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Jordan's Water Situation

- Impacts of recently implemented policies on the water sector -

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Abstract

Jordan has in recent years implemented a series of courageous policy issues to conserve, improve and rehabilitate its water resources situation. The first major steps have been undertaken to solve the problem of aquifer over-exploitation.

Metering and pricing the extracted groundwater for all purposes including irrigation together with the prohibition of drilling will certainly lead to savings and conservation of the groundwater resources and to shift to low water-consuming crops and to increasing efficiencies. In the case of industrial water it has already lead to the introduction of water saving devices, in-plant water recycling and reuse of treated wastewater. Improved conveyance system to reach a higher efficiency and introduction of water saving application systems in irrigated agriculture have become obligatory to farmers and well owners, because the extracted groundwater is priced and farmers have to pay for it. Charging a price for the extracted fresh groundwater is expected to encourage farmers to use any available treated wastewater or brackish water for those crops tolerating these types of water.

Despite the considerable accomplishments, Jordan's water sector remains in critical condition, where the water need exceed the water supply. This situation will sharpen and the gap between demand and supply will widen due to population growth. In addition, pollution of water resources and salinisation due to over-pumping are destroying major water resources and lowering the available, usable amount of water. Therefore, further management actions are still necessary to reach an environmental and hydrogeological safe situation. Therefore Jordan has national laws that authorize activities to conserve water. These laws are based upon the policy to put water resources to the maximum possible benefit.

Recent developments in the water sector in Jordan may now serve as an example for other countries with similar water situations.

I. Introduction

The history of humans in Jordan throughout the last three to four millennia has been determined and shaped largely by one major infrastructural element: water. This essential resource has great influence over human life when it is scarce. In Jordan the lifestyles of people, their socio-economic status and their conflicts have all been determined by this basic factor.

Agriculture developed when the amount of rain was sufficient to support plant life. Irrigated agriculture was practiced along water courses such as the Jordan, Yarmouk and Zerka Rivers and a number of springs pouring into the Jordan Valley as well as around the few oases in the eastern part of the country.

In the past, availability of water and the technologies used for its exploitation not only determined lifestyles and socio-economics but also limited the population to the number who could be supported by the amount of food produced. In the last few decades the population growth rate has been very high, not only due to natural growth but also as a result of the waves of refugees coming into Jordan, mainly from Palestine.

The whole of Jordan's development has been concentrated in agriculture, mainly irrigated agriculture, which entails developing water resources to be used for irrigation. Irrigated agriculture created job opportunities through less expensive investments for both Jordanians and refugees. This averted the potential catastrophes of poverty and hunger, and fostered domestic peace in Jordan. But, with the sharp increase in population and agricultural development, as well as the establishment of many small, medium-sized and even heavy industries (potash, phosphate and fertilizers), the available water resources were insufficient to meet development aspirations, especially because the spectrum of water uses has widened and the intensity of water needs has increased. Population growth, higher standards of living, industrialization, irrigation and other activities accelerated the exhaustion of available resources.

Despite the implementation of intensive water projects and conservation measures, water shortage is the major obstacle to Jordan's development. This puts specialists and politicians under severe stress concerning the future of the country's economic growth, especially by considering the numerous water problems of the country: increasing demand, limited resources, depleting resources, over-exploitation, exhaustion of non-renewable resources and pollution.

Background Information

The prevailing climate in Jordan is semi-arid. Only the highlands in the west and northwest can be characterized as Mediterranean. Jordan receives an average yearly amount of precipitation ranging from 30mm in the southeast and east to about 600mm in the northwest (DOM, 2004). Compared to this evaporation is very high: in the cooler north-western areas, it is about 1800 mm/a, in the southeast it goes up to 4200 mm/a. This is respectively, three and 140 times the amount of average annual precipitation (NWMP, 1977).

Perennial water in Jordan is found mainly in the rivers and wadis of Yarmouk, Zerka, Mujib, Zerka-Ma'in and Hasa. These discharge water during all seasons into the Jordan River, the Dead Sea and Wadi Araba, but its ultimate destination is the Dead Sea. In addition to rivers and wadis, the Azraq Oasis, situated 100 km to the east of Amman, holds water in all seasons. These sources, excluding the jointly-owned Yarmouk River, discharge approximately 160 MCM (million m^3) annually, less than the average discharge of the Nile in one day and less than that of the Euphrates in two (SALAMEH, 1996).

The groundwater resources of the country are of two origins:
1) recent and renewable groundwater and
2) fossil groundwater, which receives no or only a very small amount of recharge.
The latter is non-renewable in technical terms and the exploitation is equivalent to a mining process. The fossil groundwater resources are mainly found in the southern and eastern parts of the country. They infiltrated into the aquifers tens of thousands of years ago, when the prevailing climate was more humid (LLOYD, 1969). Such water can be considered a reserve for dry years.

The renewable groundwater resources of Jordan without the Yarmouk, amount to about 340 MCM/a. They suffice for the greater part of domestic, industrial, and agricultural needs of the highlands.

II. Evaluation of the Water Sector Situation

Implemented Projects

As mentioned above, water resources development is of great concern and forms a major target for the country. Dams were constructed, irrigation canals were built, and domestic water supplies were extended to serve 96 % of the inhabitants including the remote and sparsely populated areas of the country. Even in areas where the source of water lies tens of kilometres away from the settlement, water was brought to the inhabitants through pipe connections. 24 cities and towns accommodating around 70 % of Jordan's population are now served by sanitary sewage systems and waste water treatment facilities (MOWI, 2004).

In the Jordan Valley area, the King Abdullah Canal (formerly the East Ghor Canal) was constructed along the eastern bank of the Jordan River. It extends some 110 km and irrigates

17,000 hc. Other irrigation projects were implemented in the southern area of the Dead Sea, putting around 4,600 hc to use. In addition, the lands of the Jordan Valley lying above the reaches of the canal were irrigated using the waters of the side wadis and some groundwater, bringing the total irrigated land in the Jordan Valley to around 28,000 hc (JVA, 2004).

Concerning domestic water supplies, expensive projects proved to be necessary in order to serve the population centres, which generally lie removed from potential water resources. For example, the capital Amman gets its domestic water from various sources extending 100 km to the east (Azraq) and 55 km to the west (Jordan Valley area), with pumping heads of up to 650 m and 1400 m respectively, in addition to friction heads. This is, for a non-oil-producing country, a very expensive affair.

Water use and resources development

The population of Jordan of presently 5.4 million inhabitants is growing at the high rate of 2.9 %/a (DOS, 2004). That rate is not expected to decrease in the next one to two decades. Accordingly, the population of Jordan is expected to grow to 6.4 million by the year 2010 and to 8.5 million by 2020, i.e., doubling each 23 years. If living standards and population structure remain at their present state, domestic water use will also double in the same time period. Any rise in living standards or social-structure order will result in higher demands, which will exceed double the present daily consumption.

The actual present per capita daily water use is 85 l. Of the present total amount of water pumped to consumers of about 260 MCM/a, one quarter, is lost through corroded leaky pipes, another quarter is used illegally (not being paid for), and a fraction is used by small-scale industries (WB, 2001). The planned industries are also expected to consume more water. The demand is calculated to rise from around 45 MCM/a at present to 85 MCM/a by the year 2010 and to 125 MCM/a in 2020.

Around 650 MCM/a water were used for irrigation during the last few years, distributed between surface and groundwater resources (figure 1). Added to domestic and industrial consumption, the total water use comes to 915 MCM/a. The total extractable and renewable water resources of the country are around 900 MCM/a. It is worth mentioning at this point that some of the resources are over-exploited, such as Dhuleil Azraq, Disi, and Wadi Arab, whereas other resources are still underutilized such as Mujib, Zerka Ma'in and Yarmouk, but projects to utilize them are being implemented. But in general, the water resources still to be developed are very meager, suffer from salinity or are partly shared with other countries (SALAMEH AND UDLUFT, 1999).

Even if the amount of water used for irrigation is limited to its present level, and if water projects and extractions are redistributed to achieve the safe-yield concept, Jordan is now using all its available and renewable resources and is over drafting its groundwater resources (figure 2).

The increasing demand for water led planners to develop the most accessible sources. Other less optimal water resources have also been developed, e.g. water from Azraq was piped 100 km to Amman, causing the groundwater level in that area to drop several meters within a few years. This resulted in saltwater intrusions from deeper saline aquifers and the drying up of a unique oasis, thus damaging the natural habitat of the area (SALAMEH, 1996).

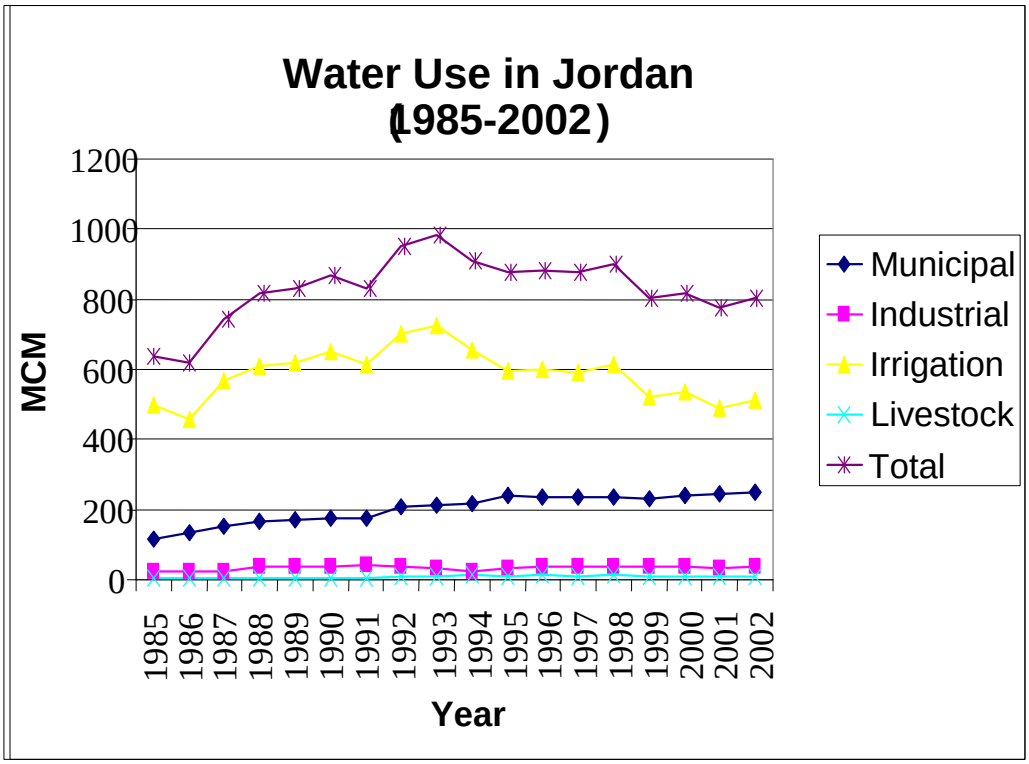

Figure 1: Water use in Jordan over the past years.

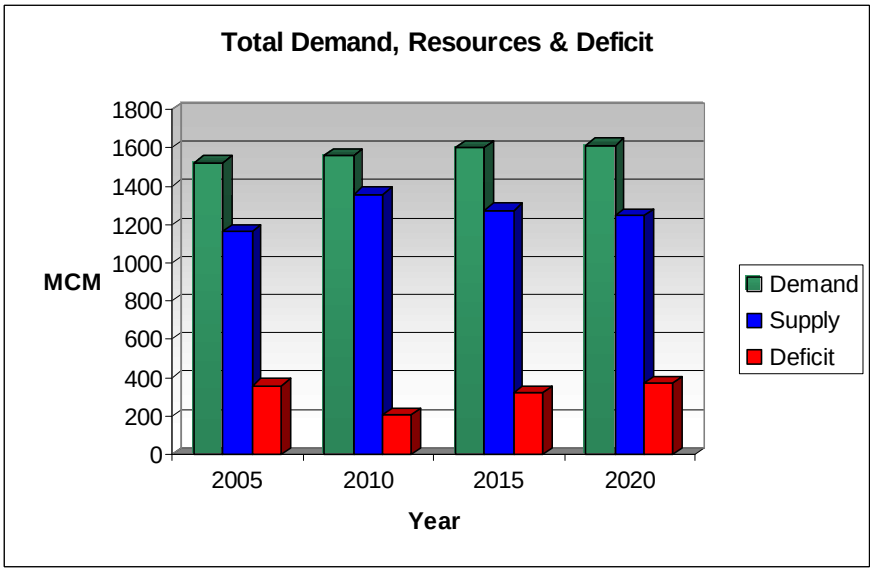

Figure 2: Total demand, supply and deficit.

Not only were renewable water resources used, but extractions were expanded to include the fossil water resources, which have been stored underground for thousands of years. Some of these resources have been exhausted because their replenishment rates cannot cover the extraction rate. This is the case in Dhuleil and Jafr. The Azraq and Disi areas are now also threatened to meet the same fate.

In the past, failure to carefully plan some water projects has resulted in exhaustion or damage to some water resources.

Pollution and over-exploitation

During the last three decades small and medium-sized industries have been established in Jordan, concentrated mainly in the Amman-Zerka area. Effluents from these industries are only partly treated and are directly discharged either into the nearby wadis or into the sewerage system, causing the deterioration of surface and groundwater quality. This type of pollution is limited in its distribution and extent, and major steps were taken to alleviate its effects.

The major pollution problems are the result of inadequate treatment of domestic wastewater inefficient wastewater treatment plants, the choice of inferior waste water treatment systems and inappropriate reuse schemes.

Jordan's scarce water resources, lack of perennial flows, hot climate and relatively low per-capita use of water result in a dense waste water with highly concentrated pollution parameters, which renders the current unsuitably chosen treatment plants and technologies inadequate. The insufficiently treated effluents are not diluted, due to the scarcity of perennial water such as rivers. The toxicity of effluents and the hot climate accelerate eutrophication processes in surface-water bodies, rendering the main reservoirs highly eutrophic (ageing lakes). The effects of treatment-plant effluents are also damaging to the groundwater resources, especially the effluents of waste stabilization ponds in the Khirbet es Samra (Amman-Zerka area), Mafraq, Aqaba and Ramtha areas. Waste-stabilization ponds have proved to be unsuitable for countries with poor water resources, where sewage is very concentrated, evaporation rates are high, and where no dilution takes place, added to the problem of the extremely unwise choice of treatment sites. The wrong choice of solid-waste disposal sites and methods has led to deterioration of both surface and groundwater in their areas.

Over-exploitation of aquifers on the account of the country's reserves of non-renewable and fossil water is gradually leading to aquifer depletion and exhaustion. In certain areas, e.g. Dhuleil Jafr, Azraq, over-exploitation is also leading to aquifer salinisation by the mobilization of saltwater bodies which are in contact with the fresh water resources.

Most of the groundwater in Jordan is extracted from the north-eastern part of the Amman Zarka Basin. The rate of pumping, especially for agricultural purposes, has by far exceeded the amounts that are naturally recharged by rainfall. The safe-yield of all aquifers of the country can now hardly

cover the municipal and industrial demand, nonetheless these groundwater resources are over-exploited at a rate of approximately 300 MCM/a, mainly used in irrigation along the highlands (WB, 2001).

Even if no groundwater were allowed to be used for irrigation and if groundwater quality deterioration were stopped immediately, the groundwater stock of Jordan would not recover. The incurred damage during the eighties and nineties is irreparable, and irreversible if groundwater bodies are not allowed to recover by a policy aiming at extracting amounts less than the safe-yields.

Additional Sources

The choices for increasing water resources within Jordan are limited to sea-water desalinization at Aqaba and treated waste water reuse. The first choice is very expensive and can hardly be accommodated within the economy of the country since fuel has to be imported. In 2003, 27 desalination plants were available and seven plants were under construction. Most of the plants are operated privately by farmers to desalinate brackish water for irrigation purposes. Only some plants are operated by WAJ (Water Authority of Jordan) for drinking purposes. WAJ operates four existing desalination plants and further two are under construction. All these plants are run or will be run by WAJ to treat saline water for drinking water supply. The units are all of a small size compared with plants e.g. in the Gulf Region (some 8,000 m³/d). In 2003 23 desalination plants for irrigation purposes were under operation, while further three were under construction. The first unit started operating in 1996. All plants are constructed and run privately by farmers. In all plants reverse osmosis technology is applied. The capacity of the plants are 20 - 80 m³/h (total capacity almost 1,000 m³/h).

Intersea Desalination Scheme (Red-Dead Project)

The Red-Dead Project foresees a connection between the Red and the Dead Sea. The difference of the water level between the Red Sea and the Dead Sea of about 400 m would offer good conditions for hydropower generation. Generated electric power will be used for the desalination process. 141 km of tunnel and closed pipe as well as 39 km of an open channel are required to conduct seawater from the Red Sea to the Dead Sea. The intake structure is planned to be at Aqaba. An alignment of the transfer pipe will be constructed along Wadi Araba/Arava. A reverse osmosis plant will be located south of the Dead Sea.

Wastewater Treatment

In 2002, 19 wastewater treatment plants were in operation including the plants of Wadi Hassan and Wadi Mousa (completed 2001/02). Planned development of wastewater treatment foresees in addition the construction of 17 new plants is proposed during a period of 10 to 12 years. After

completion of all planned measures the total number of treatment plants will increase to 36. In several of the newly planned treatment plants sand filtration is proposed as tertiary treatment instead of maturation ponds. Based on the existing studies and reports on the planning of related sewerage systems as advised by the various studies, wastewater quantities were estimated up to the target year 2020. Effluent quantities of the plants were estimated based on inflow and on a reduction caused by losses due to evaporation and/or infiltration in the underground within the treatment plants. Table 1 shows the total wastewater inflow and effluent of the treatment plants taking into account the assumptions presented above.

With regard to future reuse of treated waste water in most of the new planned treatment plants local reuse systems were selected in particular for the small treatment plants of low effluent quantities. However, most of the effluent quantity will be conducted to irrigation systems more or less far from the treatment plants site due to the fact that the treated wastewater of the big plants (e.g. As Samra, Zarqa, Irbid) is not reused close to the treatment facilities.

Another alternative to be considered is importing water from other countries. A feasibility of the Euphrates River was carried out, but no further action was taken because of the riparian rights of that river and the high cost of implementing the project (HUMPHREYS AND PARTNERS, 1985).

Table 1: Future development of wastewater treatment

Unit		**2005**	**2010**	**2015**	**2020**
Wastewater inflow to treatment plants 1)	MCM/a	134	191	227	262
Wastewater effluent of treatment plants	MCM/a	126	179	213	245

Including touristic and industrial inflows

General Assessment of the Water Sector Situation

Only expensive projects to utilize water resources can postpone Jordan's crisis a little longer. But even limiting agricultural uses at their present water-consumption rate, allowing domestic demand to cover only the natural increase of population without any rise in living standards or in per-capita consumption and letting planned industries obtain minimal amounts of their needed water, using all the available resources and developing them to safe-yield limits, will only satisfy this restricted demand until the year 2010.

The government of Jordan pays the capital cost of all the large irrigation projects. Although it is expected that farmers would irrigate their crops more efficiently if irrigation water prices reflected the actual cost, subsidizing irrigation water is still government policy. Pricing this water artificially low has led to the inability to satisfy the demand. Users of fossil-water resources for irrigation in Azraq, Dhuleil, Disi and other areas pay only for the pumping costs, but not for exhausting these

non-renewable national resources. Current practice in this area will certainly lead to the depletion and the loss of the nation's future water and food security. Paying a certain cost now might lead to saving and conserving at least part of the water and may be to reconsideration of the economic feasibility of projects.
In the coming decade high-cost projects and environmental hazards will make large water projects unattractive and difficult to implement. Therefore, policymakers have started recently to change their strategies to lower the demand for and increase the efficiency of water instead of increasing the supply.

The increasing demand for water, as a result of population growth and improvements in the standards of living, is gradually leading to competition for the water resources. Projects of additional supplies are becoming more and more expensive and very scarce because of the unavailability of additional resources. Such a situation is expected to gradually lead to economic consideration of water supply and allocation practices.

In the past four decades social and political issues determined the water use allocations in the country. But the scarcity of water and the expenses of allocating new resources require new thinking and new management procedures.

Water allocations for certain agricultural activities may have to be curtailed, which may in turn cause difficult socio-economic and political problems (more expenditure on foreign currency, increasing unemployment, less food production and eventually social unrest).

The increasing demand for water and the competition among water use sectors made the management and development of the water sector through the policy of project-by-project, area-by-area or users group-by-users group planning insufficient. Therefore, the Ministry of Water and Irrigation has recently developed a water strategy with adequate dynamic instruments to enable comprehensive planning.

The change to an efficient water economy is not an easy task. But this change has recently started in Jordan. The technologies for that are available. Therefore, allocation of more funds to improving the efficiency of water systems is rendering unnecessary expensive, environmentally unsound projects, such as some of those carried out during the eighties and nineties of the last century.

The present shortage in water resources and the expected sharpening of demand should give rise to water policies involving more efficient conservation systems rather than the traditional search for new resources. The challenge facing us is to develop and introduce the necessary technologies for water and waste water systems. The increase in population makes this challenge more difficult. The traditional policy of developing new resources to satisfy needs is, in the case of Jordan, almost exhausted. Now is the time to formulate new policies and change management strategies. Investment in leakage detection and maintenance is a more economical way to increase the efficiency of water supply. Water leaking from pipes represents a great loss since, although it has been collected, purified, pumped and distributed, it does not reach the consumer to pay for it. It is

now necessary for waste water treatment and reuse to become an integral part of water services. Although waste water is polluted, proper treatment can make its application in irrigation quite safe. It also has advantages over fresh water: waste water contains the nutrients necessary to support plant growth.

Outlook

In the year 2001, the country's total water demand was in the range of 1350 MCM/a, of which only 774 MCM/a was supplied due to water shortages. It is expected that this demand will reach 1565 MCM/a by year 2010 (figures 3 and 4). By 2020 the demand will be around 1616 MCM/a, with the increase in demand being mostly needed by municipal and industrial uses. Increased population, and urbanisation, in addition to improved standards of living are expected to boost municipal uses from its current level of 83 l/c/d, to 142 l/c/d by the year 2020. The irrigation demand will decrease starting 2005, when demand management measures show results, and sink further after 2010, when the irrigation with fossil groundwater in the Disi area as recommended stops. Also, the relative amount of irrigation water of the total demand will be decreasing, to about 60% in 2020 from 73% in 1998. It is foreseeable that especially irrigation demands cannot be met within the planning horizon from 2005-2020. Total renewable water resources will not exceed 1150 MCM/a in 2020.

The challenge for Jordan will be to match the foreseen demands with the available conventional and non-conventional resources. The National Water Master Plan (NWMP, 1977) gives the guidelines that originate from the balancing between water demands and resources. In order not to overuse the available resources, especially renewable groundwater, Jordan's water demands need to be in accordance with what water can be made available at reasonable cost and lowest possible environmental impact. Embedded in the gross demand projections as outlined above are assumptions related to the effect of demand management:

- Water loss reduction programs to reduce the municipal network physical losses. A total saving of 100 MCM/a in municipal demand will thus be realised. Actual amounts of savings will depend eventually on amounts of water allocated for this sector. This reduction in physical losses should also contribute to savings in tourism demand estimated at 1.8 MCM/a in 2020.
- Irrigation savings are showing, due to gradual use of more effective irrigation methods; potential savings in the upland could amount to 31 MCM/a. This should release some pressure off the over-stretched groundwater resources. Savings in lining of canals in the uplands would result in releasing a further 5 to 12 MCM/a by the year 2020. Potential savings in the Jordan Valley estimated at about 20 MCM/a should allow expansion of irrigated agriculture in the region by 3270-3830 ha compared with areas irrigated in 1998. Alternatively it should allow transfer of the same amount of fresh water to the urban areas in the uplands. These and a wealth of other demand management measures are and will be necessary to bring down the present and projected demand to the available resources, in addition to reallocation between sectors.

Figure 3: Total water demand in 1998 and future demand projections (MCM/a).

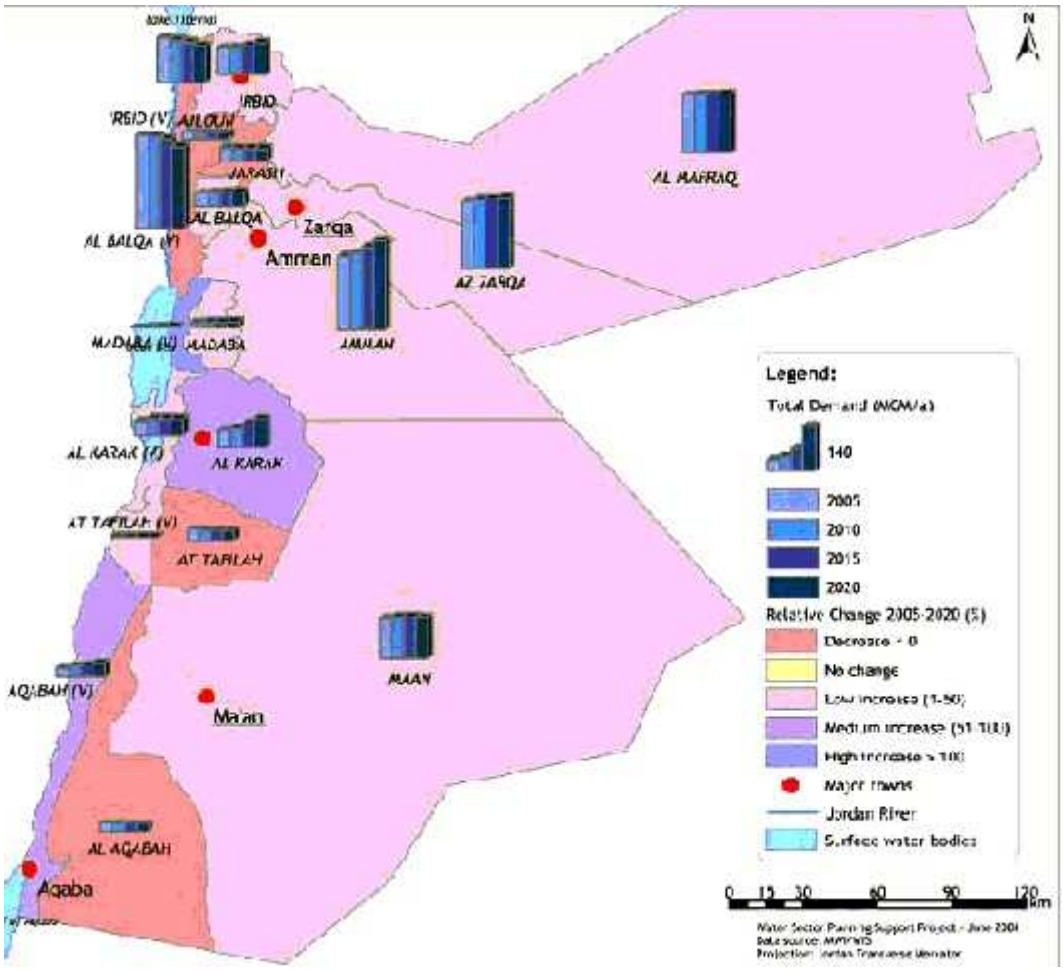

Figure 4: Total Gross Demands per Governorate 2005-2020 (MCM/year)

III. Recently undertaken strategies and programs to improve the water situation

Groundwater Resources Planning and Development

The basic strategy and policies for the water sector in Jordan are compiled and published in Jordan's Water Strategy and Policies (MWI, 1998). One of the main objectives for the future is the reduction of groundwater abstraction to the level of safe-yield to guarantee a sustainable use of the scarce groundwater resources in Jordan. The quantity of Jordan's economically developable renewable groundwater is approximately 300 MCM/a. The reduction of groundwater abstraction is assessed as being achievable by the year 2020. If this goal is not achieved, irreparable damages of groundwater will occur, leading to a further reduction of the usable groundwater resources. A comparison of groundwater abstraction rates with the safe-yield in different basins in Jordan shows, that a reduction in groundwater abstraction must be done mainly in Amman-Zarqa, Dead Sea, Azraq, Yarmouk, Jordan Valley and Jafr basins. A reduction scheme for the Ministry of Water and Irrigation is developed. It states, that the use of renewable groundwater for municipal and mainly irrigation water use will be reduced until 2020 in order to reach the safe-yield. From a practical point of view the reduction of the abstraction must be done stepwise. A proposed reduction schemes from 1998-2020 is developed. It relies on the findings of water balances and the results of water balances and allocation. As a consequence the reduction of groundwater abstraction leads to a deficit in water supply. To bridge the gap, different options are available such as: use of known fresh fossil groundwater, use of known brackish groundwater, prospection and development of unused groundwater resources and increase of artificial groundwater recharge.

Groundwater Protection and Quality Conservation

For groundwater protection, the development and implementation of a programme is needed in order to ensure that plans for groundwater protection, management, monitoring and restoration are defined, integrated and managed in a cost-effective manner.

It should be noted that from the legal and regulatory point of view, the existing laws in Jordan are strong enough to control the use of groundwater resources and protect groundwater. However, until now the application of these laws is still unsatisfactory, thus suggesting the need for future strengthening of law enforcement.

To improve groundwater protection several groundwater protections projects were implemented in the past. The main project is the "Groundwater Resources Management" project, which is carried out together with the Federal Institute for Geosciences and Natural Resources (BGR). The objective is to elaborate and implement groundwater protection measures by implementing groundwater protection areas in Jordan and applying concepts for groundwater contamination prevention. In order to implement the Groundwater Protection Areas in the country, a "Higher Committee for Water Resources Protection" was established, with the aim of preparing national guidelines for the delineation of groundwater protection areas, and to propose corresponding by-laws. The establishment of groundwater protection zones is initiated in the public interest and will

be coordinated by the Ministry of Water and Irrigation under the WATER AUTHORITY LAW (1988) with its subsequent amendments as well as on the By-Law of the WATER AUTHORITY OF JORDAN (2002).

Well drilling prohibition

Driven by depleting aquifers and deteriorating water qualities the Ministry of Water and Irrigation (MoWI) approved in the early nineties of the last century a by-law prohibiting the drilling of new wells in most parts of the country, where aquifers were afflicted by depletion and quality degradation. Exempt of this by-law were only new wells for governmental municipal water supply, universities, hospitals and military camps. In addition repairs of existing wells were allowed, but only with the same specifications of the well to be substituted. All drilling companies were officially informed about the new by- law and about the fines introduced against those who violate the by- laws (worth mentioning here is that groundwater levels in Jordan generally lie tens to hundreds of meters below ground surface and therefore manual excavations are irrelevant).

Impacts on water resources

The by-law prohibiting the drilling of new wells did not allow the acceleration of depletion and salinisation of aquifers. It did not stop them, they continued at their same rates without additional deterioration.

In Jordan around 300 MCM/a of groundwater are extracted for agricultural uses. The number of applications for drilling licenses (before issuing the drilling prohibition by-law) were around 5% of all existing farmer wells per year. These applications were about to start declining as a ratio of the total wells when the by-law was issued. Due to the fact that no permissions were issued to drill new wells, the savings in the first year after prohibition were around 15 MCM. This saving was expected to gradually decline to around 10 MCM in this last year. The total savings in the year 2001 are then estimated at 125 MCM (MWI internal reports). The total savings in all the years 1991-2001 are calculated to sum up to 750 MCM. This water is now still stored in the aquifers and has been saved from being extracted and consumed in irrigation.

Putting a price for the extracted non-agricultural water

In 1998, a new tool for groundwater resources management was applied. According to that, a new regulation was issued putting a price for all the extracted groundwater used for purposes, except irrigation, but including industrial, commercial, universities, military, hospital and municipal uses. The charge was a flat rate of 100fils ($US 0.15) per cubic meter. On all wells producing water for the above uses mentioned above, water meters were installed and read on a regular basis. The

MoWI was commissioned to read the meters and collect the bills. In 1999 the per cubic meter charge was raised to 250 fils equivalent to $US 0.37 (WAJ, 2000).

Effects on the groundwater resources

Industries in water stressed areas in Jordan, especially in the Amman-Zerka area used to have difficulties in obtaining enough water from their own wells especially during the dry season, because the aquifers become overused and partly depleted. Therefore, the metering and fees collection regulation forced them to recycle water and to installed water saving devices.

The other industries found it more economic to apply in-plant recycling and to install water saving devices. Savings, in general are estimated at around 10% of the total used amounts in industry, which is equivalent to 4.5 MCM/yr. Worth mentioning here that savings and recycling have their upper limits and before the application of metering and fee collection instructions some industries were very close to the upper limit of savings and recycling with reasonable cost.

Charging the groundwater amounts abstracted for agricultural uses

In 1999 the MoWI took a decision to install water meters on all the wells pumping water for agricultural uses. The first target of this program was to measure the abstracted amounts from each aquifer. The second came to remind farmers to abstract only the amounts of water stated in their well drilling license.

Effects on the groundwater resources

Practically the effects on the groundwater bodies have not yet been measured because the installation of meters has started only about 4 years ago and the reactions of groundwater bodies does not happen that fast. Due to the decrease in amounts of produced groundwater it is logical to expect a decline in the depletion and salinisation rates of aquifers and hence linger life periods of productivities and yields.

Metering water amounts extracted for irrigational uses

The MoWI started one year ago to charge the groundwater extracted for agricultural uses for amounts exceeding the requirements of family businesses. It is also introduced a block type of tariffs, where charges increase with the increasing amounts of extracted water.

Metering and pricing regulations are expected to result in saving appreciable amounts of groundwater, alleviating herewith over-exploitation and salinization of aquifers. As a result of that

policy measure, farmers started to rethink their water use efficiency, to introduce water saving devices and to choose crops requiring less water.

IV. Summary

Jordan has national laws that authorize activities to conserve water. These laws are based upon the policy to put water resources to the maximum possible benefit.

The first steps toward a solution to the problem of over-extraction of groundwater resources has been implemented by the Ministry of Water and Irrigation

Together with the metering, pricing and the prohibition of drilling will certainly lead to further savings and conservation of the groundwater resources and to shift to low water-consuming crops and to increasing efficiencies.

In the case of industrial water it has already lead to the introduction of water saving devices in-plant water recycling and reuse of treated wastewater.

Improved conveyance system to reach at a higher efficiency and introduction of water saving application systems in irrigated agriculture have become obligatory to farmers and well owners, because the extracted groundwater is priced and farmers have to pay for it.

Also charging price for the extracted fresh groundwater is expected to encourage farmers to use any available treated wastewater or brackish water for those crops tolerating these types of water.

Despite the considerable accomplishments, Jordan’s water sector remains in critical condition, where water needs exceed water supply. This situation will sharpen and the gap between demand and supply will widen due to population growth. In addition, pollution of water resources and salinisation due to over pumping are destroying major water sources leading herewith to lowering the available, usable amounts of water. Therefore, further managerial actions are still necessary to reach an environmental and hydrogeological safe situation.

V. References

DOM (Department of Meteorology) (2004): Annual reports, Amman/Jordan.

DOS (Department of Statistics) (2004): Annual reports, Amman/Jordan.

JVA (Jordan Valley Authority) (2004): Open files and annual reports, Amman/Jordan.

LLOYED, J. W. (1996): The hydrogeology of the southern desert of Jordan, UNDP/FA212, Tech rep. 1, Rome.

MOWI (Ministry of Water and Irrigation) (2004): Annual report, Amman/Jordan.

NWMP (1977): National Water Master Plan, Jordan. Bundesanstalt für Geowissenschaften und Rohstoffe, Bonn and GTZ, Eschborn.

SALAMEH, E. (1996): Water quality degradation in Jordan. Royal Society for the conservation of Nature and Friedrich Ebert Stiftung, Amman.

SALAMEH, E. AND UDLUFT, P. (1999): Towards a water strategy for Jordan. Hydrogeologie und Umwelt, H. 18, Wuerzburg.

HUMPHRIES, H. AND PARTNERS (1985): River Euphretes. MoP, Ministry of Planning, Jordan.

WAJ (Water Authority of Jordan) (2000): Open files and annual reports, Amman/Jordan..

WATER AUTHORITY LAW (1988): Government of Jordan, Amman/Jordan.

WATER AUTHORITY BY-LAW (2002): Government of Jordan, Amman/Jordan.

WB (WORLD BANK) (2001): Water sector review update. Report No.21946-JO.