MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support

GROUNDWATER MANAGEMENT COMPONENT

Curtailment of Groundwater Use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: An Economic Analysis

by

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Table of Contents

List of Tables

List of Figures and Diagrams

List of Appendices

Executive Summary

Groundwater from the Amman Zarqa Basin (AZB) is an important and valuable natural resource. Water from the Basin is being seriously over-abstracted. Consequently, the water table is dropping and water quality is declining. This threatens the durability of one of the principal sources of M&I supply for the Amman area, and is thus of strategic importance to Jordan. Irrigation, which is generally thought to be a relatively low-value use, accounts for about half of current abstraction.

This socio-economic study evaluates various options for improving the management of groundwater in the AZB uplands. Specific objectives of the study are:

- Study agricultural production and water use in the uplands.
- Estimate the value of groundwater used in irrigation.
- Show what will happen if over-abstraction continues.
- Study options for curtailing irrigation use, and determine the social and economic impacts of curtailment. Options studied include:
    - Raise water use efficiency with an Irrigation Advisory Service.
    - Government buy out of wells and/or farms.
    - Reduce cropped area by imposition of license limits.
    - Exchange recycled water for groundwater.
- Help define future role of agriculture in the AZB.

Evaluation of agricultural production and water use was based primarily on analysis of data collected from the Rapid Appraisal (RA) survey of 156 farms, conducted by the Groundwater Management Component in 2001. The survey covered farms irrigating from the Basalt-B2/A7 aquifer, which accounts for almost 89 percent of AZB groundwater.

Crop budgets were taken from other studies, and interviews with area farmers were used to adapt the budgets to reflect the current cost structure and farming practices in the AZB. A farm-crop model, based on these budgets, was then developed to estimate farm production and income.

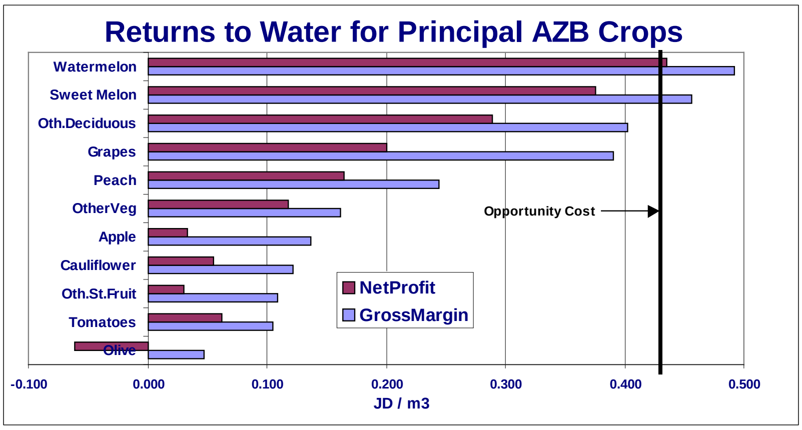
The value of water used in irrigation

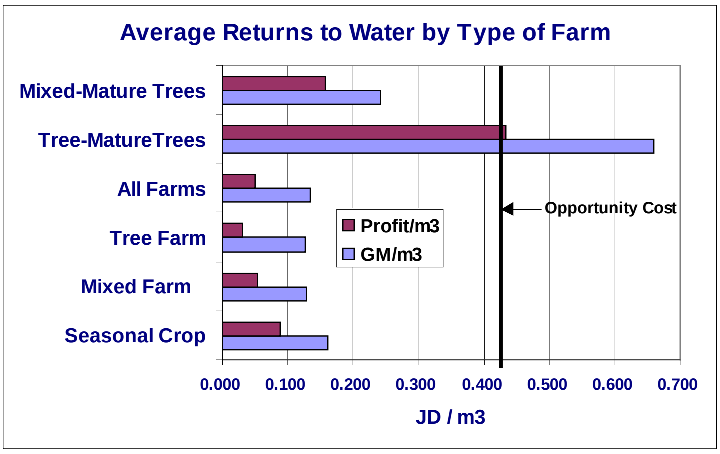
The crop and farm budget analysis was used to estimate the value of water in crop production. Value at the farm level was also estimated for each of the three main types of farm found in the area – that is, for *tree farms, seasonal crop farms* and *mixed farms*. Both *gross margin* and *net profit* per cubic meter (m3) were used as measures of water value. In each case the agricultural values of the water were compared to the *opportunity cost* of water, meaning its value to the national economy.

For purposes of this study, the opportunity cost of groundwater was defined as the government's cost to develop alternative sources of supply. Specifically, the estimated capital cost for the proposed Disi Conveyor Pipeline was used as the opportunity cost. Water from Disi is expected to cost JD 0.424 per m3, in annualized terms. This value may be lower than the true opportunity cost since it does not include any allowance for annual operation and maintenance costs.

The crop and farm water value analysis was based on typical farms. It shows that, on average, the value of water to irrigation farms is less than the opportunity cost. Obviously, many farms are above average. Such farms get higher than average yields and specialize in higher valued crops. The value of water to many of these farms is above the opportunity cost of water. From an economic point of view, it is not desirable to curtail water use by such farms.

The value of water used in production was found to vary from crop to crop (see the attached chart: "Returns to water for principal AZB crops"). Watermelon and sweet melons were found to have water values similar to the opportunity cost, but for most crops it is less. For tomatoes, the second most important crop (15 percent of area in the B2/A7), the value of water is quite low. For olives, the crop that accounts for the highest proportion of land area in the Basin (40%), the profit per m3 is negative. It is important to note that many of the olives and other fruit trees in the Basin have been planted quite recently and have still not reached the age of full production. Since the primary budget analysis used average yields for all olive plantings, the value of production and of water is lower than it would be for mature trees.





Farm budget analysis shows that the value of water for typical farms is very low at the farm level, which combines the values of all crops grown. The bottom portion of the attached chart "Average returns to water by type of farm" shows the value for average farms in the basin. This shows that the value of water used by most farms is quite low. The top of the chart shows adjustments in the value measures for tree farms and mixed farms (farms that grow both seasonal crops and trees), allowing for the effects of increased productivity as trees mature. This indicates that the value of water to tree farms is expected to be higher than the opportunity cost, after trees mature.

The effects of continued high abstraction

If nothing is done to curtail abstraction in the basin, this will have serious impacts on all water users. The water table will decline, and salinity levels will increase. This will have various negative impacts on agricultural users. Costs of pumping will increase, and yields of many crops will decline due to the salinity. The aquifer is expected to go dry in some areas, and it is estimated that 74 wells will have to be abandoned by 2015 as a result. Other wells will need to be deepened or reconstructed.

The attached table shows the estimated costs of the various effects of the continued over-abstraction. Results are expressed in present values (PV), and a 10% rate of discount was used for effects occurring over the next 20 years. Total impacts are expected to be from JD 11 to JD 21.

Summary of Losses if Abstraction Continues (JD)		
Item	Present Values	
	Low estimate	High estimate
Increased Energy Costs	**944,929**	**1,607,010**
Deepen & reconstruct wells	**670,869**	**1,214,034**
Abandon wells	**4,906,566**	**6,664,873**
Income loss due to salinity	**4,272,903**	**11,517,602**
Totals	**10,795,267**	**21,003,520**

The low and high range of the estimate depends upon various factors. In the case of energy costs for pumping from deeper water tables, the low estimate assumes that energy prices will remain constant, while the higher range assumes that they will increase by 5% per year. The low salinity estimate assumes that the average salinity level of the groundwater will reach 1500 ppm, while the higher estimate assumes that it will reach 2000 but that farmers will make some shifts in cropping pattern, toward more salt tolerant crops.

Restriction of abstraction by license enforcement

Jordan has a well licensing system, but it is not effective at limiting abstraction. About a third of the licenses have no quantitative limits. The limits set on most of the other two thirds of the licenses authorize annual abstraction of either 50,000 or 75,000 m3, but the current average abstraction on these wells is about 220,000 m3/year. Thus far the government has not attempted to enforce its license limits.

Although a metering system was implemented starting in 1995, it is still not fully operational. While around 90 % of the wells surveyed were found to have meters, only around 61 % of the meters were working.

If the government's licensing and metering system were fully operational, it would provide a good basis for limiting groundwater abstraction. For the system to be effective all well licenses must have limits and all wells must have working meters. Furthermore, all wells must have working meters.

It is recommended that the government move to strengthen its licensing system by setting limits on all wells that currently do not have them and by ensuring that all wells have meters that work.

Water charges

Given the fact that wells have already been established and that relatively large farms have been based on these wells, it will be difficult for the government to enforce limits that are very restrictive. This would result in large losses for farmers – especially for those who have invested heavily in tree crops – and would be difficult politically. If water charges were used in conjunction with license limits, however, this could provide necessary incentives for farmers to reduce their water use.

Most farms do not earn high enough incomes to afford water charges of JD 0.250 per m3, which is the rate currently paid by industrial well operators. The study shows that many farms could afford a block rate based on 0.015 JD/m3 for water within limit,[1] and 0.100 JD/m3 for water above limit. Farms that are highly productive could afford to buy water

[1] For this analysis it was assumed that all license limits would be set at 100,000 m3 per year.

above quota, but farms that only grow low valued crops and are not efficient could not afford the high valued water. They would either have to limit their crop area and restrict water use, or go out of business. But it would be their choice. Thus, water charges would constitute an *incentive system* which is *voluntary*.

Wells buy-out

Information developed in the farm-crop modeling system was used to estimate what it would cost for the government to buy out some wells. The objective of buy-outs would be to encourage the low-water-value producers to quit farming, and leave the water in the ground.

Two approaches were used in estimating the cost of buying out wells. The first was based on the expected farm incomes (gross margins) from lower than average farms, while the second was based on estimated investments in wells, pumps, irrigation systems and orchards.

The attached table shows what it would cost from JD 10.5 to JD 18.5 million to buy enough wells to save 20 MCM of groundwater. Water purchased in this way would have an average annual cost of 0.062 to 0.109 JD/m3. This is very low compared to the opportunity cost (0.424 JD/m3) of building new projects to get the water.

WELL BUY-OUT CALCULATIONS				
Values to consider (JD/farm):				
	Seasonal Crop Farms	Mixed Farms	Tree Farms	
TOTAL BUY-OUT COST (JD)				Grand Total
Based on income	4,975,218	3,262,265	2,299,903	10,537,385
Based on investment value	5,264,079	7,678,746	5,565,506	18,508,331
Annualized value of water (JD/m3 per year):				
Based on income	0.065	0.055	0.067	0.062
Based on investment value	0.069	0.131	0.162	0.109
Opportunity cost of water	0.424	0.424	0.424	0.424

It is expected that the buy-out program will work most effectively if the system of water charges is implemented at the same time. The two together will amount to a “carrot and stick” approach. Knowing that they will have to pay water charges, farmers who do not know how to produce high valued crops will be encouraged to sell their farms rather than lose money by having to pay the water charge. Farmers who object to water charges will have the option of selling their farm.

It is recommended that the buy-outs and water charges be implemented jointly so that the two approaches complement each other.

Irrigation Advisory Service

Studies carried out by the Groundwater Management Component indicate that there is considerable inefficiency in irrigation practices in the Basin. There is over-watering of some tree crops, for example. The studies indicate that it should be possible to reduce water consumption by 15% to 20% by providing suitable technical advice to farmers through an Irrigation Advisory Service (IAS). It is estimated that 5 MCM of groundwater could be saved after the IAS had operated in the Basin for five years and that this savings would continue beyond that point. The total present value of savings is estimated at JD 11.5 million, compared to a PV of cost of just JD 0.2 million.

Substitution of recycled water

Studies previously conducted by the Water Reuse Component have indicated that establishing constructing systems of pipes to supply recycled water to farmers does not pay because the farms do not earn enough money to be able to pay for the water which is delivered to them.

The present study finds that it makes good economic sense to supply recycled water to farms without charge. The value of groundwater saved in this way (the JD 0.424 opportunity cost) is greater than the estimated 0.380 JD/m3 cost of supplying pressurized water through pipes. The saving in pumping costs that they will experience as a result of receiving pressurized, piped water will help farmers to offset the added costs and lower returns that they are expected to experience as a result of using the wastewater.

It is fortunate that there is a specific need for recycled water in the Dulayl and Hashimiya areas, not far from the As Samara wastewater treatment plant, because the quality of their groundwater is deteriorating, and some of the wells are expected to go dry.

Future of agriculture in the Amman Zarqa Basin

Agriculture has an important future place in the AZB uplands, although it will entail considerably less use of water and less farm area than today. The more skilled and efficient farms are earning good returns to their money at present. And the incomes on many farms with tree crops can be expected to improve in coming years as the trees mature. To be able to pay for water and survive, some farms can be expected to improve their performance with technical assistance (IAS and agricultural extension) and better marketing. Fruit and vegetable exports from the uplands currently make an important contribution to Jordan's foreign exchange earnings. In this context, ***it is recommended*** that future marketing programs base their promotion on the value of crops that are irrigated with *clean groundwater.*

1. Introduction

Over-exploitation of the groundwater resources of the Amman Zarqa Basin (AZB) poses serious concerns for all who use these waters. Metropolitan Amman and nearby industrial areas, who obtain a significant proportion of their supply from the Basin, are experiencing increasing shortages and face the need to develop costly new water sources. Farmers who have established expensive deep wells in the area over the past several decades have seen the water table drop in some areas to the extent that wells have been abandoned. Added costs associated with pumping from deeper depths and caused by deterioration in water quality are of increasing concern to all users. The situation raises a number of serious questions:

- What are the impacts of over-abstraction?
- Can the current over-exploitation of groundwater resources in the AZB be controlled in the face of rapidly increasing demands?
- How can the AZB aquifers be more effectively managed to promote the durability of the supply for municipal and industrial purposes, while preserving quality and thus ensuring sustainable use in the future?
- What role should irrigated agriculture, which is generally thought to be a low-value use of water, play in the future water use scenarios for the Basin?
- If abstraction of water for irrigation is to be curtailed, how should this be accomplished?

The Groundwater Management Component[2] is one of the two primary working groups in the Water Resource Policy Support activity. The main objective of the Groundwater Management component is the exploration and implementation of options for reducing groundwater use in irrigated agriculture in the AZB uplands. The principal output of this component will be action plans for irrigation water management in the Northeast Highlands of the AZB, which will be completed as a result of a participatory review by stakeholders of the technical, economic and regulatory feasibility of alternative future groundwater management strategies.

1.1 Socio-Economic Considerations in Groundwater Management

Human life depends upon water, and thus water has great value in human consumption and for other domestic purposes. Water use has other important economic ramifications. Water is an essential input for agricultural production and is also an important productive input for many industries and services. Particularly where water supplies are limited, as they are in Jordan, it is expected that economic science – the study of the allocation of scarce resources – will have much to say about water use and allocation.

[2] All of the personnel of the Groundwater Management Component were instrumental in supporting the preparation of this study. Dr. Mohammed Chebaane, Team Leader, provided tireless support, numerous sources of reference, and careful guidance. Dr. Kamel Radaideh, Water Resources Specialist and consultant to the component, was skillful in organizing and translating questions and answers during field interviews of farmers. He was instrumental in providing information on well and irrigation system investment costs, on pump operations and irrigation practices, and on irrigated land values. Engr. Lana Al Naber, Junior Water Engineer, was quick and very helpful in preparing tabulations of information collected from the Rapid Appraisal survey, and in explaining survey responses. Engr. Ahmed Abu Hijleh, Groundwater Specialist, was tireless in his pursuit of statistical data on agriculture in Jordan and the Basin, and in collecting information from well license files of the Water Authority of Jordan.

My fellow consultant, Dr. Amer Jaberin, Professor of Agricultural Economics at the University of Jordan, provided information on prices and other facts about Jordanian agriculture and water use. Above all, he shared in developing the economic methods used in the study.

The allocation of water has broad social and economic aspects. Not only is water a basic human need for consumption, but it also provides the productive base from which people derive their livelihood. Irrigated agriculture provides food for the consumption of all humans, and it provides income to farmers and farm workers. This in turn stimulates employment and income in related economic sectors such as food processing, transportation, and input supply. Thus, the allocation of water has important implications for the social well being of the communities and groups that depend on it.

Water is a *strategic good* and derives much political importance from this fact. Regions or countries with adequate supplies of water have a basis upon which to grow and expand their economies. Thus, the need for water stimulates political activity. In regions where water is scarce, the potential for economic growth and improvement of wellbeing may be limited. If a community or a country has no reserve supply of water to rely upon in times of catastrophe, it may not be able to respond to or survive such events. In the case of groundwater aquifers, where recharge is limited, the decision of whether to mine the resource for current use must be weighed against the value of maintaining the resource as a *strategic reserve*.

Sustainability is another consideration in the allocation and use of water. Will the way in which water is being used at present interfere with the well being or capabilities of future generations? In Jordan, concern for sustainability is often expressed in terms of wanting to ensure the *durability of supply* from the aquifer. Because withdrawals from AZB have exceeded the rate of natural recharge, the water table has declined and salinity levels have increased. These factors threaten the durability of supply.

The allocation of water involves tradeoffs. Water used for one purpose inevitably comes at the cost of losing its benefit in some alternative use. To allocate water to one type of use will tend to *benefit* the people and communities that depend upon this use, and groups who are denied water for consumption or productive uses can be expected to experience *costs* as a result of not having it. Because of the resulting benefits and costs, which fall on different groups in differing ways, considerable political pressures arise regarding the allocation of water, particularly as its scarcity increases.

1.2 Principles of water allocation.

In deciding how water should be allocated, the guiding economic principle is that water, like other scarce resources, should be allocated to those uses where it has the highest *value*. But how is the value of water to be measured or determined? The value of most goods and resources is measured in terms of their price in the market. But water is usually not marketed like other goods – it is often allocated by government decisions - and thus market prices are often not available as a value measure. Consequently, economists have taken alternative approaches in valuation.

Where it is used in agricultural or industrial production, the value of water can be estimated through what is known as the *residual value* or *imputation method.*[3]
In this approach, the value added or profit per m3 of water is derived from the farm budget or industry profit and loss statement. Normally, it is recognized that value estimates obtained from the residual value method are high, since they usually include value derived from other factors which are not valued in the budget, such as land or the labor from farm family labor.

[3] A more complete discussion of water valuation can be found in Schiffler, Manuel, The Economics of Groundwater Maqnagement in Arid Countries: Theory, International Experience and a Case Study of Jordan, London and Portland, Oregon: Frank Cass Press, Published in association with the German Development Institute, 1998.

Domestic water users often pay a government (municipal) authority for the water they receive, but the price which governments charge is usually based on the *costs of delivery*, and perhaps on political considerations, rather than the value of the water to the consumer. Nevertheless, users in water scarce areas are often willing to pay private vendors for additional water deliveries, and the prices paid in such cases are said to reveal the preference of the water user. Thus, using the price that users pay private vendors is referred to as the *revealed preference* approach to valuation, and it provides an optional means of valuing water.

Another method of valuation is known as the *opportunity cost* approach. Here it is asked what it would cost to obtain additional supplies of water from an alternative source. The fact that groundwater in the AZB is now being over-abstracted has caused the Government of Jordan to begin development of alternative sources of supply for municipal and industrial (M & I) users in the Amman-Zarqa urban area. The costs of obtaining water from new projects such as the Disi Pipeline or the Wihdeh Dam on the Yarmouk River can thus be seen to represent the opportunity cost for AZB groundwater.

The value of water has multiple dimensions. Normally, the value of water is viewed in terms of *quantity* . However, water *quality* is also an important dimension of value. Water which is too salty or which is contaminated with other minerals or biological waste may be worthless for human consumption, or for use in agricultural production. In the AZB uplands, the salinity of water has already begun to increase as a result of over-drawing on the aquifer. *Time* and *location* are other important dimensions of water value. Water may be worth more in Amman, for example, than it is in other areas where supplies are more readily available. Water may be more valuable in the summer than in the winter.

1.3 How water is allocated in practice.

Under Jordan law, water falls under government control, to be managed in the public interest through various government authorities. The Water Authoirty of Jordan (WAJ) undertakes to supply domestic and industrial water through municipal systems, the Jordan Valley Authority (JVA) supplies surface water for irrigation, and the government, through WAJ, has authority over groundwater use. In view of the increasing scarcity of water, current government policy on allocation is to give first priority to municipal and industrial water needs, rather than to agriculture.

Current policy notwithstanding, over the past 40 years licenses have been issued that permit private farmers to extract groundwater for irrigation. The licenses provide a potential basis for controlling groundwater abstraction, but so far they have not been used to do this. Some but not all of these licenses carry quantitative limitations, but there has been no attempt to enforce these limits.

The government does not require irrigators to pay for the water itself. Thus, although the water is scarce and it has a substantial opportunity cost, since there is no payment, the farmer is not forced to take this scarcity into account in his decision making. Consequently, the farmer tends to use more water than he would if he had to pay for it, and he finds it possible to grow low valued crops that would not be grown if he had to pay for the water.

While irrigators in the AZB and other parts of Jordan do not pay any fee for the groundwater they use, they do incur substantial expenses to pump the water. The costs of pumping are high enough, particularly in the AZB uplands where pumping depths average 191 meters, to cause farmers to try to reduce the amount of water that they use. But under this system they are not forced to recognize the full value (opportunity cost) of the water. Thus, under the current system the farmer does not have sufficient *incentive* to conserve water.

1.4 Objectives of Socio-Economic Analysis

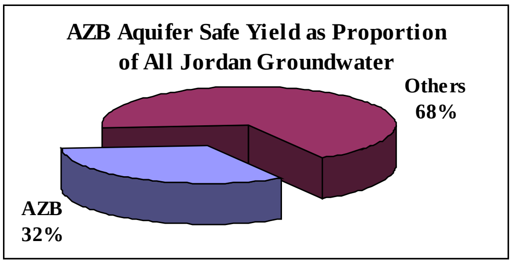
The purpose of the socio-economic analysis addressed in this report is to provide important background information for an action plan that is intended to limit the abstraction from the AZB aquifers. Specific objectives of the analysis are the following:

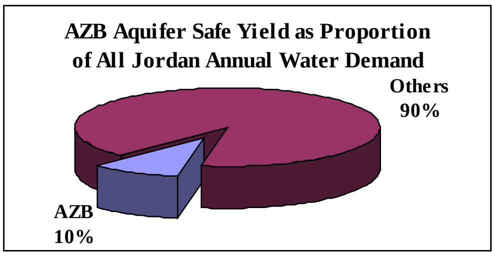
- Estimate the value of water used for irrigation, and to identify high and low value crops according to the financial and economic returns per unit of water consumed.
- Analyze social aspects of irrigation farming in the AZ Highlands, including role in population distribution, employment, and differential impacts on key social groups.
- Estimate the farm incomes generated by irrigation farming in the AZB, and analyze the aggregate value of this farming to the local and national economies.
- Evaluate what will happen to agriculture (production and incomes) if there is no management intervention, and as levels and quality water continue to decline.
- Analyze the socio-economic impacts of alternative groundwater management options including: 1) establishment of an irrigation advisory service, 2) regulatory limitation of water abstraction, 3) regulatory limitation of cropped areas, 4) well buy-out, and 5) replacement of groundwater with treated wastewater.
- Recommend measures to mitigate social impacts of the above.
- Address related marketing issues.
- Consider institutional and management aspects of the proposed groundwater management fund.

2. Background

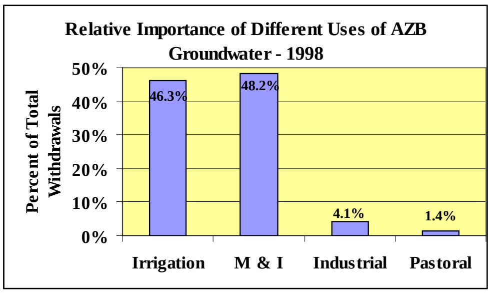
Water is scarce in Jordan, which is among those countries with the lowest quantities of renewable water resources per capita in the world. It's 4.5 million inhabitants have to rely on only about 153 m3/capita/year of renewable water resources. Jordan's renewable annual water supply, composed of both groundwater and surface sources, is far below what the country requires to satisfy increased demands of population growth (both natural and immigration), higher living standards, expanded irrigated agriculture, growing industrialization, and increased tourism.[4] Jordan has been covering an annual water deficit of more than 200 MCM by overdrawing highland aquifers and exploiting non-renewable groundwater.

The Amman-Zarqa Basin is one of Jordan's primary water sources. On a safe yield basis, the groundwater aquifers of the Basin account for almost one third of Jordan's annual groundwater supply. Viewed in even broader perspective, the safe annual supply of the AZB amounts to about 10% of Jordan's current total annual water demands (910 MCM).





According to the Ministry of Water and Irrigation (MWI) data base, withdrawals from the AZB aquifers in 1998 amounted to 149.7 MCM, which as about 170% of the annual recharge[5]. Thus, the AZB is one of the Basin's which is being seriously over-drafted. Withdrawals from AZB aquifers are used for many purposes, including agriculture, livestock, municipal and industrial (M&I). As the chart shows, withdrawals for irrigation and M&I use each account for almost half of total withdrawals. Direct industrial use (4.1%) is also significant; this refers to water withdrawn by industries that obtain water from their own wells rather than from the M&I system that is operated by the Water Authority of Jordan (WAJ).



This study focuses primarily on agricultural use of water. The first agricultural wells were not established in the AZ uplands until the early 1960s. Much of the initial motivation to develop irrigated agriculture came from the government's desire to settle and provide improved services to the Bedouin tribes who traditionally occupied and used the area[6]. The tribal groups were motivated to settle, due partly to the growing precariousness of their traditional way of life, and due to obtain education for their children.

[4] Sara, Yasser M., Economics of Water, Ministry of Water and Irrigation, report commissioned by German GTZ, October 1998, page 2 of 12. (Reference is to 1995 data).

[5] For more details, see Ministry of Water and Irrigation, Water Resource Policy Support Project, Groundwater Management Component, "Rapid Appraisal of Groundwater Use and Users in Amman-Zarqa Basin Highlands," draft, January 2001.

[6] For a discussion of the settlement of the area, see Abu Jaber, Kamel, The Badia of Jordan.

While dryland agriculture – primarily the cultivation of barley and wheat – was important to the traditional way of life, it was only one of many activities upon which Bedouin survival depended. Livestock production was long a mainstay, but this had been undermined by decades of over-grazing, which reduced the productivity of the range for both grazing and occasional production of grains. The situation was made more difficult by a drought in the decade of 1969-1979 led to the loss of much of their herds and the abandonment of large parts of the traditional areas of pasture and the establishment of settlements. Many of the villages in the northeast

The government's initial attempts to introduce the Bedouins to irrigation farming entailed the development of government wells that supplied water to groups of small farms, through lined canals. An example of this was the Dulayl Project. According to Abu Jaber[7], these projects were not very successful. He described the farmers as being "very poor at farming" due to "lack of basic agricultural skills or dislike for the occupation." After five years, he reported, "there was ample evidence that farm units were neglected." Furthermore, while "…several hundred households were settled down… the cost involved in those developments was too high and it was doubtful that this investment represented the best available opportunity for those people. Settlers did not put available resources to optimum use and if current practices continue, it would not be at all surprising to find those farms returning to the desert."

So far, however, irrigation farming has not been abandoned to the desert. Due partly to the examples and experience that the government irrigation projects had provided, many private individuals subsequently applied for licenses to construct their own irrigation wells. Through the 1970s and 1980s, the government encouraged such well development. Initially, the Natural Resources Authority (NRA) was the licensing agency. Except for a few wells licensed near the end of their tenure, the NRA's licenses did not state any quantitative limitation on water abstraction. In 1984 WAJ assumed responsibility for all licensing of privately owned wells, including industrial wells. Licenses issued since then have included limits on abstraction, but these limits have not been enforced.

To obtain a well license, it is necessary to own land. Originally, the Bedouins were the recognized landowners of the area. Eventually, however, investors from other areas bought some of the land from the original owners. In some cases, the new landowner secured a license and developed a well, while in other instances the land was purchased together with a well that had already been developed. In contrast to the small 25 dunum farms that had been established in the government projects, the farms based on private wells often run several hundred dunums or more in size.

While the government eventually quit establishing new irrigation projects of the Dulayl type, it did continue with the development of roads, schools, domestic water supplies, and other infrastructure for the towns of the AZB, as it was doing in other parts of the Badia and rural Jordan. Due to such infrastructure improvements as well as to the development of farming and the availability of other job opportunities in the area, the Bedouin groups have gradually discontinued much of their traditional way of life. Most have now taken up residence in permanent houses rather than the tents that had been the basis for their former nomadic existence.

Due to well development, irrigated agriculture has become a base industry in the economy of the AZB. In 1999, for example, Mafraq and Zarqa governorates, which cover the area in the

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[7] *Op. cit.*, pp. 100-114. Abu Jaber further reports that "traditionally, the Bedouin despised manual labor and vocations, though he might offer his services out in the wage labor market under severe economic pressures." p. 100

Amman-Zarqa Uplands,[8] together accounted for 16% of Jordan's total tree crop area and 24% of its vegetables.[9] Furthermore, as will be discussed in Chapter 4, it appears that Upland production areas account for a disproportionately high amount of Jordans' fruit and vegetable exports. Thus they are and important source of the country's foreign exchange earnings. Furthermore, as the analysis in Chapter 5 will demonstrate, agricultural production in the Basin is responsible for about 2,200 permanent jobs and 5,500 temporary jobs for agricultural workers.

By the early 1990s, based on studies of the natural recharge of the various AZB aquifers, the MWI and WAJ began to realize that there was not sufficient water to support the high levels of abstraction that had evolved in the Basin. It is now recognized that, as a result of high abstraction, the water table is declining and salinity is increasing. This poses threats to the long-term durability of the water supply. Very few new agricultural well licenses have been issued since 1992, but as explained above, total abstraction from those already licensed constitutes a serious concern

What is to be done about the over-abstraction? Given the key role which agriculture plays in the national and AZB economies, abandoning agriculture entirely might not be wise. If some curtailment of agricultural use is in order, how much should this be? What would be the benefits and costs associated with reducing agriculture in the Basin? How might the reduction best be accomplished. The purpose of this report is to address these issues.

[8] Mafraq also includes a relatively small part of the Yarmouk River Basin, and Zarqa includes the Azrak area, both of which are outside the Amman-Zarqa Basin.
[9] According the annual report of the Jordan Department of Statistics.

3. Irrigated Agriculture and Related Water Use in the AZB

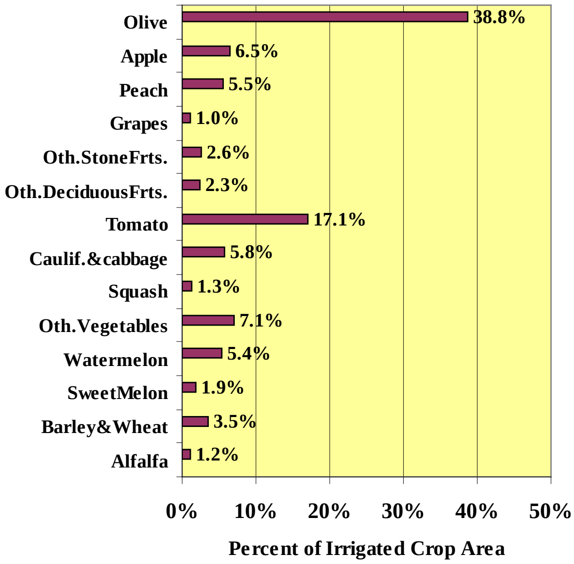
The purpose of this chapter is to describe the crops and farming of the AZB in the context of irrigation water use. The information presented here is derived from several sources. First, a Rapid Appraisal (RA) survey was carried out by the Groundwater Management Component in 2000. Questions about wells and water use, cropping patterns, crop yields, and crop prices were asked of a sample of 157 basin farmers. Sample farms were taken from the Basalt B2/A7 aquifers, which account for about 80% of the groundwater supply in the AZB Uplands. Primary results of the survey were reported in a previous report.[10, 11] Additional findings are summarized here.

Another important source of information was farm interviews conducted by the consultant during January-February 2001. These interviews were used especially to develop and adapt crop budgets tat had been developed in studies[12] of Jordan Valley farms and other areas. Farm budgets developed in the interviews and on information from the RA survey form the primary basis for financial and economic analysis of water use in this report. Results of the farm budget analysis are presented first in this chapter, and they are used as the basis for the analysis of irrigation curtailment options presented in Chapter 6.

3.1 Cropping Pattern.

Figure 3.1 shows the overall cropping pattern of farms in the AZB, as determined from the RA survey. This cropping pattern is virtually the same as that reported by the Department of Statistics for Mafraq and Zarqa governorates combined, which helps to validate the results of the survey. It shows that olives are the major crop being grown in the area, accounting for 39% of the total irrigated crop area. Tomatoes (17% of the crop area) are the second most important crop.

Figure 3.1 Cropping Pattern of AZB Farms Irrigating from Basalt B2/A7 Aquifers



Cropping patterns in the two governorates are not the same, as is shown in Figure 3.2. Mafraq governorate, which encompasses the higer part of the AZB highlands and was developed later, has a much higher proportion of seasonal crops – mainly vegetables and melons, but also some barley and wheat. The Zarqa area, where development started

[10] Ministry of Water and Irrigation, Water Resource Policy Support Project, Groundwater Management Component, "Rapid Appraisal of Groundwater Use and Users in Amman-Zarqa Basin Highlands," draft, January 2001.

[11] The survey was based on a weighted, stratified random sample, where the strata were six annual well abstraction categories, as described in the RA report. Many of the additional findings here are based on an expansion of the sample results, based on re-weighting of the abstraction categories, designed to provide an accurate picture of all farms in the Basalt B2/A7 aquifers.

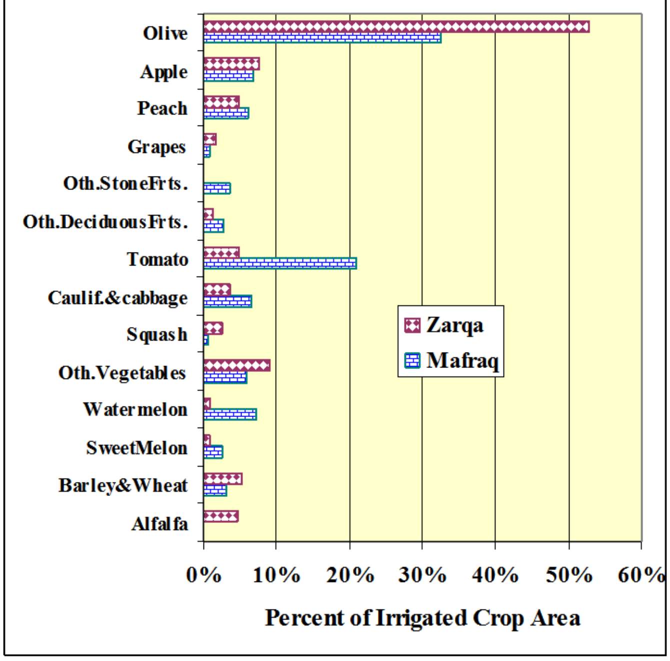
[12] Starting budgets were taken primarily from FORWARD, Assessment of Water Quality Variations in the Jordan Valley, USAID, MWI, Jordan Valley Authority, and Water Authority of Jordan, June 2000 and from Agricultural Credit Corporation (Jordan), A Guide for Agricultural Costs and Returns , Planning and Research Department, 1998.

in the early 1960s, is closer to Amman. It has a much higher proportion of tree crops than the Mafraq area. While the overall cropping pattern for the subject aquifers is 58% tree crops, 68% of the cropped area in Zarqa farms is in trees, compared to only 53% in Mafraq.

3.2 Size and Types of Farm.

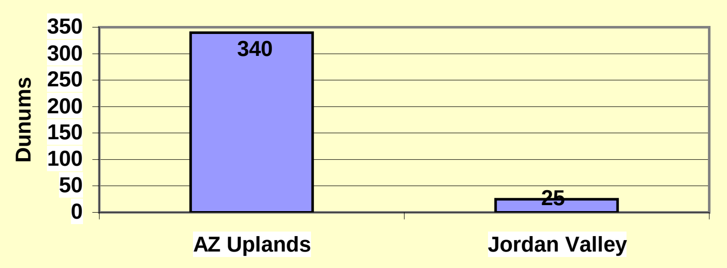
One of the most interesting factors disclosed by the survey is the relatively large size of the farms in the AZB uplands. As Figure 3.3 demonstrates, they average about 340 dunums of irrigated area, compared to only 25 dunums which is the size usually reported for irrigated farms in the Jordan Valley.

Figure 3.2 Comparison of Cropping Patterns for Mafraq and Zarqa Areas of Basalt B2/A7



Based on the RA survey and a count of licensed agricultural wells licensed, it is estimated that there are 340 total farms irrigating from the Basalt and B2/A7 aquifers. The survey showed significant differences in three major types of farms. There are *tree crop farms*, which specialize exclusively in tree crops, *seasonal crop farms*, which have only seasonal crops, and *mixed farms*, which have both trees and seasonal crops.

Figure 3.3 Size of Irrigated Farms in Jordan



As shown in Table 3.1, the Mixed Crop Farms are the most numerous of these, while the tree crop farms are the least numerous. The table also indicates that a high proportion of the Tree Crop Farms (43 of 89) were found to be "large" (> 359 dunums), while there are no large seasonal crop farms.

Table 3.1 Number of Farms (Wells) Irrigating from Aquifer:

Farm Size:	Farm Type:			
	Tree Crop	Seasonal Crop	Mixed Crop	All Farms
Large (>350 dunums)	43	0	45	88
Medium (180 - 350 du)	21	56	44	121
Small (<180 dunums)	25	46	38	109
All Farms	89	102	127	318

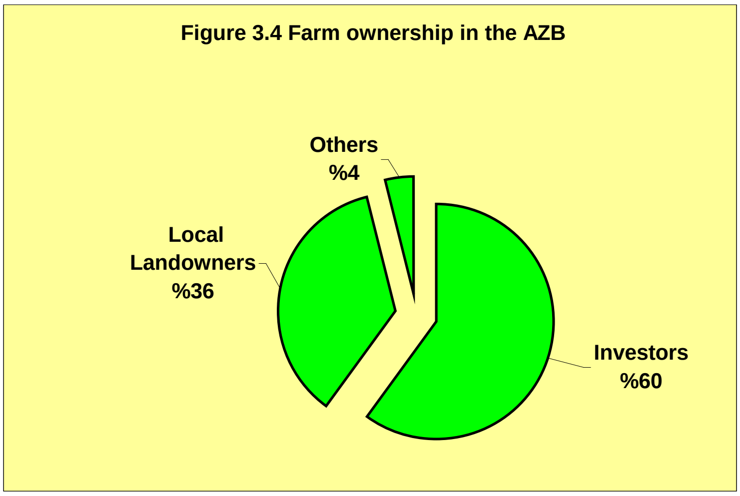
Understandably, there is a big difference in the cropping patterns of the three farm categories. These are shown in Table 3.2.

Table 3.2 Cropping Pattern by Farm Type (% of area in crop)				
Crop	Farm Type			
	Tree Crop	Seasonal Crop	Mixed Crop	AllFarms
Olive	**57.9%**	**-**	**41.5%**	**38.8%**
Apple	**15.4%**	**-**	**3.3%**	**6.5%**
Peach	**12.9%**	**-**	**2.9%**	**5.5%**
Grapes	**1.7%**	**-**	**1.0%**	**1.0%**
Oth.StoneFrts.	**7.5%**	**-**	**0.5%**	**2.6%**
Oth.DeciduousFrts.	**4.5%**	**-**	**1.8%**	**2.3%**
Tomato	**-**	**42.9%**	**18.1%**	**17.1%**
Caulif.&cabbage	**-**	**15.0%**	**6.0%**	**5.8%**
Squash	**-**	**2.9%**	**1.5%**	**1.3%**
Oth.Vegetables	**-**	**14.6%**	**8.8%**	**7.1%**
Watermelon	**-**	**13.3%**	**5.8%**	**5.4%**
SweetMelon	**-**	**3.7%**	**2.4%**	**1.9%**
Barley&Wheat	**-**	**6.0%**	**4.8%**	**3.5%**
Alfalfa	**-**	**1.7%**	**1.8%**	**1.2%**

Table 3.3 shows the size and distribution of area according to type of crop and type of farm. It shows that Mixed Crop and Tree Crop farms are quite large by comparison to Seasonal Crop farms.

Table 3.3 Average Irrigated Crop Area[13] by Type of Farm and Type of Crop (dunums)				
Type of crop	Type of Farm			
	Tree Crop	Seasonal Crop	Mixed Crop	All Farms
Tree Crops	**380.5**		**212.9**	**279.6**
Seasonal Crops		**194.8**	**186.9**	**190.2**
Totals	**380.5**	**194.8**	**399.7**	**331.5**

3.3 Farm Ownership and Management.



Farm ownership in the area is varied. Owners who were classified as “local landowners” in the RA survey constitute only 36% of the farms in the area. These are people who are considered to be originally from the area, such as Bedouins, who have constructed wells and developed their own

[13] Note that total *irrigated crop area* (331.5 dunums average for all farms) is greater than the average *irrigated farm area* (318 dunums) shown in Figure 3.3. This is due to “double cropping,” i.e. growing more than one seasonal crop during the year by some farmers.

farms. The largest single category of owners were classified as "investors" (60 % of the farms), meaning those who did not originally come from the area but who have purchased land and wells – or who have constructed wells on lands they purchased – from area natives.

A relatively small number of the well farm owners are Ex-Government officials and military (4%) who were identified as "others". Some farms have more than one type of owner[14] and were classified as "Combination" ownership.

There are a number of different management arrangements for farms, and the arrangements vary somewhat according to type of ownership, as Table 3.4 demonstrates.

Table 3.4 Type of Farm Management According to Type of Ownership

Type of Owner	Type of Management – Percent of Farms						
	Owner	Manager	Tenant	Share-cropper	Laborer	Un-known	Total
Local Landowner	51%	17%	21%	8%	4%	-	100%
Investor	48%	32%	8%	6%	3%	3%	100%
ex-Gov't Official	17%	17%	67%	-	-	-	100%
Combination	100%	-	-	-	-	-	100%
All types	50%	25%	14%	6%	3%	3%	100%

Owners who operate their own farms constitute the most common arrangement. Hired managers are also common. Investors utilize the highest proportion of paid managers. In the RA survey it was learned that some of these paid managers are highly qualified. For example, several of them have degrees in agricultural engineering.

The fact that in 22% of the cases tenants, sharecroppers, or even hired laborers are in charge of the farm suggests that some farms may not be very effectively managed. In most instances where the owner is not the farm manager (50% of the cases, according to the survey), the owner does not live on the farm.

3.4 Farm Investments.

Investments in AZB farms can be substantial, and these vary significantly depending on the type and size of farm, and according to the depth of the well. Table 3.5 shows estimated investment costs for farms of average size for each of the three principal farm types. Appendix Table B-1 shows additional details on estimated investment costs. These costs were developed from conversations with farmers, and with the guidance of a knowledgeable expert[15].

[15] Dr. Kamel Radaideh, Water Resources Specialist and consultant to the component, was instrumental in providing information on well and irrigation system investment costs, and on irrigated land values.

Table 3.5 Estimated Farm Investment Costs, Typical Farms of Average Size (JD)				
Type of Farm	**Tree Crop**	**Seasonal Crop**	**Mixed Crop**	**All Farms**
Land	**75,598**	**39,610**	**80,721**	**66,038**
Well, pump, motor & irrigation system	**83,402**	**74,208**	**86,514**	**81,893**
Orchard	**225,193**	**-**	**121,742**	**113,452**
Total Investment	**384,194**	**113,818**	**288,977**	**261,384**
Average size	**380.5**	**194.8**	**399.7**	**331.5**
Avg.investment (JD/du)	**1010**	**584**	**723**	**788**

3.5 Crop productivity, costs of production, and crop prices

For the analysis presented here, productivity (crop yield) measured in tons per dunum was determined primarily from information reported by farmers in the RA survey. The basic survey findings are shown in Appendix Tables A-1 through A-4. Survey yields were compared to data reported by the Department of Statistics (Appendix Table A-5). Where possible, prices from the survey were compared to prices for upland crops derived from reports of the Department of Statistics (Appendix Table A-6). As noted above, budgets for crops grown in the area were taken from previous studies and adapted to current circumstances of the AZB through interviews with area farmers. Irrigation energy costs were obtained by analysis of information reported by farmers in the RA survey.[16]

In the course of developing the budgets, yields and prices reported by survey farms were usually used in preference to those reported by the Department of Statistics (DOS). This is significant in the case of the two major crops, olives and tomatoes, since the yields reported in the survey were higher than the DOS data in both cases. Prices reported by survey farmers were higher than those derived from DOS market reports (Appendix Table A-6) in some cases (watermelon, cauliflower) and lower in others (tomatoes, apples, peaches), but they were comparable for olives and grapes.

A significant adjustment was made in the yield of olives, the crop which accounts for the greatest area in the cropping pattern, because 1999 was known to be a low yield year in that crop's alternate bearing cycle. In this case, the average of 1998 and 1999 yields was used. This resulted in using an average of 0.57 tons/dunum, rather than the 0.35 tons/dunum reported in the survey for 1999.

Detailed budgets for each crop are reported in Appendix B, Tables B-1 through B-10. The results of the budget analysis are summarized in Table 3.6 below.
Estimated net results per dunum for each crop are expressed at the bottom of the table in terms of *Gross Margin* (gross revenue minus variable costs) and *Net Profit* (gross revenue less total costs). It is seen that the Gross Margins are estimated to be positive for all crops, while the net profits are positive for all crops except olives.

[16] See RA Survey Report, op. cit.

Table 3.6 Crop Budgets		Seasonal Crops				
		Tomato	Caulif./ Cabbage	Other Veg.	Water-Melon	Sweet Melon
Crop Yield	tons/du	7.217	1.860	3.157	4.500	3.927
Labor use	days/du	30.2	12.5	16.4	5.6	14.7
Crop Price	JD/ton	54.7	144.3	131.1	74.6	125.0
Gross Revenue	JD/du	394.8	268.4	413.9	335.7	490.8
Input use and costs:						
Water, pumping energy	JD/du	47.8	31.2	47.2	25.9	36.6
Seeds/plants	JD/du	21.8	18.4	37.3	10.0	3.5
Manure	JD/du	13.0	13.0	12.8	13.0	13.0
Fertilizers	JD/du	35.5	35.5	26.3	35.5	35.5
Pesticides	JD/du	25.0	25.0	44.0	17.0	17.0
Mulch/misc	JD/du	16.6	10.8	16.6	10.8	16.6
Machinery	JD/du	10.0	7.0	6.4	5.1	8.6
Maintenance, WPMI	JD/du	4.8	4.8	4.8	4.8	4.8
Interest, working cap.	JD/du	25.6	16.8	24.0	12.8	18.0
Labor cost	JD/du	120.9	50.0	82.2	27.8	73.5
Tot. Variable Cost	JD/du	321.0	212.5	301.7	162.6	227.0
Fixed costs:						
Depreciation, WPMI	JD/du	23.1	23.1	23.1	23.1	23.1
Interest, WPMI invest.	JD/du	7.4	7.4	7.4	7.4	7.4
Total Fixed Cost	JD/du	30.5	30.5	30.5	30.5	30.5
Gross Margin	JD/du	73.7	55.9	112.2	173.1	263.8
Net Profit	JD/du	43.3	25.4	81.7	142.6	233.3

Table 3.6 Crop Budgets…continued		Tree Crops					
		Olive	Apple	Peach	Grape	Other Stonefruit	Other Deciduous
Crop Yield	tons/du	0.570	1.521	1.815	2.770	1.311	1.815
Labor use	days/du	19.4	13.1	14.9	61.2	17.8	27.1
Crop Price	JD/ton	367	280.0	294.4	294.0	323.8	383.3
Gross Revenue	JD/du	209.2	425.9	534.3	814.4	424.7	695.7
Input use and costs:							
Water, pumping energy	JD/du	46.9	70.3	66.5	65.7	69.2	66.5
Seeds/plants	JD/du	Included as a part of capital costs, through depreciation & interest.					
Manure	JD/du	8.8	18.8	25.0	37.5	25.0	22.5
Fertilizers	JD/du	10.0	64.5	64.5	64.5	64.5	50.9
Pesticides	JD/du	16.0	22.5	22.5	22.5	22.5	20.9
Machinery	JD/du	6.6	15.1	15.1	15.1	17.1	13.0
Maintenance, WPMI	JD/du	4.8	4.8	4.8	4.8	4.8	4.8
Interest, working cap.	JD/du	13.8	22.4	23.4	35.1	24.8	23.7
Labor cost	JD/du	70.2	66.4	74.1	193.0	85.9	101.0
Tot. Variable Cost	JD/du	177.0	284.8	295.9	438.3	313.9	303.1
Fixed costs:							
Depreciation, WPMI	JD/du	23.1	23.1	23.1	23.1	23.1	23.1
Interest, WPMI invest.	JD/du	7.4	7.4	7.4	7.4	7.4	7.4
Depreciation, orchard	JD/du	11.6	36.2	22.6	72.5	23.8	35.7
Interest, orch. Invest.	JD/du	32.0	39.8	24.9	79.8	26.2	44.1
Total Fixed Cost	JD/du	74.1	106.4	78.0	182.8	80.4	110.3
Gross Margin	JD/du	32.2	141.1	238.4	376.1	110.8	392.6
Net Profit	JD/du	(41.9)	34.7	160.4	193.3	30.4	282.2

3.5.1 The value of water used in upland irrigation. As explained in the first chapter of this report, a common approach to measuring the value of water used in agricultural production is known as the *residual value* method. In this approach, the farmer's gross margin or the net profit is divided by the quantity of water used, thus providing the *gross margin per m3* or the *net profit per m3*. The residual value method was employed here.

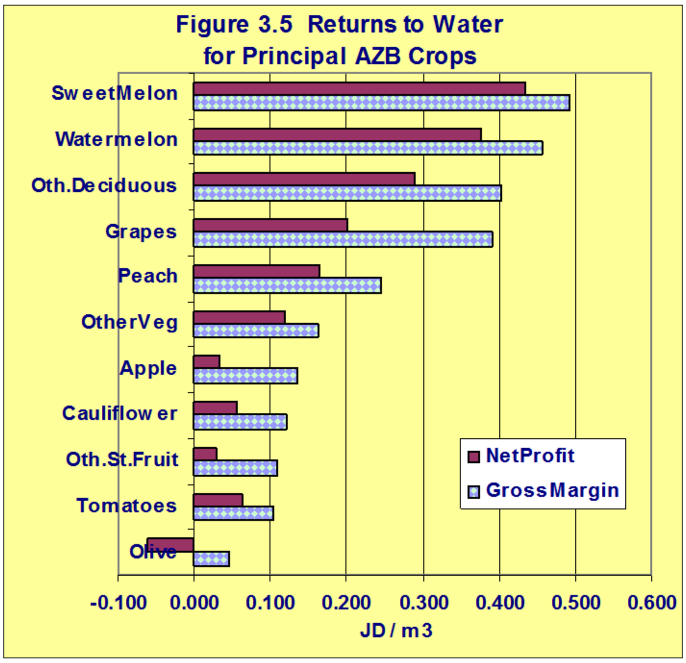
Table 3.7 Net Crop Water Requirements (m3/dunum)

Crop	Mafraq	Zarqa	Weighted. Average
Tomato	750	613	701
Cauliflower & Cabbage	500	384	458
Other Vegetables	750	591	693
Watermelon	413	321	380
Sweet Melon	581	458	536
Olive	688	688	688
Apple	1062	975	1031
Peach	1004	923	975
Grape	1043	822	963
Other Stone Fruits	1045	960	1015
Other Deciduous Fruits	1004	923	975

Note: The net requirement is the total crop requirement divided by an estimated 80% efficiency for drip irrigation in the AZB.

To determine the amount of water which the crops use, an analysis of information reported by farmers in the RA survey was used in conjunction with estimates of the evapotranspiration requirements for each crop in the Mafraq and Zarqa areas. The net water requirements for each crop are listed in Table 3.7. Here, *net requirement* refers to the estimated nominal water requirement for the crop, plus an adjustment for the efficiency of the system. It is believed that the drip irrigation systems in the Basin are currently about 80% efficient. Thus, the net crop requirement equals the nominal crop requirement divided by 0.8. In view of the fact that many of the tree crops are still relatively young, the water requirements for the tree crops, particularly olives, was adjusted downward.

The value of water used in each crop is shown in Figure 3.5, which is based on weighted average water use for Amman and Zarqa combined. Using gross margins, the value varies from a high of 0.492 JD/m3 for sweet melon to a low of 0.047 JD/m3 for olives. Naturally, the net profit measures are somewhat lower than the gross margin measures. Because the estimated net profit for olives is negative, value of water used to irrigate olives is also negative. Can this really be the case?



As will be discussed at length in Chapter 6, the overall water values shown in Figure 3.5 are quite low in comparison to the value of this water in other uses.

3.5.2 The problem of immature trees. The fact that the estimated profits from olives are negative raises important questions. That the value is negative is surprising because many farmers in the Basin have been planting olives in recent years – they probably would not do so unless they think it is a profitable crop to grow – and because olives occupy far more area than any other crop in the area. If the analysis of olives is somehow incorrect, this could cast doubt on the overall findings of this study.

The data for olives was examined very closely. One of the factors examined closely was the relationship between tree age and tree yield. This can be an important consideration because it takes a number of years for most tree crops to come into full production. If the trees in the farms surveyed are not in full production, the resulting estimate of product value can be distorted from a long-term point of view.

One of the questions asked in the RA survey was about the age of the trees. Many farms did not report this information. Of the 87 cases where it was reported, however, 44 indicated a tree age of five years or less. Most trees do not reach full production until well after their fifth year. Olives are particularly slow to come into production. While olive trees do begin to produce significant crops by the time they are 5-10 years, they do not reach full production until they are 20 years of age or more. Of those farms reporting the age of their olive trees, 68% indicated an age of 10 years or less. Such trees are a long way from full production.

A revision of tree yields was made, based on discussions with growers and taking account of the yields that were reported for older tree plantings in the survey. The results for olives and other important permanent crops are shown in Table 3.8. This analysis also accounts for the fact that the tree crops will use more water as they mature.[17] Thus, net returns are expected to increase significantly after trees mature. While the net income for olives is estimated to be positive, the analysis here suggests that it will still not match the returns from other permanent crops – particularly not the high returns estimated for grapes.

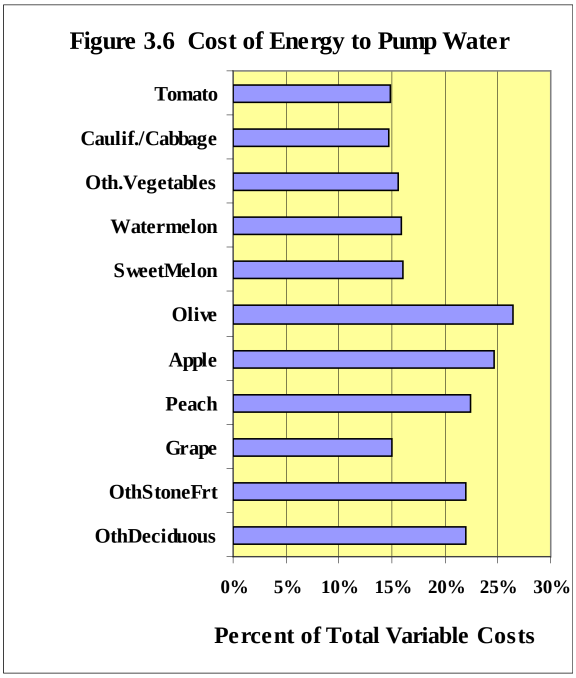
Table 3.8 Analysis of Effects of Tree Maturity on Yields

Crop	Current situation – immature trees			Future situation - mature trees		
	Avg. Yield (tons/dun)	Value of water in irrigation		Adj. Yield (tons/dun)	Value of water in irrigation	
		GrossMargin (JD/m3)	NetProfit (JD/m3)		GrossMargin (JD/m3)	NetProfit (JD/m3)
Olives	**0.570**	**0.047**	**(0.061)**	**1.272**	**0.203**	**0.136**
Apples	**1.177**	**0.137**	**0.034**	**1.521**	**0.194**	**0.115**
Peaches	**1.453**	**0.245**	**0.165**	**1.815**	**0.293**	**0.225**
Grapes	**0.870**	**0.390**	**0.201**	**1.450**	**0.837**	**0.703**

3.5.3 Energy Costs. Energy are a significant factor in the individual budgets and summarized in Table 3.6. Analysis of RA survey results showed that the cost of energy to pump water from wells in the AZB varies according to the depth of the well and according to the energy source. Most wells in the Basin are powered by electricity, but some pumps are operated by diesel engines, which is slightly more expensive than electricity. To pump one m3 of water from an AZB well, the cost of the electricity varies from 0.030 to 0.100 JD/m3, while the cost Diesel fuel was found to vary between 0.050 and 0.130 JD/m3. At the average pumping depth for Basin farms (191 m), electricity costs 0.062 JD/m3, compared to the slightly higher price of 0.078 JD/m3 for diesel fuel.

As shown in Figure 3.5, pumping energy costs vary from 15% to more than 25% of total variable production costs, according to the crop. This is very high by world standards.

[17] Thus, the net irrigation requirement for olives is expected to increase from 688 m3/dunum to 1065 m3/dunum, and that for apples would increase from 1031 to 1269.

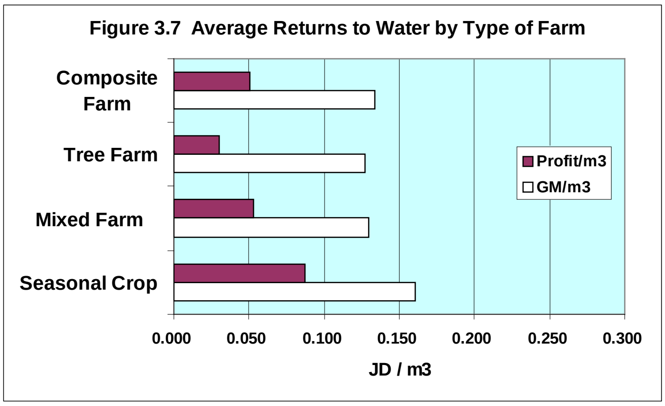


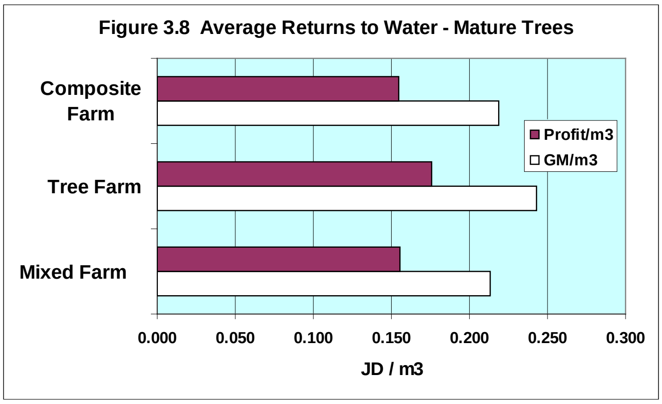
It is estimated that the total cost of lifting water with an electric pump for a well with average water depth in the AZB Uplands is 0.099 JD/m3, including depreciation and interest on the investment in the well, pump and motor. Compared to the 0.015 JD/m3 average fee paid by Jordan Valley irrigators, for example, this is quite high.

It is clear that the high energy costs associated with having to lift the water from considerable depths is one reason why the value of water in irrigation is relatively low in the AZB.

3.6 Costs and returns to well and farm investments.

The preceding analysis deals with the value of water on a crop by crop basis. Most farms grow more than one crop, however, and it is thus important to consider the overall value of the water used in all crops. For these purposes, a farm-crop budgeting model was developed to explore returns to water at the farm level. A copy of this model in its basic configuration is provided as Appendix Table B-2.





The farm-crop model can be adapted to meet various types of analytic needs. In the basic configuration, it estimates the overall sales revenues, production costs, gross margin, net profit and *return to water* for the *composite farm.* The "composite" farm is designed to represent typical or overall average conditions in the Basin. It is of average size, it grows all crops in an average cropping pattern, and it takes its water from a well of average depth.[18] However, the model can readily be altered to show the returns to water when circumstances differ.

The farm-crop model was first used to estimate the returns to water for each of the basic farm types, assuming current average

[18] The RA survey shows that an average farm on the Ba-B2/A7 aquifer has 318 dunums of irrigated *farm area*. It cultivates 188 dunums of tree crops and 143 dunums of seasonal crops for a total irrigated *crop area of 331 dunums.* This farm.uses 236,000 m3 of water per year, pumped from a water table which is 191 meters deep. The cropping pattern of the composite farm is the same as the overall average for the aquifers, as shown in Figure 3.1.

crop yields. The results are shown in Figure 3.7. This shows that the Gross Margin per unit of water on typical farms ranges between 0.13 – 0.16 JD/m3 of water used, depending on farm type, and the Net Profit ranges between 0.05 – 0.08 JD/m3.

Returns can be expected to improve as tree production increase with maturity. This is seen in Figure 3.8, which shows the effects of the expected yield improvements listed in Table 3.8 above on returns to water for the composite farm, as well as for typical tree crop and mixed farms. As Figure 3.8 shows, it is estimated that Gross Margins will increase to the 0.21 – 0.24 JD/m3 range, depending on farm type, and that Net profit will increase to 0.15 – 0.18 JD/m3.

Above-average farms. The results discussed so far have been related to “average” farms. What about those farms that are above-average in their performance? How well do they do? How high are their returns? What are their returns to water? How many farms attain significantly higher returns?
A special tabulation of the RA survey was made in order to try to answer these questions.

Of the 156 farms responding to the survey, 78 reported information in sufficient detail to permit estimation of their gross incomes (sales revenue). These are analyzed in Table 3.9. Of the 78 with known revenues, 37 (47%) were found to have revenues which are higher than the breakeven point – that is, high enough to cover total costs of production as determined in the budget analysis. In other words, 47 percent of AZB farms were profitable in 1999, judging by the costs of production estimated to prevail in the basin; this implies that 53% of the farms were not profitable. What kinds of returns did the profitable farms earn on the water they used? As Table 3.9 indicates, this varied from 0.124 JD/m3 for the seasonal crop farms to 0.381 per JD/m3 for the tree crop farms.[19]

The final point considered in the sales revenue analysis was to determine how many were earning returns above 0.400 JD/m3 on their water. As the table indicates, only five of the 78 farms (6%) have net profits above this level.

Table 3.9 Survey Farms With Known Sales Revenues

	Mixed Farms	Seasonal	Tree	All
Number of farms	33	29	16	78
Number of these with crop sales revenues above breakeven levels	12	16	9	37
Average value of water to farms operating at a profit.	0.216	0.124	0.381	0.229
No. of farms with revenues high enough to mske profits of JD 0.40 per m3 or more for their water.	2	1	2	5

3.7 Economic versus social costs and prices.

The analysis above is all based on the actual market prices and costs which farmers face. It is known as *financial analysis* or *market price analysis*. While it is important to understand the financial picture from the farmer’s point of view, the reality from the point of view of the national economy may be somewhat different. Financial analysis can be misleading if market prices are *distorted*. It is known, for example, that Jordanian fruit and vegetable producers are protected by tariffs that make it difficult for imported products to enter the country. From an economic point of view, protective tariffs are considered to be a distortion because they cause

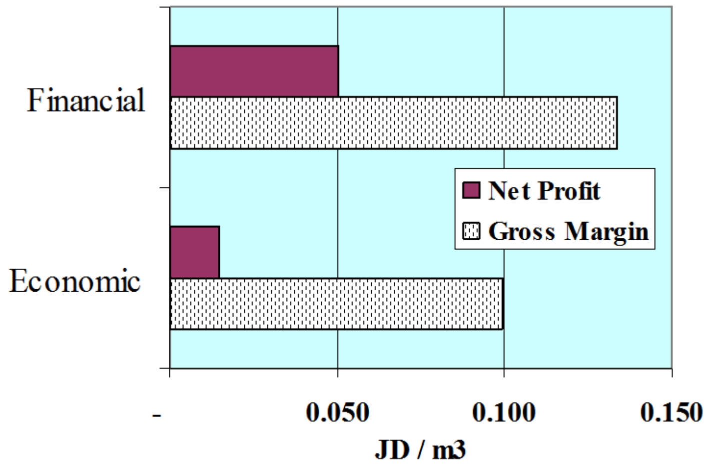
[19] The average income for the tree crop farms is distorted by the fact that one large farm reported total sales revenue in excess of JD 1,500 per dunum.

the domestic price to rise above competitive prices on international markets. In correcting for distortions such as this, economists try to convert the prices and costs which growers experience to their true economic values. This is called *economic analysis*, in contrast to the financial or market analysis.

Jordan's protective tariffs are not the only distortion that must be taken into account in an economic analysis. Fertilizer imports are also taxed. This makes it more expensive to farm. Furthermore, the Jordanian Dinar is currently over-valued. This has the effect of making imported products less expensive than they would be if the Dinar were priced at an exchange value that reflected international parity.

Taking these distortions into account, the farm-crop model was used to carry out an economic analysis of the returns to water for the composite farm. The results of this analysis are shown in Figure 3.9. While the 30% tariff which has prevailed on most of Jordan's fruits and vegetables[20] in recent years does provide substantial protection to producers of these crops, the effects of the tariff are significantly reduced by the current overvaluation of the exchange rate[21]. The overvaluation of exchange almost entirely offsets the tariff on fertilizer imports. The net effect of the corrections is to reduce the value of water used in irrigation. Whereas the Gross Margin earned on water was estimated at 0.134 JD/m3 in the financial analysis, in economic terms it is estimated at only 0.099 JD/m3. This is a reduction of more than 25 percent. The reduction in net profit is similar.

Figure 3.9 Economic vs. Financial Analysis of Returns to Water for the Composite Farm



The net effect of the distortions in Jordan's agriculture is to make it more attractive for Jordan's farmers to use irrigation water. These distortions thus encourage farmers to use groundwater that would otherwise be available for municipal and industrial purposes.

[20] This was the rate which prevailed in 1999. Beginning in 2000, under the WTO agreement, Jordan's tariffs have actually been increased.

[21] For this analysis, it was assumed that the JD is over-valued by 19.8% .

4. Evaluation of Water Curtailment and Improved Management Options

There are numerous ways in which water abstraction for irrigation can be curtailed. First, GOJ can *enforce* its existing system of *well license limits*. In addition to imposing quantitative limits, GOJ can also *impose water user fees (water tariffs)*, to discourage over-use and to discourage the irrigation of low-valued crops. Recently, it has been suggested that the government *buy out the wells*, or that they *buy back well licenses*. This would eliminate pumping from such wells. Another possibility is to *substitute treated wastewater* for groundwater.

Another series of proposals relate to improving management of irrigation water use and agriculture, both to reduce abstraction and to ensure that the water that is used results in the highest possible benefit to the economy. In this regard, it has been proposed that an Irrigation Advisory Service be established, to show farmers how to irrigate efficiently and how to configure and operate their pumps, wells and irrigation equipment in more efficient ways. Currently, the upland areas have very limited agricultural extension service. Improved agricultural extension could help farmers improve production and marketing practices.

Before evaluating these options, it is important to consider what will happen to irrigation and agriculture in the Basin if water use is not curtailed, thus assuming that over-abstraction continues without being checked.

4.1 Effects of Continued Over-Abstraction.

The effects of continued over-abstraction of water from AZB aquifers are generally well known, although until recently it there has been little quantitative information about what is happening in the Basin.

Experience during the past 20 years shows that over-abstraction causes 1) *decline in the water table* and 2) *decline in water quality*. The decline in water quality is manifested primarily in terms of increased salinity. In economic terms, pumping costs increase for all water users – for industrial and municipal users as well as crop irrigators – due to the increased depth of pumping. The increase in salinity causes the economic value of the water to be reduced for all users. In the case of municipal and industrial users, saline water must either be processed to desalinize it, or it must be mixed with less saline water; either option is expensive.

Although the effects of salinity vary from crop to crop, in general it can be said that crop yields decline after salinity reaches certain threshold levels. As salts from saline water accumulate in the soil, yields decrease to the point where it is necessary to apply additional irrigation water for leaching. This may help yields to recover, but the additional water requirement for leaching serves to further reduce both the technical and economic efficiency of irrigation.[22] Beyond certain water salinity levels, it is no longer possible to grow some crops,

4.1.1 Estimates of change in water table and quality during next 20 years. A model of the Basin's two primary aquifers, the Basalt and the B2-A7, has been developed by the Groundwater Management Component[23] to predict future changes. The model is in the process of being validated and calibrated, and it has already been run for various scenarios to

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[22] For information on the effects of salinity, see Hanson, Baline, Stephen R. Grattan, and Allan Fulton, Agricultural Salinity and Drainage, USDA Water Quality Initiative, University of California, Davis, 1999.
[23] Model was developed by Yehia Majali, consultant to the Groundwater Management component.

show the predicted effects of different levels of abstraction and under differing scenarios. The model shows that if abstraction for agricultural purposes continues at current levels[24], the water table can be expected to drop by an additional 10 to 25 meters, depending upon location within the aquifer. The model also shows that the aquifer go dry in some areas. The average of the draw down projected over the next twenty years is expected to be 10 meters. According to the model, salinity levels are expected to increase from current levels of 400 – 1000 ppm to a range of 1000 – 5000 ppm.

4.1.2 Economic impacts of decline in water table. Several different types of economic impacts can be anticipated from the decline in water table. All users will experience increased costs of energy, either electricity or diesel fuel. In some cases the table will decline beyond the reach of the existing well, and it will need to be deepened, which will cause the owners to incur significant costs. In areas where the aquifer goes dry, wells will be abandoned entirely, causing the value of the investment and any future earnings from the farm to be lost.

From the Rapid Appraisal (RA) survey it was determined that energy costs for pumping varied from about 30 fils/m3 for shallow wells to about 130 fils/m3 for deep wells. Diesel fuel costs were about 20 percent higher than electricity costs. Pumping costs averaged 75 fils/m3. The average pumping depth, which approximates the average water table depth, was 191 meters. An increase of 10 meters over the next twenty years implies that the water table will increase 0.5 meters per year on average – more than this in some areas, of course, and less in others. The average cost per m3 utilized is expected to increase only 0.2 fils/m3 during the first year, but by the year 2020, the annual cost per m3 will have increased by 3.9 fils/m3.

A summary of the economic analysis is shown in Table 4.1 below. It is seen that the additional pumping costs are not great in the first year but by the time that the increases accumulate over the next 20 years they could be considered quite burdensome. By the year 2020, the average cost of production is expected to increase by JD 2.80 per dunum. This will further erode the economic viability of many crops – many of which are already of doubtful viability. The cost of JD 930 per farm will represent a significant drain on the incomes of many farmers. Projected on an area-wide basis, it will amount to JD more than JD 295,000.

Table 4.1 Additional Energy Costs Due to Increased Depth of Water Table (JD)

	Per Dunum	Per Farm	For all Farms Pumping from Basalt B2/A7 Aquifers
Increase in annual costs (assuming no increase in energy costs):			
Year 1 (2001)	0.140	46	14,783
Year 10 (2010)	1.402	465	147,829
Year 20 (2020)	2.805	930	295,658
Present Value of cost increased over next 20 uears (10% discount rate):			
Assuming constant energy prices		2,971	944,929
Assuning 5 % annual increase in price		5,053	1,607,010

The preceding analysis assumes that energy costs will not change during the coming 20 years, but this is unlikely since energy is likely to become scarcer, causing prices to rise. Thus, the end result is likely to be more severe than the table suggests. For example, if energy costs

[24] In this scenario it is also assumed that new wells for municipal use are added in the "corridor" area, as planned, which will cause total abstraction in the Basin to increase by an additional 10 MCM per year.

grow at an average of five percent annually, the total cost per year would be JD 747,000 thousand by the year 2020, rather than the JD 295,000 shown in the table.

To understand the *effect of the additional costs* over the next 20 years, it is useful to determine their *present value,* as is common in financial analysis.[25] Present values per farm and for all farms in the Basin is also shown in Table 4.1. If energy costs do not change (which is unlikely) over the next 20 years, the present value of added costs for all farms is estimated at almost JD 945,000. If energy price increases average 5 % per year over the period, the present value of energy cost increases is expected to total JD 1.6 million for the subject aquifers.

In addition to the above, there will be *costs of deepening or reconstructing* wells for many farms. This can vary from JD 15,000 to JD 75,000 or more per well, depending upon the circumstances. In some cases, it will be possible to merely deepen an existing well and simply increase the length of the existing pump column, while using the existing motor. At the other extreme, reconstruction of the well will be the only solution, and may also require a new pump and motor.

For purposes of the present analysis, it is assumed that 30-45% of the wells (110-165 farms) can be merely extended and rebuilt at an average cost of JD 18,750 while 5-10% (18-36 farms) have to be entirely reconstructed at an average cost of JD 61,000 per well. On this basis, the total cost is expected to be JD 2.14 million.

Table 4.2 Costs of Well Deepening and Reconstruction

	Deepen & Rebuild Well		**Reconstruct Well**	
	Minimum	Maximum	Minimum	Maximum
Percent of wells	30%	45%	5%	10%
Number of wells	110	165	16	32
Cost per well	18,750	18,750	61,000	61,000
sub-totals	2,062,500	3,093,750	976,000	1,952,000
Combined Totals				
		Minimum	Maximum	
		3,038,500	5,045,750	

Some farms will be lost entirely because the wells will go dry in certain areas. The farms will be abandoned. The groundwater model shows that two this will happen in two different well field areas, resulting in the loss of 74[26] wells. The loss due to the abandonment of farms can be viewed in different ways. One approach would be to consider the investment value that is lost when the well is abandoned. A second approach is to consider the value of the income stream which will be lost. The results of these two approaches are summarized in Table 4.3.

For the lost investment approach it is estimated that the initial investment for well, pump, irrigation system and orchards on a typical mixed farm is JD 215,117. It is assumed that at the time of abandonment half of the investment life has already passed on the well, pump and irrigation system, and thus that half of the value (JD 40,963) would be depreciated. No depreciation is made for the investment in orchards.[27] The remaining value of farm

[25] *Present value* (PV) is a financial calculation used to discount the future value of money to the present time. If a payment of X is to be received n years in the future, then PV(X) = X/(1+I)n, where i is an appropriate "rate of discount", normally equal a prevailing rate of interest.
[26] The first well field will dry up by 2005, resulting in a loss of 30 wells. The second will go dry by 2015, resulting in the loss of 44 more.
[27] Because the trees are growing and production is increasing, orchard values normally do not depreciate during the first 10-20 years of life of the orchard. This period would be even longer for olive trees. Since most orchards in the area are still relatively young, little if any depreciation of

investment remaining half is worth JD 174,144. For all 74 farms ,the loss would sum to JD 11.4 million. The present value of this loss is JD 4.9 million, as shown in the table.

Table 4.3 Cost of well abandonment due to drying up of aquifer in some zones:	
Lost investment approach:	
Original investment, well, pump and irrigation equipment, typical farm	81,893
Investment in tree crop orchards	113,452
Assume that the investment in WPI is half depreciated	(40,947)
Residual investment value lost, per well	154,399
Present Value of investment losses, next 20 yrs.	**4,906,566**
Lost future income approach	
Projected annual gross margin	**31,668**
Less 1/2 of capital costs of shorter term investments	(3,847.46)
= Adjusted net annual income expected	27,821
Present Value of income loss over next 20 years, all 74 farms	**6,664,873**

Under the lost future income approach, the results of estimated income from RA survey are used. The analysis of survey results (see Chapter 3 above) indicates that a typical mixed farm earns a gross margin of about JD 31,600 per year. The investments for the well and orchard have already been made and cannot be avoided. However, the farm can still expect to incur capital costs (replacement investments) for shorter lived investment items such as the pump column, pump motor and irrigation system. After accounting for these, the value of income lost is estimated to be about JD 27,800, and the present value of this over the next 20 years for all 74 farms is JD 6.7 million[28].

An other way to estimate well abandonment losses is to use the same approach used to obtain cost of wells buy out. In this case the 17.3 MCM loss owing to abandonment of wells would cost around 18.2 MCM, which is the same as the cost of buying wells having a yield of 17.3 MCM.

4.1.3 Costs associated with increased salinity. Ultimately, salinity is detrimental to all crops, but effects and severity vary. Some crops are more affected by it than others, and some crops have much lower salinity thresholds than others. Table 4.4 summarizes the expected effects of salinity for vegetable and fruit crops grown in the AZB uplands, based on information from a recent extension publication of the University of California at Davis. The table shows that many of the irrigation crops of the AZB are quite sensitive to salinity. Among the tree crops, the pome fruits (apple, pear) are quite sensitive, as are the stone fruits (peach, apricot, plum). Grapes are somewhat less sensitive, while olives are seen to be quite tolerant. Although there is currently relatively little date production in the AZB, the tolerance of date palms to salinity suggests that they might be considered as a replacement crop if salinity levels should become quite high.

Among the vegetables, it is seen that onions are very sensitive, while many others are known to be moderately sensitive. Of the crops which are currently grown in the Basin, only squash (zuchinni type) are considered to be moderately tolerant to salinity. Asparagus is not currently grown in the Basin, but it is quite tolerant to salinity and thus might be considered as an alternative vegetable crop for the area.

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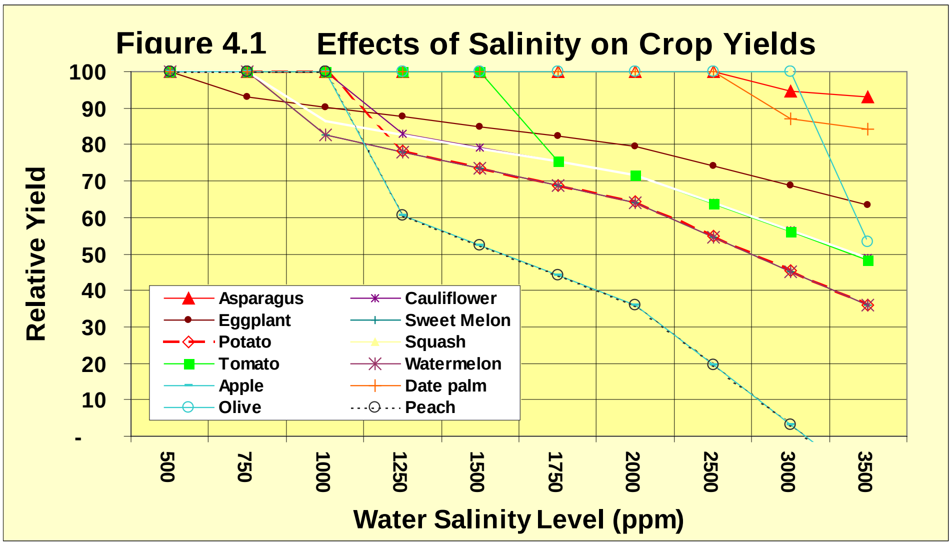
orchards would be justified in most cases. This assumes that the orchards have been well designed and well maintained.

[28] In the present value calculations, the losses are phased in gradually over 20 years, to simulate the aquifer going dry. Thus, the total annual income loss by 2005 (30 farms) comes to just over JD 834,000, while the annual income loss totals over JD 2 million by 2015.

Table 4.4 The Effects of Salinity on Vegetables and Tree Crops					
Vegetable Crop	Salinity Tolerance Rating	Yield Effect Threshold (ppm)	**Tree Crop**	Salinity Tolerance Rating	Yield Effect Threshold (ppm)
Asparagus	T	2624	Almond	S	960
Cabbage	MS	1152	Apple	S	1024
Cauliflower	MS	1152	Apricot	S	1024
Eggplant	MS	704	Cherry, sweet	S	1024
Sweet melon	MS	960	Date palm	T	2560
Onion	S	768	Grape	MS	960
Pepper	MS	960	Olive	MT	3008
Potato	MS	1088	Peach	S	1088
Spinach	MS	1280	Pear	S	1024
Squash, Zuchinni	MT	3008	Plum, prune	S	960
Tomato	MS	1600			
Watermelon	MS	960			
Source: Adapted from Hanson, Grattan and Fulton, Agricultural Salinity & Drainage, U of California, Davis, 1999.					
Note: T = Tolerant; MT = Moderately Tolerant; MS = Moderately Sensitive; S = Sensitive. The Yield Effect Threshold is the level above which salinity begins to affect yield.					

From information provided in the same study, it is possible to estimate the magnitude of salinity's effects on the yields of these same crops. Detailed estimated of the degree of yield reduction for the crops show in Table 4.4 are presented in Appendix C, Table C.1. These estimates show that while there is little if any effect on most crops up to the point where salinity reaches 1000 ppm, beyond that point significant yield reductions occur. Figure 6.1 is based on the calculations of Appendix C. It illustrates quite vividly how salinity is expected to affect the yields of important basin crops.

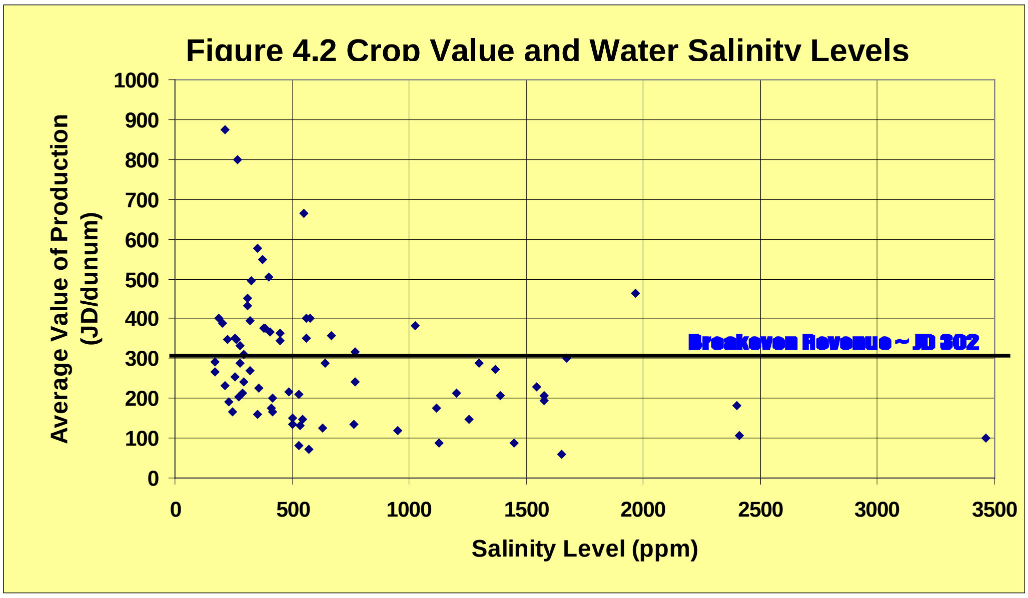


Fiaure 4.1 Effects of Salinity on Crop Yields

In particular, the graph shows that impacts on the production (yields) of apples and peaches is quite dramatic at salinity levels above 1000 ppm. Although seasonal crops such as eggplant and watermelon are affected at lower salinity levels, the slope of the yield reduction line is not so steep as that for the fruits. Although olives are not affected until salinity exceeds 3000 ppm, the rate of yield reduction beyond that point is very pronounced. The graph also shows the tolerance of crops like asparagus and dates[29], which are currently not grown in the basin, to salinity.

By the time salinity reaches 1500 ppm, the yields of many tree crops are affected significantly. It is doubtful that the pome fruits and stone fruits would be grown at all above levels of 2000 ppm. Among the vegetables grown in the AZB, only squash remains unaffected at levels above 2000 ppm. While tomatoes and spinach are affected at this level, the effects are still relatively slight. Yield reductions on other vegetables are significant.

The scatter graph in Figure 6.2 plots the average value of production in AZB farms against the salinity of their well water. This data was based on information obtained from 74 farms in the RA survey. The analysis show that salinity is already impacting the value of production of AZB farms. The graph also includes a "breakeven" line at JD 302 per dunum. This is the estimated amount required by typical farms to cover total costs of production. In other words, the value of their production must equal this amount if they are to break even. Below this amount they lose money. As seen in the graph, all but two farms with salinity above 1000 ppm have incomes which are below breakeven.



The farm model from Chapter 3 was utilized in conjunction with the relative yield curves shown in Figure 6.2 to estimate the impacts of increased salinity on production. Results are summarized in Table 4.5. At 1500 ppm, average revenue per dunum is reduced by JD21.71 (6.4% reduction from base case scenario). The amount of reduction in farm production value for the entire Ba B2/A7 aquifer is estimated to be more than JD 1.62 million[30]. At 2000 ppm salinity, the reduction in production is considerably more drastic. Even with allowances for adjustments in the cropping pattern (shifting some area from crops such as watermelon and sweet melon into less sensitive vegetables), the value of production is expected to decline by more than 11% and is estimated to be some JD 2.9 million for the entire aquifer. The benefits from adjusting the cropping pattern are limited, at least in the short run, because such a high proportion of the area is in permanent tree crops which cannot be changed rapidly.

[29] Only a few dates are currently being grown in the Basin, while no asparagus is grown there.
[30] For this analysis, it was assumed that salinity will effect 75,000 dunums. This is 75% of the approximatedly 100,000 dunums of area being irrigated in the aquifer, based on the expectation that salinity will not become severe for those wells located most directly in recharge areas..

Table 4.5 Effects of Saline Water on Productivity and Production In the AZ Basin Uplands			
	Reduction in Annual Value of Production		
Scenario	**Avg. Per dunum**	**Entire Ba B2/A7**	**% of base scenario**
1500 ppm salinity	JD 21.71	JD 1,628,486	6.4%
2000 ppm salinity	JD 47.97	JD 3,597,392	14.2%
2000 ppm, after adj. in cropping pattern	JD 39.08	JD 2,930,857	11.5%

4.1.4 Summary of added costs if high abstraction continues. The costs associated with decline in water table and increased salinity over the next 20 years are summarized in Table 4.6. Depending on the underlying assumptions, as discussed above, some estimates are given as both low and high. Here the added energy costs have been summed over the entire period and calculated at present value.[31] The high estimate is based on the assumption that energy prices will increase at five percent per years, reflection growing limitations on world supplies. Since salinity will build up only gradually, it is was assumed that its effects build up in equal annual steps over the 20 year period, until they reach the levels shown in Table 4.5 above. As in the case of energy, salinity losses are calculated in present value terms. It is seen that total losses are expected to be around JD 52.650 million, depending on the underlying assumptions. The greatest losses are expected to come from energy costs and salinity.

Table 4.6 Summary of Losses through 2020 if High Abstraction Continues, Present Values (@ 10%) of Costs Over Next 20 Years (JD)		
		Estimate
Increased Energy Costs		5,900,00
Deepen & reconstruct wells		5,050,00
Abandon wells		18,200,000
Income loss due to salinity		23,500,000
Totals		**52,650,000**

4.2 Licensing and Quantitative Limitation of Abstraction.

The Government of Jordan has a system for limiting abstraction of groundwater for irrigation. This is the well licensing system. The system is flawed, however, in that the licenses issued before 1984 do not specify quantitative limits. Furthermore, the administration of the system is not effective since there has not been any enforcement of the license limits even where they do exist.

4.2.1 The Licensing System. Some of Jordan's first deep agricultural wells were established in the Dulayl area of the AZB in the early 1960s. Initially, the Natural Resources Authority (NRA) was the licensing agency. Except for a few wells licensed near the end of their tenure, the NRA's licenses did not state any quantitative limitation on water abstraction, nor did they state any limitation on the land area that could be irrigated. In 1984 the Water Authority of Jordan (WAJ) assumed responsibility for all licensing of privately owned wells, including industrial wells. Beginning shortly thereafter, quantitative limits were specified on most new irrigation well licenses. Initially these were set at either 75,000 m^3 or 50,000 m^3 per year. After 1990 virtually all new irrigation wells licenses specified a quantity of 50,000 m^3. Relatively few new agricultural licenses were issued after 1992.[32] However,

[31] Downward adjustments are made in energy costs due to the farms which are abandoned.
[32] The latter is according to Dr. Khair Al Hadidi, director of the Department of Well Licensing, WAJ.

licenses have been issued for purposes of cleaning or deepening existing wells, or to construct new wells to replace old wells that failed.

A review was made of WAJ files for wells on farms contacted for the RA survey. For the 130 wells where files were available, the licensing status is shown in Table 4.7. This shows that about two thirds of the wells have quantity limits specified. Sixty wells (46%) are licensed for 50,000 m3 per year, while 27 wells (21%) are licensed for 75,000. The remaining 33% have no quantity limit. In recent years when licenses have been re-issued for cleaning and other purposes, older wells that originally had no stated quota have been limited to the 50,000 m3 level.

The majority of the licenses do not limit the area that may be irrigated with the well. Some 60 wells (46%) have 100 dunum irrigation limits specified on the license. Interestingly, the licenses issued for many wells in the 1980's state that the well owner is required to irrigate *at least 25 percent* of his farm area. This shows that the government was really trying to encourage more irrigation at that time, rather than to limit abstraction.

Table 4.7 Summary of License Status for Wells in RA Survey

Quantity Limit:	**Number of Wells**	**Percent**
Quantity limit, 50,000 m3/yr	60	46%
Quantity limit, 75,000 m3/yr	27	20%
No quantity limit	43	34%
Total	130	100%
Irrigation Area Specification:		
Maximum 100 dunums	61	47%
Minimum of 25% of farm	22	17%
No mention of irrigation area	48	37%
Total	130	100%
Original Issue Date of License:		
1961-1983	68	52%
1984-1990	28	22%
After 1990	34	26%
Total	130	100%

While there has been growing concern about over abstraction, the WAJ has not attempted to enforce license limits on abstraction. Enforcement would be difficult since not all wells carry quantity limitations, and it would not be possible to enforce limits on all wells. Furthermore, until recently wells were not metered and it would have been impossible to enforce limits.

According to the Water Regulations[33] of 1977, the government[34] an *annual* abstraction license issued by the government for all agricultural wells. While the licenses issued since 1990 state that they are annually renewable, this provision has not been enforced. According to the 1977 regulations, the government[35] has the authority to specify abstraction limits on all wells.

If the government is to control groundwater abstraction, it must utilize its authority to issue annual abstraction permits and to limit the amount of abstraction. This will not be easy at first, since the government has set a precedent of allowing farmers to do more or less as they wish. It will be particularly burdensome for irrigators who have made large investments in

[33] Also referred to as "by-laws."
[34] At the time the regulations were written, the administrative authority for this would have been the Natural Resources Authority. For administration of ground and surface water, the NRA has since been replaced by WAJ.
[35] In the regulations it was stated that the Vice President of the NRA Board of Directors would have this authority. Apparently the authority would now fall to the President of the WAJ Board.

tree production to cut back on water use. Simply stated, it would cause a large portion of the trees to die and investments would be lost. Thus, it may be necessary to allow tree growers to continue to farm for awhile, until they have had the chance to earn a return on their investments. Some types of trees, particularly olives, represent longer-term investments because they take quite awhile to come into full production. Thus, the government may wish to phase in its enforcement of abstraction limits on a gradual basis. This could be done by requiring that users pay relatively low fees (water tariffs) for quantities used beyond the license limit.

It is recommended that the government exercise its right to issue annually renewable abstraction licenses for all agricultural wells in the Basin. These annual licenses should all carry abstraction limits. In cases where the original drilling license has a specified limit, this should be used on the annual license. In the case of older licenses, where no limit was stated, it is suggested that a limit of 75,000 m3 per year is applied – this is equal to the higher amount specified on those licenses which do have them.

Beginning in early 1990s, a separate license form was developed for industrial wells. These licenses do not contain a quantitative limit, but industrial users are required to pay a fee of JD 0.25 per m^3 for the water that they abstract.

Numerous wells in AZB are operated by WAJ to provide municipal and industrial water for Amman and all major towns of the AZB, including Zarqa and Mafraq. There has been no licensing or quantitative limitation on these wells. WAJ is currently preparing to construct several new wells in the [corridor] which will further over-draw the Basin's aquifers.

4.2.2 Water Metering. To enforce quantitative limits, it is necessary that there be a means of measuring the quantity abstracted from each well. Beginning in 1995, WAJ began installing meters on all agricultural wells. To date, however, not all wells have had the meters installed, and many of the meters that have been installed are not operational. In the RA survey of agricultural wells in the Ba-B2/A7 aquifers, it was determined that meters had been installed on only 138 wells (90%) for the 156 farms surveyed, but only 88 (61%) of these meters were functioning properly.

The administration of the metering system does not function smoothly. Although farmers were billed for the meters[36] when they were installed, but they were not forced to pay for them immediately. Rather, when a well owner needs to renew the license in order to have the well deepened or cleaned, he is forced to pay the outstanding bill for the meter at that time. Not interest is charged. The WAJ Department of Security, which is in charge of the metering system, is responsible for repairing meters when they break. They bill the well owner JD 50 per repair visit, but well owners are reluctant to pay this fee.

With only 64 percent of the meters operating, the metering system cannot be effective.

Observations made by the RA survey team indicated that some farmers tamper with the meters and even may break them on purpose, because they recognize that they will eventually be used as a basis for charging for water.

In the opinion of the consultant, for the government to control abstraction of groundwater there is simply no alternative but to make the water metering system effective. Meters must be installed on all wells. They should each be sealed in an effective way that will prevent tampering. Competent, trained meter readers must read them on a regular basis. WAJ should train technicians to repair the meters immediately when they break down.

[36] The charge for meter and installation varied from JD 250 to JD 520, depending upon the size of the well pipe.

Meters have also been installed on industrial wells and are used to measure the water that they abstract for purposes of billing.

Use of municipal and industrial [37] water is measured both at the well and at delivery points to the actual users. However, more than 55 % of the water in the municipal systems is unaccounted for[38]. Physical (leakage and transmission) losses alone account for over 30%[39], while the remainder is due to accounting and other administrative deficiencies.

4.2.3 Farm Area and Cropping Pattern Restrictions. Other quantitative restrictions are often proposed as a means of limiting groundwater abstraction. The initial agricultural well licenses in Jordan did not specify any limitation on the amount of land to be irrigated. After the WAJ assumed authority for licensing in 1984, [many] licenses included information on the amount of farm land that the license holder owned and it was stated that "at least 25 percent" of this area would be irrigated. In other words, at that time the intention was to ensure that the water would be used rather than to limit it.

Beginning in the early 1990's, however, most new agricultural well licenses specified a limit of 100 dunums on the area to be irrigated with the well.

Some of the farmers contacted in the RA survey suggested that the government should impose irrigation area limits as a means of controlling water abstraction, while others suggested that the government should impose a cropping pattern[40] as a means of accomplishing this.

The idea of imposing a cropping system would not be an effective means of limiting water use. Jordan tried to impose cropping pattern restrictions during the 1980s as a means of ensuring that certain crops were not over-produced, and thus to prevent decline in certain product prices. The job of enforcement was assigned to the agricultural extension service. It proved to be virtually impossible to enforce. Farmers resisted, and they developed an antipathy for extension agents, which served to reduce the effectiveness of that system. It did not work then, and it would probably not work now as a means of controlling abstraction.

Limiting the total area irrigated, rather than controlling the cropping pattern, might serve to limit water abstraction somewhat. This is less direct than controlling water use through metering, however, it would be more time consuming, and would probably be no easier to operate than the metering system. It would probably mean adding an extra body of employees, which would add further to WAJ operating costs. If the government should decide to limit the total crop area, this should not be viewed as a substitute for metering and license restrictions.

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[37] Here, the "industrial" part of M&I refers to those industrial users who obtain water through the various municipal water systems administered by WAJ, as distinct from those who have their own wells.

[38] Sara, Yasser M., Economics of Water, Ministry of Water and Irrigation, report commissioned by German GTZ, October 1998, p.17 in Chapter IV.

[39] Physical losses are 30% for Amman and 35% for Irbid.

[40] Until the late 1980's the Government of Jordan normally specified the cropping pattern which was to be used by farmers, particularly in the Jordan Valley. Originally used mainly as a means for planning delivery of irrigation water through the Jordan Valley Authority's canal system, this practice has since been discontinued due to the economic inefficiencies which resulted from it.

4.2.4 Illegal Wells. While there are apparently very few illegal wells in the AZB – only two were counted among the 173 wells enumerated in the RA survey – such wells are reported to be more common in other groundwater aquifer areas. They represent another facet of the government's difficulties in enforcing its groundwater management system. This being the case, it becomes all the more difficult for the government to enforce abstraction with its regular licensing system. Thus, the government must move vigorously to close down all illegal wells.

4.2.5 Potential savings from effective license restriction enforcement. What savings could result if well license limits were enforced? Analysis based on the RA survey indicates that there are currently some 318 wells being actively used for irrigation on the B2/A7 aquifer and that these wells pump an annual total of about 80 MCM of water. Judging by the license information shown in Table 4.7 for the 130 wells from the RA survey, some 46% of wells have stated license limits of 50,000 m3 per year, while 21% have specified limits of 75,000 m3[41]. Under the 1977 water regulations, WAJ apparently has authority to set limits on the remaining 33% of wells. If all wells were licenses were set at 100,000 m3 per year, and these limits were enforced, this would reduce total abstraction to about 32 MCM for the subject aquifers. This would be a saving of 48 MCM, or 60 percent of current use.

While the savings from license enforcement would obviously be considerable, the results of this degree of restriction would spell disaster to most farms in the basin. The average farm size found in the survey was about 330 dunums of irrigated area. With average water requirements of about 714 m3 per dunum, varying somewhat according to the cropping pattern of the farm, a limit of 100,000 m3 would be enough to farm only 140 dunums. According to the RA survey, only 20% of farms are of this size or smaller. Thus, with a limit of 100,000 m3, about 63 of the 318 farms irrigating from Ba B2/A7 would have sufficient water.

Undoubtedly, many larger farms would be able scale back the size of their operations and be able to survive the limits outlined above. But for many it would be impossible to cope with the new limits. This is true especially for the large tree farms and larger mixed farms with trees, where a loss of water will mean death for the trees in the harsh desert climate of the AZB. The RA survey analysis shows that some 134 farms in the Basin (42% of the total) are tree farms and mixed farms having with more than 300 dunums of irrigated crop area. These farms account for an estimated 89% of the area planted to trees in the Basin. It would be impossible for farms of this size to get by with 100,000 m3 of water or less, considering that their minimum requirements are 250,000 m3 per year. Being limited in this way would mean that half or more of their trees would dry up, which would spell financial disaster for many of them.

Thus, while effective license limit enforcement has the potential of generating great reductions in groundwater use, it would be a severe measure that would have drastic effects on many farmers in the AZ Basin.

4.2.6 Water use fees. Water user fees represent an option to strict license enforcement. Such fees are a means of inducing farmers and others to use water more efficiently. Such fees would cause water users to recognize the fact that water is a scarce resource and to take this into account in their decision making. User fees constitute one type of *incentive system*.

Water user fees are collected from Jordan Valley farmers, although the amount they pay averages only about 15 fils/m3 and is not enough to cover the Jordan Valley Authority's (JVA) full costs of dam operation and canal delivery. Since the fee does not cover the full

[41] According to WAJ authorities, a few wells have annual limits of 100,000 and 150,000 m3. However, such wells were not found in the review of files conducted for this study.

delivery costs, it is clear that Jordan Valley farmers are not paying anything to reflect the opportunity cost (scarcity value) of the water they use.

Industrial well operators in Jordan are charged 250 fils/m3 for the groundwater that they pump. While this value probably does not reflect the full *opportunity cost* or *scarcity value* of the water, it is a significant charge.

If applied to irrigation water, a water charge of JD 0.25 per m3 would come to JD 178 per dunum, at current average water use. This represents an increase of almost 75% in the farmer's average variable costs. The analysis of AZB farm incomes in Chapter 3 indicates that most upland farms would experience great financial losses if they had to pay this for their water. This amount is well over twice the estimated gross profit and almost 14 times the net profit of such a farm. A water charge of this magnitude would drive most farms out of business. It would mean the loss of jobs to agricultural workers, and it would cause other undesirable social impacts on the entire AZB area, as discussed in the report by Jabarin on the Socio-economic aspects of highlands agriculture.

Although charging farms at the same JD 0.25 rate paid by industrial users would not be feasible, there is good economic justification for charging groundwater irrigators something for the water that they abstract. It does not necessarily take such a high charge to encourage irrigators to use water with more care and to focus their efforts on higher valued crops. Furthermore, the existence of a fee would serve to encourage inefficient, less capable irrigators to quit farming, or to sell their farms to more skilled and productive farmers.

User fees may be structured in different ways. One approach is to impose a *flat rate* charge on all water that is used, as in the example above. In some countries, irrigation districts use so-called *increasing block* rate structures, similar the rate system that is applied for municipal users in Jordan. With increasing block systems, the initial quantities used are charged at a low rate, and a the rate increases as water use increases. There may be step increases for several different levels of higher use.

Increasing block systems have several advantages over flat charges. First of all, they allow users to meet certain basic water needs at a lower cost. Higher use is discouraged by the higher rates, but skilled farmers who are more efficient and know how to grow higher valued crops will still be able to obtain the water they need, since their skill will enable them to afford the higher rates.

4.2.7 Applying water use fees in combination with license limitations.

A simple way to structure a block rate charge system for the AZB would be to charge either zero or a low rate for water use within the licensed quantity, and a higher rate for use above this quantity. One consideration is to determine how much money farmers can afford to pay. This is difficult to judge, since there are always considerable variations in ability and financial status from one farm to the next. Nevertheless, the analysis of the *composite farm* from Chapter 3 (332 dunums of irrigated crop area, with an overall average cropping pattern of both trees and seasonal crops)is again helpful.

Take, for example, a base rate of 15 fils/m3 for the first 75,000 m3, with additional use charged at 40 fils/m3. This would cost a typical farm just over JD 7,000 per year. It represents an increase of over 9 percent in variable farming costs, and it would reduce the farm's gross profit (gross margin) by almost a quarter and the net profits by more than 60%. Thus, it would be a significant cost to the farmer. The RA survey analysis shows that many farms are currently earning far less than this amount for the water they use. To pay water fees and still be able to operate profitably, such farms would have to become more efficient with their water use. They would need to learn to grow higher valued crops, as well as reduce their area of lower valued crops. Farms that did not do this would be forced out of business; however, the water they have been using would be saved.

While the two-step block rate of 15 and 40 fils/m3 would provide obvious incentives to use less water, the 40 fils/m3 charged for over-quota water is still very low. It is low compared to the value of water in non-agricultural uses, and it is low in comparison to most estimates of the opportunity costs of water in Jordan.

Whatever the water charge, it would be preferable to phase it in gradually over a period of years, to give the farmer a chance to adjust and cope. If the rate described in the preceding paragraph were implemented gradually over a period of years, many farmers would be able to adjust. They would adjust in several ways: 1) eliminating low valued crops, 2) learning how to grow higher value crops, and 3) becoming more productive with the crops they are growing. Other farmers would go out of business.

Table 4.8 shows the estimate total collection of water use fees from two different structures. Rate 1 requires a payment of 15 fils/m3 for all use up to an assumed license limit of 100,000 per farm, and a payment of JD 0.040 per m3 for use above this quota. Rate 2 uses the same JD 0.015 for use within the quota, but charges JD 0.250 for use above this amount. In each case the fees would be phased in over a period of five years, to provide the farmer a chance to adjust. Rate 3 assumes that there would be no charge for water within the license limit. If the block rate described above were implemented over a period of five years, many farmers would have the time needed to adjust. Others would undoubtedly go out of business.

If the block rate described above were implemented over a period of five years, as is shown in the table, many farmers would have the time needed to adjust. Undoubtedly some of the less productive farms, and those producing lower valued crops, would go out of business because they can't afford to pay for the water. But the number of failures would be less if the rate is implemented gradually.

Table 4.8 Water Use Fees Under Three Alternative Fee Structures					
Total annual fees generated (JD):					
Rate structure (JD/m3 for water use under limit & over limit)	**2003**	**2004**	**2005**	**2006**	**2007-20**
Rate 1. (0.015 & 0.040)	200,906	401,813	602,719	803,625	1,004,532
Rate 2 (0.015 & 0.100)	431,081	862,163	1,293,244	1,724,326	2,155,407
Rate 3 (0.0 & 0.100)	383,625	767,250	1,150,876	1,534,501	1,918,126
Average fees per dunum in 2007 (JD / dunum)			**Rate 1**	**Rate 2**	**Rate 3**
Farms using less than 100,000 m3/yr			9.58	9.58	-
Farms using more than 100,000 m3/yr			18.90	41.26	37.27
Average of all farms			**18.33**	**39.34**	**35.01**
Average bill per farm in 2007 (JD)			**Rate 1**	**Rate 2**	**Rate 3**
Farms using less than 100,000 m3/yr			775	775	-
Farms using more than 100,000 m3/yr			7,100	15,501	14,001
Average of all farms			**5,643**	**12,109**	**10,776**

Based on analysis of farm budgets, it is projected that from 10 MCM to 15 MCM of reduction in water use will be achieved by the higher fee structure (Rate 2 or Rate 3). The analysis shows that about half the savings will be achieved through attrition – farms going out of business – and the other half will be achieved by reduction of farm size through elimination of lower valued crops. The 7.5 MCM reduction due to attrition means that about 32 farms would go out of business. It is expected that this will happen gradually between 2003 and 2007. These will be farms that are not profitable to begin with. Thus, jobs would be lost, but there would be no other net economic loss to the country.

The 7.5 MCM saved through elimination of low-valued crops would mean a reduction of 10,500 dunums in crop production. It implies that the average farm size in the Basin would decrease by about 22.4 dunums, to 307.8 dunums from the current 330.2. As in the case of non-profitable farms that fail, loss in production would not imply a net economic loss to the country because these crops are not been profitable to grow. Again, however, there would be job loss for farm laborers.

Total revenues to be collected by the water use charges are also shown in Table 4.8. It is expected that by the time the full water charge is implemented in 2007, from JD 1 to JD 2 million per year could be generated in this way[42].

4.3 Buy-out of wells.

Aside from the strict enforcement of annual license abstraction limits and levying water use fees for any amounts exceeding these, another means of reducing water use in the Basin would be for the government to buy out well licenses. Sometimes this is referred to as "wells buy-out" or even "farm buy-out", but the license itself may be the important thing to buy because it is the license which gives the well owner the right to abstract water.

The government may technically have the right to close down wells without compensating the owners, this would cause considerable losses and hardships for well owners and would be politically difficult. Furthermore, it might be considered unfair because the well owners have made costly investments in their farms and irrigation systems, in addition to the cost of constructing the wells themselves. Many have based their livelihoods on their irrigation farms. In buying out the licenses, the government would be, in effect, compensating the owners for their investments. Viewed in another way, the buy-out could be seen as compensation for future income lost. Particularly if paid over time, the buy-out money could serve as a kind of pension to help the farmers retire, or to compensate them for the livelihood (income) which they forego when they give up the license.

Which wells or well licenses should the government buy out? A number of factors would need to be taken into account to decide this. On the one hand, the government would want to purchase the greatest possible amount of water for the least possible expenditure. On the other hand, it may be prudent to buy out farms in areas that are in danger of going dry, or where salinity problems are most severe. It may also be less expensive to buy wells in areas with saline water because the salinity is already affecting their incomes, and the valuation of their farms would thus be expected to be lower.

The fact that salinity is already impacting the incomes of many irrigation farmers in the basin was illustrated above in Figure 4.2. Analysis of the information presented in the figure shows that only two (11 %) of the 18 farms with salinity above 1000 ppm reported income above the "breakeven" level of JD 302, which is the level estimated to be necessary for most farms to operate at a profit[43]. In contrast, 27 (49 %) of the 56 farms with salinity levels below 1000 ppm reported incomes above JD 302.

[42] Total revenues are based on a total farm number of 178 expected to be left after the buy-out and other water saving strategies discussed below are implemented.
[43] See farm income analysis in Chapter 3.

4.3.1 Factors to be considered in valuation of wells for buy-out. How should the wells which are bought out be valued. As noted above, their value to the farmer can be looked at in different ways. Normally, farm valuation is based on three alternative approaches:

- Investment in the farm and all fixed equipment such as wells,
- Present Value of (net) income expected from the farm, and
- Market value of the farm and fixed equipment.

Table 4.9 shows the farm investment values for typical farms of average size, as discussed in Chapter 3. It shows that the cost of the well and pump are secondary as compared to the cost of orchards.

Table 4.9 Estimated Farm Investments, Typical Farms of Average Size (JD)				
	Type of Farm			
Investment in:	Tree Farm	Seasonal Crop Farm	Mixed Farm	All Farms
Land	75,598	39,610	80,721	66,038
Well, pump, motor & irrigation system	83,402	74,208	86,514	81,893
Orchard	225,193	-	121,742	113,452
Total Investment	**384,194**	**113,818**	**288,977**	**261,384**
Average farm size (dunums)	378	198	404	330
Average investment (JD / dunum)	1016	575	716	792

Tree farms require the highest investment, because orchard is costly to establish. Mixed farms require more investment than seasonal crop farms, also due to orchard cost. Of course, farm size also makes a difference. That is why it is also useful to look at the average cost per dunum of farm size. On this basis, it is seen that seasonal crop farms cost the least, at an estimated JD 575 per dunum, while orchards have the greatest investments at JD 1016 per dunum.

Total investment cost not only varies by farm area, but also by the depth of the well required. For this reason, farms in the upper Basin (Mafraq area) are expected to have higher than average well development costs. The cost of orchard also varies according to the type of tree involved, and due to the period it takes the trees to come into production. Olive trees, for example, take several years more to reach significant levels of production than do pome and stone fruits or grapes. Grapes require trellising, which is also expensive.

In using investment value as a basis for considering what to pay for a well, the government would also have to take depreciation into account. In other words, wells and pumps that are old will be worth less than the original investment values shown in Table 4.9, because they are worn and thus are worth less than new wells. Trees, however, represent a different issue. Trees tend to become more valuable as they age, since their productive capacity increases with age. Some trees such as olives have very long productive lives, while others such as stone fruits have shorter lives. Since most of the trees in the Basin are still relatively young, their value is increasing and no depreciation should be subtracted from their investment cost, for purposes of valuation.

Market values for farms with wells should be used by the government as a point of reference in deciding how much to pay for the buy-outs. Some rough indications of market values were obtained in the course of this study. These are reported in Appendix C, Table 2 are as follows:

- ❑ For *raw land with no water*:

- JD 50 – 300 per dunum, depending on location; locations near urban areas are at the high end of the range.

- For *open land with a well but no orchard*:
  - JD 500 – 1000 for areas of 100-300 dunums; any additional area is valued as raw land.

- For *orchards with well*:
  - JD 1000 – 2000 per dunum, for good quality orchard with areas of 100-300 dunums; beyond this size values per dunum decrease.
  - JD 700 – 1250 per dunum, for lower quality orchard with areas of 100-300 dunums; beyond this size values per dunum decrease.

It is also reported that market values decline for farms depending on wells that have saline water. Where salinity is above 1500 ppm values are said to be about half of what is reported above, and above 2000 ppm the farm has little or no value.

In buying out a well, the government would probably not want to pay for the underlying land, since after the buy-out the farm owner would be left with the land to use as he wished for purposes other than irrigation.

For the *income approach* to valuation, net incomes also vary according to farm type, as was shown in Chapter 3. For average farms, *gross margins* (crop revenues less variable costs) vary from about JD 90 to JD 105 per dunum, while *net incomes* (crop revenues less total costs) vary from JD 25 to JD 50 per dunum, depending on farm type. Of course, not all farms earn these levels. In fact, analysis of the RA survey showed that almost 60% of the farms in the AZB upland have crop revenues which are less than their estimated variable costs, and the sales revenues of 73% are less than their total costs. In other words, *many farms are losing money*. The expected value of future incomes for such farms will be far lower than average. These are the farms that are earning the lowest economic returns for their water. And for this reason, the government should target lower income farms for the buy-out. As discussed above, high salinity of water is one of the factors which contributes to low incomes. Thus, farms with saline water should be another target of the buy-out. These farms should be willing to sell out for less.

In addition to the above factors, the government will also wish to consider, as a point of reference, the economic value (opportunity cost) of the water which is to be purchased. The value of the water can be estimated in various ways. For purposes of this study, it is assumed that the opportunity cost of the water is the cost of the investment required to develop alternative water supplies for the Amman area. The estimated annualized investment cost is JD 0.424 per m3 of supply for the proposed Disi Conveyor Pipeline, which is reportedly close to inception.[44] This cost is low when compared to the estimated costs for other projects such as the proposed Red Sea Dead Sea Canal project, for example, for which the annualized investment costs are estimated to exceed JD 1 per m3 of supply.

4.3.2 Estimated costs of buy-out. Of the current 75 MCM estimated current abstraction for the Basalt B2/A7 aquifers of the AZB, it is believed that some 15-20 MCM could be purchased at a fairly low cost. Many farms have been losing money, or earning only low incomes, and many have indicated that they would be willing to sell. Estimated use in the aquifers is as described in Table 4.10.

Costs of buying out seasonal crop farms are expected to be the lowest because they have the lowest investment costs and would not be giving up expensive investments in trees. However, as Table 4.8 shows, the average water use per farm is relatively low on seasonal

[44] World Bank, The Hashemite Kindgon of Jordan Water Sector Review, October, 1997, Volume II, Annex C, Attachment 1.

crop farms, because their average farm size (195 dunums) is relatively low in comparison to other farm types, and because their average water consumption is low. Thus, they use only 12.4 million of the 75 MCM in estimated irrigation water use for the subject aquifers.

Table 4.10 Estimated Water Use per Farm, and Total Use in AZB				
	Farm Type:			
	Tree	Seasonal	Mixed	All Farms
Number of Farms	89	102	127	318
Average Farm Size, dunums	380.5	194.8	399.7	331.5
Avg water use, m3/dun	819.9	613.6	684.8	714.3
Avg. water use per farm, m3	309,898	121,520	276,396	236,095
Total irrigation use, MCM	**27.6**	**12.4**	**35.1**	**75.1**

While buying out farms with orchards may present difficulties since it will be more expensive than buying seasonal crop farms, there is no other choice if the objective is to obtain 15-20 MCM. Furthermore, the survey showed that many of the mixed and tree farms with orchards are earning only low incomes at best, and many of them are in areas with saline water. Many of these farms expressed interest in selling.

It would be possible to buy 20 MCM, for example, buy buying out 74 seasonal crop farms, 25 mixed farms, and 13 orchards, as shown in Table 6.11. This would result in obtaining 9, 7 and 4 MCM from each farm type, respectively, assuming that all farms are of average size. In practice, of course, some would be larger and some would be smaller, and thus the parameters would vary somewhat from what is shown in the table.

Table 4.10 shows various types of information that is relevant to the buy-out program. The buy-out values themselves could be based either on expected income or on the (depreciated) investment values. Estimated depreciation for wells, pumps and irrigation equipment has been subtracted, but no depreciation was taken for orchards, for reasons explained above. Estimated values of investment are shown for typical farms of this size. The incomes have been adjusted to represent below-average farms[45].

The buy-out values based on farm income have been calculated as the present value of future income (gross margin), assuming that income continues at its current estimated level for the next 20 years.[46] A discount rate of 10 percent has been used. A contingency factor of 25% has been added to both the investment and present value of income, to ensure that they would be attractive to farmers. On this basis, when the income approach is used, the buy-out for the average 198 dunum seasonal crop is estimated at about JD 67,000 (JD 339 per dunum), whereas a value of some JD 177,000 would be paid for a 378 dunum tree crop farm (JD 468 per dunum).

Table 4.11 indicates that if the investment approach were used, the tree crop and mixed crop farms would receive much higher values per dunum (JD 511 and JD 883, respectively) than the seasonal crop farm (JD 234), which reflect their much higher value of investment.

According to the analysis in Table 4.11, the total value of the buy-out (20 MCM) would range between JD 10.5 to JD 12.9 million. The total cost per unit of water (the total cost of buyouts divided by 20 million) would thus be from JD 0.527 to JD 0.646 per m3. For comparison to the opportunity cost of water discussed above, these costs should be

[45] The sales revenues for all farms with incomes below estimated total costs were averaged and found to be about 60% of the composite farm.
[46] The calculation and meaning of present value are discussed in section 6.3 above.

"annualized,"[47] which means converting them from the stated total amounts to equivalent annual amounts. As shown in the table, the equivalent annual costs would range from JD 0.062 to JD 0.076. These amounts represent only 15% to 25% of the JD 0.424 opportunity cost of water described above. Thus, it appears that the buy-outs would represent an economical alternative source of water.

Table 4.11 Costs of Well Buy-Out				
Farm Type:	**Seasonal Crop Farms**	**Mixed Farms**	**Tree Farms**	**All Types**
Water purchased through buy-out (MCM)	**9**	**7**	**4**	**20**
Annual Water Use, m3/farm	121,520	276,396	309,898	
Number of wells (licenses) required to purchase	74	25	13	112
Average farm size, dunums	198	404	378	
Relevant farm investment information:				
Estimated Farm/well Investment, JD/farm	74,208	208,256	308,595	
Depreciated Investment Value, JD/farm	37,104	164,999	266,894.30	
Relevant information, on current est. income:				
Annual income, gross margin, JD/farm	6,318	12,262	16,624	
Annual income, gross margin, JD/dunum	31.90	30.38	43.98	
Return to water, JD/m3	0.052	0.044	0.054	
Values to consider in valuing buy-out:				
Present value of expected farm income , JD/farm	53,786	104,392	141,532	
Depreciated value of investment, JD/farm	37,104	164,999	266,894	
Important assumptions used in calculations:				
Time Horizon for Caluclating Present Values		20		
Rate of Discount (Interest) used in Present Values		10%		
Estimated buy-out cost per farm:	**Cost per farm (well) bought out, JD**			
Based on income [a], JD/farm	67,233	130,491	176,916	
Based on investment value [a], JD/farm	46,380	206,249	333,618	
[a] Contains 25% premium on values shown above as a contingency factor.				
Total Cost of Buy-out:	**Total cost for ALL farms (wells) bought out, JD**			
Based on income	4,975,218	3,262,265	2,299,903	10,537,385
Based on investment cost	3,432,108	5,156,230	4,337,032	12,925,371
Average cost per unit of farm area	**Cost per dunum of farm area (JD/dunum):**			
Based on income	339	323	468	355
Based on investment cost	234	511	883	436
Average cost per m3 of water purchased	**Total cost per m3 of water (JD/m3):**			
Based on income	0.553	0.472	0.571	0.527
Based on investment cost	0.382	0.746	1.077	0.646
Annualized cost per m3 of water purchased	**Annualized value of water (JD/m3 per year):**			
Based on income	0.065	0.055	0.067	0.062
Based on investment cost	0.045	0.088	0.126	0.076
Opportunity cost of water (for purposes of comparison to buy-out value)				**0.424**

In actual practice, each farm will have values that differ from those shown in the table above. It making the actual purchases it would be difficult to use the income approach, since it would require estimating the incomes of each farm. Most farms do keep records on their costs. The value of the investment, on the other hand, would be easier to estimate since the investment items (wells, irrigation systems, trees) could be readily inspected to ascertain their value

[47] The total cost figure is "annualized" by calculating the annual payment that could be derived from the total cost amount. This is the reverse of the present value calculation discussed above.

4.4 Irrigation Advisory Service

In the course of its study over the past 18 months, the Groundwater Management Component has observed and documented a number of inefficiencies in the way that farmers manage the water they use for irrigation. Virtually all farms use drip irrigation, which is potentially very efficient. However, once the vendor installs the drip system most farmers are left alone with little knowledge about how to use it properly.

There are many signs of over-irrigation. Tree farms, for example, allow water applied with drip to puddle up in mini-basins that have been mounded up about the trees. Interviews with farmers found much lack of knowledge about the water requirements of their crops. The agricultural extension service of the Ministry of Agriculture is not active in the uplands area.

For these reasons, it has been recommended that an Irrigation Advisory Service be established in the AZ uplands, to show farmers how to irrigate more efficiently. Hanson[48] has estimated that such a service could result in water savings of from 15 to 20 percent. It is planned that a program to accomplish this would require three qualified engineers, plus support staff and vehicles, for a period of three years. Total costs over the three year period would be JD 250,000. A total of 5 MCM per year are expected to come from this effort, with results building gradually from year 2003.

Valuing the water saved at the opportunity costs of JD 0.424 per m3, the present value of the water saved over the next 20 years in this way comes to JD 11.5 million. The JD 250,000 estimated cost of implementing this service, to be spread over five years, is quite small in comparison. In present value terms, the cost would be only JD 201,000.

4.5 Substitution of recycled water for groundwater.

Another way to save groundwater is by substituting treated wastewater for groundwater in irrigation. With additional M&I use in Amman and other urban areas near the AZB, the availability of recycled water from the As Samara treatment plant is expected to increase significantly over the next 5-10 years. Thus, recycled water is available for such a substitution.

Substitution of recylced water is complicated. Because it may contain pathogens, it is not suitable for vegetables and other field crops that are used for human consumption. However, recycled water is suitable for forage production and for the irrigation of tree crops. But pome fruit and many other deciduous trees are negatively impacted by the chlorides contained in the As Samara effluent. They continue to produce for 5-10 years but often die from the chlorides after that point. However, Olives and dates are not negatively impacted.

Although these potential limitations are of concern, irrigation farms in areas not too distant from the As Samara plant appear to provide ideal candidates for converting to recycled water. Well operators in the nearby Dulayl and Hashimiyah areas are experiencing problems with high salinity, and the water table is expected to go dry for many wells in this area during the next ten years. Furthermore, the existing cropping pattern on farms in this area, which is a part of Zarqa Governorate, is relatively compatible with the limitations of recycled water.

The RA survey found Zarqa farms to have the cropping pattern shown in Table 4.12. The Zarqa area has a far heavier concentration in tree crops than Mafraq, and almost 80 percent of

[48] Hanson, R. Blaine, "Technical Report: De velopment of Irrigation Advisory Service Program in the Highlands Area," Groundwater Management Component, MWI/ARD WRPS Task Order, August 2000.

these trees are olives. The Dulayl area is the center of part of a significant number of dairy farms and is already significant producer of forage (alfalfa, 5% of rotation). While much of the forage for these farms has been imported from nearby areas in Saudi Arabia, the Saudi government has recently placed restrictions on exports of such forage. Thus, the dairies require local forage supplies.

Table 4.12 Cropping Pattern by Zone

	Zarqa	Mafraq	Total
Tree Crops:	**68%**	**53%**	**58%**
Olives	53%	33%	40%
Apples	8%	7%	7%
Peaches	5%	6%	6%
Grapes	2%	1%	1%
Other tree crops	1%	6%	5%
Seasonal Crops:	**32%**	**47%**	**42%**
Alfalfa	5%	0%	2%
Barley & wheat	5%	3%	4%
Vegetables & melons	22%	44%	36%
Total	100%	100%	100%

Would the use of recycled water be economically feasible for the Dulayl-Hashimiya farms? A feasibility study recently conducted by Shaner[49] considered the use of recycled water. This study concluded that it was not feasible to use recycled water. It showed that the net benefit from farming with the water (value of production less total crop production costs) was less than the estimated cost (investment + O&M) to deliver water to farms. The study did show, however, that it would be economically feasible for farms to irrigate with the water, if the government would deliver it free of charge.[50]

It is very important to note that the feasibility study cited above did not assign any value to the water saved. As we have seen, groundwater has a significant opportunity cost to Jordan. If that opportunity cost is taken into account, the analysis of feasibility changes dramatically. The cost of supplying pressurized recycled water to farmers in the Dulayl and Hashimiya area is estimated to be JF 0.380 per m3. This is less than the JD 0.424 per m3 value of water. This means that the value of the groundwater saved is greater than the cost of supplying the water. Therefore, it would be feasible to do this.

[49] Shaner, Willis W., "Economics Study for Water Reuse for Agricutlrue and/or Forestry in the Amman-Zarqa Highlands

[50] A minimal water charge of 15 fils/m3 was also found to be economically feasible for the farmers.

Appendices