost of the Zarqa Ma'een project water—in 2010, and from US$33.74 to US$3.34 in 2020, as shown in Figure 6-4. Note that shadow prices increase along the Jordan Valley from which the water is withdrawn. Irbid sees an increase from US$0.15 to US$0.23, and Balqa from US$0.16 to US$0.24. The scarcity of water in these governorates increases with the increased competition for water. With an overall gain in social welfare of approximately US$67 million per year in 2010, and reaching more than US$1 billion per year in 2020, the pipeline and desalination projects are clearly essential infrastructure.

In the discussion that follows, we assume the capacity of the Deir Alla–Amman pipeline to have been expanded to 90 mcm/y, and the Zarqa Ma'een project to have been constructed.

In addition to the increased pipe capacity from the Jordan Valley (Balqa) to Amman, another approach to alleviate the crisis would be to reduce intradistrict leakage. The government of Jordan already has plans to bring leakage down to levels of 15% by 2010. Although this reduction in leakage clearly lowers shadow prices in the crisis governorates, particularly in Amman, where the shadow price falls to US$1.92/$m^3$, the values are still quite high in half of the governorates, especially Zarqa (US$6.92/$m^3$) and Ajloun (US$6.08/m^3). The total gain in social welfare from this reduction is an annual net benefit of almost US$220 million in 2020, suggesting that this could be a critical investment for Jordan over time.

In all of this, the shadow prices in several governorates adjacent to those in crisis—for example, Irbid, Balqa, Jerash, and Madaba—are much lower than those in Amman and Ajloun. This suggests the possibility of interdistrict conveyance. There are social limitations to these transfers, however, in that agriculture in the governorates with lower shadow prices is of great social importance, for employment as well as the aesthetic and cultural values associated with agriculture.

The Jordanian government is instead planning to use water from the Disi fossil aquifer to address the problem of persistent water shortages. It appears that pumping from this aquifer at a rate of 125 mcm/y is possible for a period of 50 years. A total of 70 mcm is currently being used from this system. An additional 55 mcm/y is added to the system in a new scenario, as well as a pipeline to Amman (initially of unlimited capacity, to let WAS determine the optimal size). Conveyance costs are estimated at US$1/$m^3$.[21]

The results obtained from WAS show that the Disi pipeline would not be used at all in 2010 but would very clearly alleviate the crisis in Amman in 2020 more than does reducing leakage alone. However, the shadow price in Amman remains quite high (US$1.13/$m^3$), and those in other districts are even higher. The net annual benefits for the Disi pipeline alone are approximately US$40 million in 2020. With a discount rate of 5% and a 20-year project life, the net present value is about US$500 million, which should be compared with the capital costs of the pipeline (estimated to be about US$600 million). This assumes no increase in population after 2020, so the actual net benefits are presumably higher.[22] Reducing leakage to 15% will have a more immediate impact on Jordan's social welfare, largely because it permits a net gain of 10% more water (as baseline leakage is 25%) throughout the country, whereas the Disi pipeline addresses one district's needs only. The volume of water that

would efficiently flow through the new pipeline, according to our results, is almost 40 mcm/y in 2020.

But that is not the whole list of possible large infrastructure projects. A long-standing proposal has been to construct a canal with an annual capacity of 850 mcm from the Red Sea to the Dead Sea, known as the Red–Dead Canal or Peace Canal. The difference in elevation would be used directly to desalinate seawater through reverse osmosis and to generate electricity, and after pumping, it would provide much-needed fresh water to northern Jordan. In addition, the project would make it possible to stabilize the level of the Dead Sea. This would be environmentally beneficial and could enhance tourism and therefore boost the region's economy.

It is worth examining whether this development makes sense from the perspective of water needs in Jordan, with a particular focus on Amman, the district with the highest concentration of population. In 2020, with the increased supply of water from the Jordan Valley to Amman, a new pipeline from Disi to Amman, and leakage reduced to 15%, the shadow price in Amman remains at a relatively high US$1.08/$m^3$.

Assuming the Red–Dead project would deliver fresh water to Madaba, the water could then be transferred to Amman at an operating cost of US$0.22/$m^3$. As long as the marginal costs of the desalination did not exceed the difference of US$1.08 and US$0.22, or US$0.86, the project would likely be beneficial from the standpoint of social welfare. It also would likely lower the costs of desalination, because the required energy—a major component—would come from the canal's own hydropower plant. But using current costs (estimated at US$0.60/$m^3$, inclusive of capital costs), shadow prices in Amman could drop below US$0.80/$m^3$.

We assume here that the Red–Dead Canal is to be undertaken for reasons other than solely the production of desalinated water. The capital costs of the canal itself therefore should not be attributed (at least not in significant part) to the desalination part of the project. Furthermore, the Red–Dead desalination project would make it inefficient to transfer water from the Disi Aquifer to Amman, because the difference between the two shadow prices would not justify the transfer costs (US$1/$m^3$). This does not mean, however, that building the line from the Disi Aquifer would not be valuable if the Red–Dead Canal is to be constructed; quite the contrary. The transfer from Disi may well be needed between 2010 and 2020, while the more complex and time-consuming Red–Dead project is being approved and constructed.

Evidently, by embodying the economics of water, the WAS tool can be a powerful aid to water decisionmaking in Jordan. It can be used to evaluate not only the systemwide benefits of infrastructure projects, but also the systemwide costs (not just the direct governmental costs) of different water policies. Finally, as shown in Fisher et al. 2005, it can aid in water negotiations and help guide international cooperation in water.

Summary

Dealing with scarce water resources is a major policy issue. Water in Jordan is state property, with the government in effect holding it in trust on behalf of the people. Water is considered by some as an economic commodity and by others as a good with critical social dimension. This understanding affects the allocation of resources, with the first notion advocating water allocation through private markets. Three important conditions are necessary to support the first argument: water markets must be competitive, cost and benefits must be private, and future discount rates must be those adopted by society. These conditions are not met in Jordan, meaning that free market is not a good enough solution to the water management problem, and government involvement is essential.

Partnership between the private and public sectors regarding water and wastewater has thus emerged as a promising way to improve the performance of public water and wastewater utilities, expand service coverage and improve the quality of service, increase operating efficiency, provide alternative mechanisms of financing investment in infrastructure, and reduce the burden on government budgets. The success of such partnership depends on the regulation role that government exercises to protect the consumer against monopoly, overpricing, and degradation of service quality. The success of the management contract for the Greater Amman area is attributed to the greater efficiency of the private sector management and adequate funding of the contract, as opposed to WAJ management and shortages in funding. A regulatory framework is a necessary but not sufficient condition for effective regulation by government; rather, it is the effective implementation of the framework that makes the difference.

A clear gap exists between water supply and demand, with increasing shortages foreseen in the future. Cooperation with bilateral and multilateral lending agencies has succeeded in providing about 42% of the funding for projects planned with the year 2010 as a time horizon. Delays in implementation will be at the expense of agricultural water. Water tariff is a highly politically sensitive issue and cannot be left to private firms to decide. Household demand and supply functions are yet to be established. The household sources of water supply should be characterized along with quality of water service, cost of water, and levels of water charges in relation to household income, and policy-related implications should be drawn based on cross-section household survey data.

The high nonrevenue water percentage is testimony to WAJ management inefficiency. Focus on renewal of distribution networks did not substantially reduce this percentage. The upward adjustment of tariffs in 1997 brought about increases in revenues. Law-abiding citizens carried the financial burdens of WAJ inefficiencies at no fault of their own. The upward adjustment of tariffs in 1995 for irrigation and 1997 for WAJ supplies helped increase irrigation water efficiency.

Municipal and industrial water is heavily subsidized by the Treasury. In 2000, the operational costs of water and wastewater, excluding capital costs, amounted to 2.5% of the GDP, of which the consumer paid 1.46% and the government paid the rest. Average cost of municipal water between 1993 and 2002 was the equivalent of US$1.115, compared with a water revenue of US$0.64 over the same period. Costs and revenues of wastewater are not included. Irrigation water is also subsidized, as cost recovery amounted to about US$0.016, compared with a cost of service of US$0.052/m^3, or about 30% of total cost in 2002. Further upward adjustment of the price of irrigation water without improving farm income will seriously jeopardize the sustainability of irrigated agriculture in the country.

The overcharges imposed by WAJ as per Regulation 85 for the year 2002 (the Groundwater Bylaw) are likely to reduce overabstraction from groundwater but not eliminate it. The most probable response to the charges for overabstraction will be to increase water use efficiency, adopt automated systems of irrigation to reduce labor cost, and increase the yield per unit flow. Farming will become more intensive, and overabstraction will continue in the Badia.

Pricing and rationing can affect agricultural water use. Analyses of cases in the text show the impact of price adjustment and calculate price elasticity. Upward adjustment will reduce open-field cultivation in favor of plastic houses and thus reduce the diversity of crops. When the World Bank extended the Agricultural Sector Adjustment Loan to Jordan, it was envisaged that upward adjustment of water tariffs would reduce water-intensive crops, but the results were to the contrary. However, increasing the price of irrigation water under a quota system does not produce the desired effect of water savings.

The Water Economic Project model uses shadow prices of water to help decide on infrastructure projects of water transfers. By embodying the economics of water, this tool can provide a powerful aid to water decisionmaking in Jordan. It can be used to evaluate both the systemwide benefits of infrastructure projects and the systemwide costs of different water policies. Finally, it can aid in water negotiations and help guide international cooperation regarding water.

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Notes

1. This is generally the advice of the World Bank as to managing water.

2. BOT is a system employed in building projects under private sector finance, whereby the builder undertakes to operate the project and collect revenues for an agreed number of years.

3. It is important to understand that demand, in particular, is not independent of price—even in the case of water. If demand and supply are equal only at an unacceptably high price, then water is truly scarce—the price reflecting the scarcity rent—and something must be done.

4. Agricultural needs were calculated at 1,500 m^3/cap/y, industrial needs at 125 m^3/cap/y, and municipal needs at 75 m^3/cap/y.

5. Farmers contest the charges and claim that the JVA's operation and maintenance

service is overstaffed and run inefficiently.

6. There are 1,000 fils to the Jordanian dinar (JD), which is equivalent to US$1.41. Hence, a U.S. cent is equal to 7.08 fils.

7. These delivery charges apply to a standard farm unit of 3.5 ha in area. If the farm unit is larger or smaller than 3.5 ha the upper limit of the consumption block is adjusted linearly accordingly. For example, if a farm unit is 5 ha in area, then the upper limit of the first block for which the first rate of US$0.011 is charged will be (2,500 m^3/3.5) = 3,571 m^3/month, and so on for the rest of the consumption levels of the other blocks.

8. It should also be noted that the overabstraction charge is not a charge for the scarcity rent of the water, but a charge to prevent harm to the aquifer involved.

9. One dunum is 1,000 m^2, or one-tenth of a hectare.

10. For a more extended discussion, see the section on capital costs in Chapter 2 of Fisher et al. 2005.

11. This is considerably greater than the reduction predicted by the regression equation.

12. The regression line shown in Figure 6-1 was derived by regressing the quantities generated by the optimizing model on the corresponding prices, not the other way around. However, we have followed the universal practice of showing demand curves with price on the vertical axis and quantity on the horizontal. This means that deviations of the model-generated points from the regression line should be measured horizontally rather than vertically.

13. Models have also been constructed for Israel and Palestine, and preliminary work has been done for models for Lebanon and Saudi Arabia.

14. For the most comprehensive treatment, see Fisher et al. 2005.

15. At present, the WAS model is a single-year model, with the conditions of the year variable by the user. A multiyear model is under construction.

16. So are capital costs, but they are handled outside the actual model in accordance with the discussion above.

17. Capital costs are not to be recovered in the price of the water, but are charged for separately, if not subsidized by the government. See our earlier discussion.

18. In actual runs of the model, the imposition of this third constraint does not appear to be required.

19. It also includes the per-cubic-meter shadow price on the capacity of infrastructure used.

20. The project was later amended and integrated into the Mujib Project. It began in 2003 and starts operation in 2006.

21. It is possible that the aquifer extends much closer to Amman, only 80 km distant, which would considerably reduce the transport cost. This possibility is still under exploration.

22. Note, however, that it also assumes that no other relevant infrastructure will be built. The discussion of the proposed Red Sea–Dead Sea Conduit that follows gives possible implications of this type of consideration.